1994

Uniform Building Code™

Volume 3

Material, Testing and Installation Standards
Preface

The Uniform Building Code is dedicated to the development of better building construction and greater safety to the public by uniformity in building laws. The code is founded on broad-based principles that make possible the use of new materials and new construction systems.

The Uniform Building Code was first enacted by the International Conference of Building Officials at the Sixth Annual Business Meeting held in Phoenix, Arizona, October 18-21, 1927. Revised editions of this code have been published since that time at approximate three-year intervals. New editions incorporate changes approved since the last edition.

The Uniform Building Code is designed to be compatible with related publications to provide a complete set of documents for regulatory use. See the publications list following this preface for a listing of the complete family of Uniform Codes and related publications.

Code Changes. Anyone may propose amendments to this code. For more information, write to the International Conference of Building Officials, 5360 Workman Mill Road, Whittier, California 90601-2298. Changes to the code are processed each year and published as supplements in a form allowing ready adoption by local communities. These changes are carefully reviewed in public hearings by experts in the field of building construction and fire and life safety. An analysis of changes between editions is published in the Analysis of Revisions to the Uniform Codes.

Marginal Markings. Solid vertical lines in the margins within the body of the code indicate a change from the requirements of the 1991 edition except where an entire chapter was revised, a new chapter was added or a change was minor. Where an entire chapter was revised or a new chapter was added, a notation appears at the beginning of that chapter. The letter F repeating in line vertically in the margin indicates that the provision is maintained under the code change procedures of the International Fire Code Institute. Deletion indicators (.) are provided in the margin where a paragraph or item listing has been deleted if the deletion resulted in a change of requirements.

Common Code Format. The provisions of the 1994 edition of the Uniform Building Code have been reformatted into the common code format established by the Council of American Building Officials. The new format establishes a common format of chapter designations for the three model building codes published in the United States. Apart from those changes approved by the conference membership, this reformatting has not changed the technical content of the code.

The chart on the page following this preface indicates how the new chapters are grouped, lists the new chapter designations and indicates the general location of the provisions from the 1991 edition. Cross-reference tables are available to assist in locating provisions of the 1991 edition in the 1994 edition.

Three-Volume Set. Provisions of the Uniform Building Code and the U.B.C. Standards have been divided into a three-volume set. Volume 1 accommodates administrative, fire- and life-safety and field inspection provisions. Chapters 1 through 15 and Chapters 24 through 35 are printed in Volume 1 in their entirety. Any appendix chapters associated with these chapters are printed in their entirety at the end of Volume 1. Excerpts of certain chapters from Volume 1 are reprinted in Volume 1 to provide greater usability.

Volume 2 accommodates structural engineering design provisions, and specifically contains Chapters 16 through 23 printed in their entirety. Included in this volume are design standards previously published in the U.B.C. Standards. Design standards have been added to their respective chapters as divisions of the chapters. Any appendix chapters associated with these chapters are printed in their entirety at the end of Volume 2. Excerpts of certain chapters from Volume 1 are reprinted in Volume 2 to provide greater usability.

Volume 3 contains material, testing and installation standards.
Metrication. The *Uniform Building Code* has been metricated for the 1994 edition. The metric conversions are provided in parenthesis following the English units. Where industry has made metric conversions available, the conversions conform to current industry standards.

Formulas are also provided with metric equivalents. Metric equivalent formulas immediately follow the English formula and are denoted by “For SI:” preceding the metric equivalent. Some formulas do not use dimensions and, thus, are not provided with a metric equivalent. Multiplying conversion factors have been provided for formulas where metric forms were unavailable. Tables are provided with multiplying conversion factors in subheadings for each tabulated unit of measurement. Metricated tables of the Uniform Codes are available from the Conference.
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CODES AND RELATED PUBLICATIONS

The International Conference of Building Officials (ICBO) publishes the family of Uniform Codes, each correlated with the Uniform Building Code™ to provide jurisdictions with a complete set of building-related regulations for adoption. Other reference materials and related codes are available to improve knowledge of code enforcement and administration of building inspection programs. Publications are continually being added, so inquiries should be directed to Conference headquarters for a listing of available products. The following publications are available from ICBO:

UNIFORM CODES

Uniform Building Code. Volumes 1, 2 and 3. The most widely adopted model building code in the United States, the performance-based Uniform Building Code is a proven document, meeting the needs of government units charged with the enforcement of building regulations. Volume 1 contains administrative, fire- and life-safety and field inspection provisions; Volume 2 contains structural engineering design provisions; and Volume 3 contains material, testing and installation standards.

Uniform Mechanical Code™. Provides a complete set of requirements for the design, construction, installation and maintenance of heating, ventilating, cooling and refrigeration systems; incinerators and other heat-producing appliances.

Uniform Fire Code™. Volumes 1 and 2. The premier model fire code in the United States, the Uniform Fire Code sets forth provisions necessary for fire prevention and fire protection. Published by the International Fire Code Institute, the Uniform Fire Code is endorsed by the Western Fire Chiefs Association, the International Association of Fire Chiefs and ICBO. Volume 1 contains code provisions compatible with the Uniform Building Code, and Volume 2 contains standards referenced from the code provisions.

Uniform Housing Code™. Provides complete requirements affecting conservation and rehabilitation of housing. Its regulations are compatible with the Uniform Building Code.

Uniform Code for the Abatement of Dangerous Buildings™. A code compatible with the Uniform Building Code and the Uniform Housing Code which provides equitable remedies consistent with other laws for the repair, vacation or demolition of dangerous buildings.

Uniform Sign Code™. Dedicated to the development of better sign regulation, its requirements pertain to all signs and sign construction attached to buildings.

Uniform Administrative Code™. This code covers administrative areas in connection with adoption of the Uniform Building Code, Uniform Mechanical Code and related codes. It contains provisions which relate to site preparation, construction, alteration, moving, repair and use and occupancies of buildings or structures and building service equipment, including plumbing, electrical and mechanical regulations. The code is compatible with the administrative provisions of all codes published by the Conference.

Uniform Building Security Code™. This code establishes minimum standards to make dwelling units resistant to unlawful entry. It regulates swinging doors, sliding doors, windows and hardware in connection with dwelling units of apartment houses or one- and two-family dwellings. The code gives consideration to the concerns of police, fire and building officials in establishing requirements for resistance to burglary which are compatible with fire and life safety.

Uniform Code for Building Conservation™. A building conservation guideline presented in code format which will provide a community with the means to preserve its existing buildings while achieving appropriate levels of safety. It is formatted in the same manner as the Uniform Building Code, is compatible with other Uniform Codes, and may be adopted as a code or used as a guideline.

Uniform Zoning Code™. This newest addition to the Uniform Codes family is dedicated to intelligent community development and to the benefit of the public welfare by providing a means of promoting uniformity in zoning laws and enforcement.

Dwelling Construction under the Uniform Building Code™. Designed primarily for use in home building and apprentice training, this book contains requirements applicable to the construction of one- and two-story dwellings based on the requirements of the Uniform Building Code. Available in English or Spanish.

Dwelling Construction under the Uniform Mechanical Code™. This publication is for the convenience of the homeowner or contractor interested in installing mechanical equipment in a one- or two-family dwelling in conformance with the Uniform Mechanical Code.

Quick-Reference Guide to the Occupancy Requirements of the 1994 U.B.C. Code requirements are compiled in this publication by occupancy groups for quick access. These tabulations assemble requirements for each occupancy classification in the code. Provisions, such as fire-resistive ratings for occupancy separations in Table 3-B, exterior
wall and opening protection requirements in Table 5-A-1, and fire-resistive ratings for types of construction in Table 6-A, are tabulated for quick reference and comparison.

Supplements to U.B.C. and related codes. Published each of the two years between editions, the Supplements contain all changes approved during that year, plus an analysis of those changes.

Metricated Tables and Figures of the 1994 Uniform Codes. The tables presented in the 1994 Uniform Codes tabulate values in inch-pound units system and are provided with multiplying factors to convert values to the SI equivalent. This publication provides all the tables and figures of the Uniform Codes completely metricated. All tabulated values will be presented in SI units without reference to the inch-pound equivalent.


CABO CODES

CABO One and Two Family Dwelling Code. Jointly sponsored by ICBO and the other model building code organizations, this code eliminates conflicts and duplications among the model codes to achieve national uniformity. Covers mechanical and plumbing requirements as well as construction and occupancy.

Application and Commentary on CABO One and Two Family Dwelling Code. An interpretative commentary on the CABO One and Two Family Dwelling Code intended to enhance uniformity of interpretation and application of the code nationwide. Developed by the three model code organizations, this document includes numerous illustrations of code requirements and the rationale for individual provisions.

CABO Model Energy Code. This code includes minimum requirements for effective use of energy in the design of new buildings and structures and additions to existing buildings. It is based on American Society of Heating, Refrigeration and Air-conditioning Engineers Standard 90A-1980 and was originally developed jointly by ICBO, BOCA, SBCCI and the National Conference of States on Building Codes and Standards under a contract funded by the United States Department of Energy. The code is now maintained by CABO and is adopted by reference in the Uniform Building Code.

TECHNICAL REFERENCES AND EDUCATIONAL MATERIALS

Analysis of Revisions to the Uniform Codes™. An analysis of changes between the previous and new editions of the Uniform Codes is provided. Changes between code editions are noted either at the beginning of chapters or in the margins of the code text.


Handbook to the Uniform Building Code. The handbook is a completely detailed and illustrated commentary on the Uniform Building Code, tracing historical background and rationale of the codes through the current edition. Also included are numerous drawings and figures clarifying the application and intent of the code provisions. Also available in electronic format.

Handbook to the Uniform Mechanical Code. An indispensable tool for understanding the provisions of the current U.M.C., the handbook traces the historical background and rationale behind the U.M.C. provisions, includes 160 figures which clarify the intent and application of the code, and provides a chapter-by-chapter analysis of the U.M.C.

Uniform Building Code Application/Interpretation Manual. This manual discusses sections of the Uniform Building Code with a question-and-answer format, providing a comprehensive analysis of the intent of the code sections. Most sections include illustrative examples. The manual is in loose-leaf format so that code interpretations published in Building Standards magazine may be inserted. Also available in electronic format.

Uniform Mechanical Code Application/Interpretation Manual. As a companion document to the Uniform Mechanical Code, this manual provides a comprehensive analysis of the intent of a number of code sections in an easy-to-use question-and-answer format. The manual is available in a loose-leaf format and includes illustrative examples for many code sections.

Plan Review Manual. A practical text that will assist and guide both the field inspector and plan reviewer in applying the code requirements. This manual covers the nonstructural and basic structural aspects of plan review.

Field Inspection Manual. An important fundamental text for courses of study at the community college and trade or technical school level. It is an effective text for those studying building construction or architecture and includes sample forms and checklists for use in the field.

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Building Department Administration. An excellent guide for improvement of skills in departmental management and in the enforcement and application of the Building Code and other regulations administered by a building inspection department. This textbook will also be a valuable aid to instructors, students and those in related professional fields.

Building Department Guide to Disaster Mitigation. This new, expanded guide is designed to assist building departments in developing or updating disaster mitigation plans. Subjects covered include guidelines for damage mitigation, disaster-response management, immediate response, mutual aid and inspections, working with the media, repair and recovery policies, and public information bulletins. This publication is a must for those involved in preparing for and responding to disaster.

Building Official Management Manual. This manual addresses the unique nature of code administration and the managerial duties of the building official. A supplementary insert addresses the budgetary and financial aspects of a building department. It is also an ideal resource for those preparing for the management module of the CABO Building Official Certification Examination.

Legal Aspects of Code Administration. A manual developed by the three model code organizations to inform the building official on the legal aspects of the profession. The text is written in a logical sequence with explanation of legal terminology. It is designed to serve as a refresher for those preparing to take the legal module of the CABO Building Official Certification Examination.

U.M.C. Workbook. Designed for independent study or use with instructor-led programs based on the Uniform Mechanical Code, this comprehensive study guide consists of 16 learning sessions, with the first two sessions reviewing the purpose, scope, definitions and administrative provisions and the remaining 14 sessions progressively exploring the requirements for installing, inspecting and maintaining heating, ventilating, cooling and refrigeration systems.

Concrete Manual. A publication for individuals seeking an understanding of the fundamentals of concrete field technology and inspection practices. Of particular interest to concrete construction inspectors, it will also benefit employees of concrete producers, contractors, testing and inspection laboratories and material suppliers.

Reinforced Concrete Masonry Construction Inspector’s Handbook. A comprehensive information source written especially for masonry inspection covering terminology, technology, materials, quality control, inspection and standards. Published jointly by ICBO and the Masonry Institute of America.

You Can Build It! Sponsored by ICBO in cooperation with CABO, this booklet contains information and advice to aid “do-it-yourselfers” with building projects. Provides guidance in necessary procedures such as permit requirements, codes, plans, cost estimation, etc.

Guidelines for Manufactured Housing Installations. A guideline in code form, implementing the Uniform Building Code and its companion code documents to regulate the permanent installation of a manufactured home on a privately owned, nonrental site. A commentary is included to explain specific provisions, and codes applying to each component part are defined.

Accessibility Reference Guide. This guide will be a valuable resource for architects, interior designers, plan reviewers and others who design and enforce accessibility provisions. Features include accessibility requirements, along with detailed commentary and graphics to clarify the provisions; cross-references to other applicable sections of the U.B.C. and the Americans with Disabilities Act Accessibility Guidelines; a checklist of U.B.C. provisions on access and usability; and many other useful references.

U.B.C. Field Inspection Workbook. A comprehensive workbook for studying the provisions of the U.B.C. Divided into 12 sessions, this workbook focuses on the U.B.C. combustible construction requirements for the inspection of wood-framed construction.

Educational and Technical Reference Materials. The Conference has been a leader in the development of texts and course material to assist in the educational process. These materials include vital information necessary for the building official and subordinates in carrying out their responsibilities and have proven to be excellent references in connection with community college curricula and higher-level courses in the field of building construction technology and inspection and in the administration of building departments. A full line of videotapes and automated products are also available.
Volume 3

UNIFORM BUILDING CODE STANDARD 2-1
NONCOMBUSTIBLE MATERIAL—TESTS


See Sections 201.2 and 215, Uniform Building Code; Section 416, Uniform Mechanical Code; and Section 211, Uniform Sign Code

SECTION 2.101 — SCOPE

This standard describes a procedure for the determination of noncombustibility of elementary materials of which building materials are composed, to indicate those materials which do not act to aid combustion or add appreciable heat to an ambient fire. It is not intended to apply to laminated or coated materials.

SECTION 2.102 — APPARATUS

The apparatus shall consist primarily of the following:

**Refractory tubes.** Two 10-inch-long (254 mm), concentric refractory tubes, 3 inches (76 mm) and 4 inches (102 mm) in inside diameter, with axes vertical and with heat applied by electric heating coils outside of the larger tube. A controlled flow of air is admitted tangentially near the top of the annular space between the tubes and passes to the bottom of the inner tube. The outer tube rests on a refractory bottom and the inner tube rests on three spacer blocks so as to afford a total opening under the inner tube equal to or greater than that of the annular space. The refractory bottom plate has a removable plug for cleaning.

**Transparent cover.** A transparent cover of heat-resisting glass or other transparent material shall be provided over the top of the inner tube with a 1-inch square (645 mm²) opening over the axis of the tubes. This cover may be in two movable parts.

**Thermocouples** or other temperature-measuring devices, preferably automatically recording, shall be provided, one for the air in the lower part of the inner tube, another on the specimen in the approximate center of the space, and a third within the interior of the specimen. A thermocouple may be provided in the region of the heating coils for better regulation of the temperature of the air in the furnace space. The two specimen thermocouples shall have a time constant [time to reach 63.2 percent of the furnace air temperature of 1382°F. (750°C.)] of five to 10 seconds.

SECTION 2.103 — TEST SPECIMENS

All test specimens shall be 1 1/2 inches (38 mm) wide by 1 1/2 inches (38 mm) thick in cross section perpendicular to the air flow in the furnace and 2 inches (51 mm) long with tolerances on the dimensions of plus or minus 1/10 inch (2.5 mm). The specimens shall be dried at 140°F. plus or minus 5°F. (60°C. ± 3°C.) for not less than 24 hours nor more than 48 hours before being tested.

Specimens in granular or powder form may be contained in thin-wall, open-top vessels of inert materials whose outside dimensions conform to the specimen shape and maximum size specified in this section. These vessels may have solid walls or be of mesh.

Not less than four identical specimens shall be tested.
SECTION 2.104 — PROCEDURE

Prepare the furnace by bringing the temperature (at the approximate position to be occupied by the center of the specimen) of the air in the furnace tube to 1382°F. plus or minus 10°F. (750°C. ± 6°C.), maintaining the furnace setting long enough to ascertain that it will remain at constant temperature in the unloaded furnace for at least 15 minutes while air passes at a velocity of 10 feet per minute (3 m/min.) plus or minus 20 percent past a loaded specimen in the tube, computed on the basis of air supply and velocity at room temperature and pressure.

As rapidly as possible, insert the test specimen into the furnace, with a thermocouple attached to the side surface of the specimen and a thermocouple inserted from the top of the specimen to its approximate volumetric center. Close the top cover to the 1-square-inch (645 mm²) opening immediately after insertion of the specimen. Readings for the specimen thermocouples shall be made at intervals not to exceed 10 seconds during the first five minutes, and as often afterwards as necessary to produce a smooth curve. Do not change the regulation of the current through the heating coils and the air flow during the test.

Continue the test until the temperatures at the specimen thermocouples have reached maxima or until it is clearly evident that the specimen does not pass this test.

Throughout the test make and record visual observations on the specimens, noting quality, quantity or intensity and duration of flaming or smoking, or both, and change of state.

Weigh each specimen before and after testing and record the weight loss to the nearest 1 percent.

SECTION 2.105 — INTERPRETATION OF RESULTS

Materials subjected to the test described in this method shall be reported as noncombustible if, for three or more of the four specimens tested, (1) the recorded temperatures of the surface and interior thermocouples do not at any time during the test rise to more than 54°F. (30°C.) above the furnace air temperature at the beginning of the test, (2) if there is no flaming from the specimen after the first 30 seconds and (3) when the weight loss of the specimen during testing exceeds 50 percent, the recorded temperature of the surface and interior thermocouples do not at any time during the test rise above the furnace air temperature at the beginning of the test and there is no flaming of the specimen.
UNIFORM BUILDING CODE STANDARD 4-1
PROSCENIUM FIRESAFETY CURTAINS
Installation Standard of the International Conference of Building Officials
See Sections 303.8 and 405.3.4, Uniform Building Code

SECTION 4.101 — GENERAL REQUIREMENTS
Proscenium curtains, when required, shall be made of approved materials constructed and mounted so as to intercept hot gases, flames and smoke, and to prevent a glow from a severe fire on the stage from showing on the auditorium side within a period of 30 minutes. The closing of the curtain from the full-open position shall be effected in less than 30 seconds, but the last 8 feet (2438 mm) of travel shall not require less than five seconds.

SECTION 4.102 — DEFINITIONS
Curtain styles regulated by this standard are defined as follows:

   BRAILLE PROSCENIUM FIRESAFETY CURTAIN is a curtain that folds up and stores in a very limited space above the proscenium opening. (See Figure 4-1-1.)

   FRAME PROSCENIUM FIRESAFETY CURTAIN is a curtain that has a rigid frame, and stores over the proscenium opening in one flat panel.

   MODIFIED FRAME PROSCENIUM FIRESAFETY CURTAIN is a curtain made of various components of both the frame and straight-lift-style curtains, and stores over the proscenium opening in one flat panel.

   STRAIGHT-LIFT PROSCENIUM FIRESAFETY CURTAIN is a curtain which stores over the proscenium opening in one flat panel.

SECTION 4.103 — CURTAIN FABRICS

4.103.1 General. A proscenium curtain shall be constructed and installed as specified in this standard.

4.103.2 Fabrics.

4.103.2.1 Asbestos. When not prohibited by federal, state or local law, an existing installed curtain may be made of one or more thicknesses of not less than 2 3/4-pound-per-square-yard (1.5 kg/m²) AAA grade wire-inserted asbestos fabric, or of another wire-inserted asbestos fabric obviously of greater fire resistance than this 2 3/4-pound (1.5 kg/m²) AAA grade wire-inserted fabric. Nonasbestos portions of these fabrics, if any, shall be flame-resistant treated so as not to support combustion.

4.103.2.2 Other fabrics. Curtains not meeting the above criteria shall be made of one or more thicknesses of a noncombustible fabric, or a fabric with a noncombustible base material which may be given a coating provided the modified fabric meets the criteria detailed in this section.

   Curtain fabrics shall not weigh less than 2 3/8 pounds per square yard (1.3 kg/m²) unless it can be substantiated by approved tests that the fabric is equivalent in strength and durability.

4.103.3 Tensile Strength. Curtain fabric shall have tensile strength of not less than 400 pounds per inch (70 kN/mm) in both the warp and fill directions.

4.103.4 Wire-insertion Reinforcement. Curtain fabric shall be reinforced with noncorrosive wire intertwined with the base fiber at a minimum rate of one wire per yard. Wire may be omitted if it can be substantiated by approved tests that it is equivalent in strength and durability.
4.103.5 Fire Test. A sample curtain with a minimum of two vertical seams shall be subjected to the standard fire test specified in U.B.C. Standard 7-1 as applicable to nonbearing walls and partitions for a period of 30 minutes. Surface temperature measurements need not be taken and the hose stream exposure need not be made. The curtain shall overlap the furnace edges an appropriate amount to seal the top and sides. It shall have a bottom pocket containing a minimum 4 pounds per linear foot (5.94 kg/m) of batten. The unexposed surface of the curtain shall not glow, and neither flame nor smoke shall penetrate the curtain during the test period.

4.103.6 Smoke Test. Curtain fabrics shall have a smoke density of no greater than 25 when tested in accordance with U.B.C. Standard 8-1. The curtain fabric shall be tested in the condition in which it is intended to be used.

SECTION 4.104 — DESIGN AND CONSTRUCTION

4.104.1 General. The various style curtains detailed below shall all be acceptable for use, except when the fly space above the stage is sufficient to allow the straight-lift, frame or modified frame styles to be used.

When the fly space is sufficient for these above-mentioned full-lift-style curtains, the straight-lift, frame or modified frame styles shall be used for proscenium openings 50 feet (15 240 mm) wide or less and 30 feet (9144 mm) high or less; and the frame or modified frame styles shall be used for openings over 50 feet (15 240 mm) in width or 30 feet (9144 mm) in height.

Curtain installations in new facilities with openings over 50 feet (15 240 mm) in width or 30 feet (9144 mm) in height shall be the frame or modified frame construction.

Regardless of curtain style, the curtain shall be made of continuous strips of fabric as specified above, sewn together vertically using minimum 1-inch-wide (25 mm) double-needled overlap seams. These vertical seams and all other functional stitching on the curtain shall consist of two rows of lockstitch stitching using flame-resistant thread, conforming to the test requirements of Section 4.103.

The curtain shall overlap the sides of the opening at least 18 inches (457 mm) and the top of the opening at least 24 inches (610 mm).

All style curtains, except the frame style and the modified frame style (unless it has batten pockets and vertical side edge hems), shall have minimum 6-inch (153 mm) flat [12-inch (305 mm) circumference] single-thickness pockets at the top and bottom of the curtain to hold the pipe battens, and double-thick vertical side edge hems each a minimum of 1 1/2 inch (13 mm) wider than the length of side edge guide brackets being used and width of the metal hem reinforcing pieces being used, if any, except that hems shall not be less than 4 inches (102 mm) in width. Should the curtain fabric being used be an acceptable nonwire-inserted (nonwire reinforced) fabric, batten pockets shall be double thick and vertical side edge hems shall be triple thick or faced with wire-inserted (wire reinforced) webbing or fabric (raw edges turned under). Pockets and vertical side edge hems shall be sewn as specified above. Minimum 1 1/2-inch (38 mm) inside diameter metal battens shall be placed in the top and bottom curtain pockets when the proscenium opening height is 18 feet (5486 mm) or less and width is 34 feet (10 363 mm) or less. For openings 50 feet (15 240 mm) or less in width [but more than 34 feet (10 363 mm)], and 30 feet (9144 mm) or less in height [but more than 18 feet (5486 mm)], the top and bottom metal battens shall not be less than 2 inches (51 mm) inside diameter. Metal battens shall be Schedule 40 steel pipe, Schedule 80 steel pipe or other metallic tubing meeting or exceeding the tensile strength and performance standards of Schedule 40 steel pipe. All batten joints shall be reinforced with minimum 18-inch (457 mm) sections of said pipes or tubing internally and shall be riveted.

A minimum 3-inch-thick (76 mm) yield pad made with an outer covering of the curtain fabric, filled with fiberglass or other noncombustible materials, in such a manner so as to achieve a minimum 3-pound-per-cubic-foot (48 kg/m³) density, shall be sewn beneath the bottom batten pocket.
with four rows of flame-resistant thread (two on each side of the pocket) in such a manner so as to force the bottom batten to compress the yield pad firmly against the stage floor, producing the best possible seal when the curtain is lowered.

4.104.2 Straight-lift Style. The straight-lift-style curtain shall meet the general requirements detailed above with vertical side edge hems reinforced with one piece of 0.064-inch-thick (1.63 mm) (16 gauge) plated or painted sheet metal on each side of the hem on each side of the curtain for its full vertical height so that both faces are covered 5 1/2 inches (140 mm) deep, or with minimum 2-inch-wide by 1 1/2-inch (51 mm by 38 mm) projection by 1/8-inch-thick (3.2 mm) steel angle/2-inch-wide (51 mm) by 1/8-inch-thick (3.2 mm) steel flat piece set (plated or painted) clamped on both edges for the curtain’s full height. Either edge-reinforcement system shall be fastened to the side edge hems with pairs of minimum 3/16-inch (4.8 mm) plated tubular or solid steel rivets, or bolts spaced not more than 6 inches (153 mm) on center vertically.

Curtains for proscenium openings, 50 feet (15 240 mm) or less in width and 30 feet (9144 mm) or less in height, shall use a roller guide/metal track side edge guide system, using guides with at least two roller or ball bearing steel wheels each, and 0.079-inch-thick (2 mm) (14 gauge) galvanized steel tracks (installed rigidly in place so that roller guides will operate smoothly with a wind load of 2 pounds per square foot (95.8 Pa) over entire area of curtain). Each guide shall be attached to the curtain’s metal stiffened edges by way of three or more minimum 3/16-inch (4.8 mm) plated tubular or solid steel rivets, or bolts through a plated steel strap assembly (0.064-inch-thick (1.63 mm) sheet metal stiffening system), a minimum 3/8-inch (9.5 mm) machine screw assembly (attached to the projecting flange of the angle iron/flat steel edge stiffening system), or an equivalent attachment system. Guides shall be on maximum 18-inch (457 mm) vertical centers.

Curtains for proscenium openings 42 feet (12 802 mm) or less in width and 22 feet (6706 mm) or less in height may have a bronze-alloy, oil-impregnated wood, or other spool-type guide wire side edge system, where the guide wires are at least 1/4-inch (6.4 mm) diameter 7 by 19 galvanized aircraft cable installed securely using at least 3 3/8-inch (9.5 mm) locked turnbuckles, thimbles and three forged wire rope clips (or one swagged fitting) at the end of each guide wire; or the roller guide system with either hem reinforcing/stiffening system as detailed above. Guides shall not be more than 18 inches (457 mm) on vertical centers.

An approximate 3-inch-diameter (76 mm) smoke seal made of the curtain fabric and filled with fiberglass insulation or other noncombustible materials, to a density of not less than 3 pounds per cubic foot (48 kg/m³), shall be attached to the upstage side of the proscenium wall, above the proscenium opening. The seal shall contact with the curtain’s top batten pocket, and compress against it when the curtain is in its deployed position to make as smoke-tight a seal as practical.

4.104.3 Braille Style. The dead hung braille-style curtain shall meet the requirements detailed above in Sections 4.104.1 and 4.104.2, except for the following:

1. Curtain shall have minimum 5 percent fullness in the height only.

2. Side edge guide system shall be bronze spool guides on a maximum 18-inch (457 mm) vertical centers on both of the curtain’s vertical edges, without any type of edge reinforcing/stiffening system.

3. Galvanized minimum 1/4-inch (6.4 mm) diameter 7 by 19 aircraft cable vertical life lines shall be located on maximum 10-foot (3048 mm) horizontal centers with the outermost two cables a maximum of 3 feet (914 mm) from either of the curtain’s vertical edges. Each life line shall operate on a path reinforced with a layer of the curtain’s fabric (raw edges turned under) or equivalent webbing, with plated steel D (dee) rings on maximum 18-inch (457 mm) vertical centers.
4. Seven by 19 aircraft cable for \( \frac{3}{8} \)-diameter (9.5 mm) or smaller sized and 6 by 19 or other flexible independent wire rope core, wire rope for larger sizes, sized using a minimum 8 to 1 safety factor, shall be used for the drive lines which connect the winch to the cable clew.

5. In lieu of the approximate 3-inch-diameter (76 mm) smoke seal detailed in Section 4.104.2 above, an attached fill piece smoke seal made of the curtain fabric, spanning the gap from the curtain to the upstage portion of the proscenium opening's wall above the opening, shall be installed.

The lift lines detailed above in conjunction with the D (dee) rings create an accordion-fold-type storage arrangement.

4.104.4 Frame and Modified Frame Style.

4.104.4.1 Frame-style curtain. The frame-style curtain shall consist of a rigid steel or metallic alloy frame, with a frame thickness not less than \( \frac{1}{120} \) of the width, and \( \frac{1}{96} \) of the height of the proscenium opening, but in no case less than 4 inches (102 mm) in thickness, complete with interior steel or metallic alloy members, such that when the required single thickness is battened to the downstage side (audience side) of the frame, the assembly will operate smoothly, and perform as required, when subjected to a lateral load of 2 pounds per square foot (95.8 N/m²) over the entire area of the curtain.

The side edge guide system shall consist of vertical steel flat edges parallel to the face of the curtain with bronze bushings on this vertical steel edge on both upstage and downstage surfaces, or in the grooves traveled by these vertical steel edges located in the vertical steel smoke pockets on each side of the proscenium opening.

A separate yield pad, the cross section of which shall be square with each edge measuring approximately the same as the thickness of the frame, shall be made of the curtain fabric and filled with fiberglass or other noncombustible materials to a density of not less than 3 pounds per cubic foot (48 kg/m³). The yield pad shall be attached beneath the bottom frame member so that it will compress and seal when the curtain is lowered.

A separate upper smoke seal, the same as detailed in Section 4.104.2 above, except that the seal shall be approximately 5 inches (127 mm) in diameter, shall be attached to the top of the frame on the downstage edge (edge facing the audience), and rigged so that the smoke seal is forced to compress against a steel or metallic alloy angle or other solid noncombustible material protruding from the proscenium wall above the opening (optionally, seal may be mounted above the proscenium opening on the upstage side and rigged to force the smoke seal to compress against a steel or metallic alloy member protruding downstage from the top member of the curtain’s frame).

This curtain style is rigged like and operates like a straight-lift curtain except that the lift lines, blocks and all other involved operating equipment, shall be sized to accommodate the size and weight of the assembly with a minimum 8 to 1 safety margin.

4.104.4.2 Modified frame-style curtain. The modified frame-style curtain shall be any variation or combination of the frame style immediately above, and the straight-lift-style curtain that minimizes the horizontal movement or bowing of a curtain to a point where the curtain assembly will operate smoothly and perform as required when subjected to a lateral load of 2 pounds per square foot (95.8 N/m²) over the entire area of the curtain.

This curtain style, like the frame style, is rigged like and operates like a straight-lift curtain, except that the lift lines, blocks and all other involved operating equipment shall be sized to accommodate the size and weight of the assembly with a minimum 8 to 1 safety margin.

SECTION 4.105 — OPERATING EQUIPMENT

Vertical smoke pockets which contain the curtain’s vertical edges and guide system shall be fabricated of minimum \( \frac{1}{4} \)-inch-thick (6.4 mm) structural steel shapes and plates (plated or painted), with a bolted construction using minimum \( \frac{3}{8} \)-inch (9.5 mm) diameter Grade 5 bolts spaced not
more than 4 feet (1219 mm) on center to attach plates to the steel shapes for the entire height of the smoke pockets, or at least for removable sections at the bottom of each smoke pocket (plate portions only), at least the height of the opening plus 4 feet (1219 mm) for frame and modified frame styles of semirigid construction, or at least 6 feet (1829 mm) for all other styles. These smoke pockets shall extend vertically from the stage floor to a point 1 to 3 feet (305 to 914 mm) above the top of the raised curtain and shall be securely fastened to the upstage side (side away from audience) of the proscenium wall, with minimum \( \frac{1}{2} \) -inch-diameter (13 mm) Grade 5 anchors or bolts in concrete spaced not more than 4 feet (1219 mm) on center, with minimum \( \frac{3}{8} \) -inch-diameter (9.5 mm) Grade 5 anchors or bolts in concrete spaced not more than 2 feet (610 mm) on center, or an anchoring system equivalent in strength on concrete or other surfaces. The smoke pockets may vary in depth and width, depending on the style of curtain and the distance the smoke pockets are set back from the vertical edges. Straight-lift curtains shall not have less than 8-inch-deep (203 mm) pockets, braille curtains shall not have less than 8-inch-deep (203 mm) pockets, and frame and modified frame curtains shall have pockets at least 4 inches (102 mm) deeper than the thickest batten or frame member; the pockets shall be at least 11 inches (279 mm) wide set back a minimum of 6 inches (153 mm) from the vertical edges (stage left/stage right) of the proscenium opening, and contain at least 8 inches (203 mm) of the curtain's vertical edges.

The curtain's side edge guide system shall be as specified in Section 4.104 above.

Straight-lift and braille curtains for proscenium openings 50 feet (15 240 mm) or less in width and 30 feet (9144 mm) or less in height shall not have less than \( \frac{1}{4} \) -inch-diameter (6.4 mm) 7 by 19 galvanized aircraft cable life lines 10 feet (3048 mm) or less on center, with the end overhang not more than 3 feet (914 mm). Attachment to battens shall be accomplished through the use of two-piece pipe clamps made of minimum 0.105-inch-thick (2.7 mm) (12 gauge) steel, or equivalent material (plated or painted) with corners rounded and the entire assembly deburred.

The clamps shall attach to the battens using two minimum \( \frac{1}{2} \) -inch (9.5 mm) Grade 5 bolts, one under the batten and one over the batten, with the lift cable securely attached using a thimble and three forged wire rope clips (or one swagged-type fitting). Other methods of attachment that can be shown to be equivalent shall be acceptable as long as the lift lines are not tied in a clove hitch, and they do not require cutting the curtain fabric and leaving exposed cut edges. Frame and modified frame curtains may require larger diameter lift lines to meet the requirements in Section 4.104.4; galvanized cable or wire rope, 7 by 19 aircraft cable for \( \frac{3}{8} \) -inch (9.5 mm) diameter or smaller sizes, and 6 by 19 or other flexible independent wire rope core rope for larger sizes shall be used.

Straight-lift-style curtains for openings 34 feet (10 363 mm) or less in width and 18 feet (5486 mm) or less in height, and braille-style curtains of all sizes, may be designed to operate using properly sized manual and electric winches of various styles, all with adjustable hydraulic-assisted, speed-governing devices; any model with handles shall be so designed that the handle is removable, with an appropriate sign in English and other languages prevalent to the facility's area, stating DANGER! REMOVE HANDLE AFTER USE! prominently displayed near the location of the winch.

Curtain lift lines shall pass through sheaves in or under the gridiron, over to the counterweight guides or winch clew. Cables shall fasten to the curtain's top batten as detailed above. Connections to the braille curtain's bottom batten shall be accomplished by a loop at the end of each lift line secured with three forged wire rope clips, or minimum \( \frac{1}{16} \) -inch-thick (4.8 mm) clam-shell-type steel pipe clamps, and to the counterweight guides or winch drive line clew, using \( \frac{3}{8} \) -inch (9.5 mm) locked turnbuckles, thimbles and three forged wire rope clips (each lift line cable). Swagged-type fittings (one per connection) may be used in lieu of three forged wire rope clips. Clove hitches shall not be used and the batten pocket shall not be cut to facilitate the installation of the lift lines.

Straight-lift- and braille-style curtains shall have safety stay chains of a straight-welded link minimum \( \frac{1}{4} \) -inch (6.4 mm) proof coil chain fastened securely to the curtain's top batten. Frame and modified frame-style curtains shall also have the same type safety stay chains, except they shall be sized to support safely the weight of the curtain. There shall be one more stay chain than the number...
of supporting cables and, except for the stay chains at the ends of the curtain, all stay chains shall be centered between the supporting cables. One end of each stay chain shall be securely attached to the curtain's top batten (or top of a frame), with the other to the gridiron, if of steel construction; otherwise, the upper stay chain ends shall be fastened to $\frac{3}{4}$-inch (19 mm) bolts bolted through the proscenium wall. Safety chains shall be so adjusted that they support the curtain when it is lowered and the bottom batten is resting on the yield pad and supported by the floor. In the case of the braille-style curtain, the safety chains will also be the method of holding the curtain's top batten in its stationary position.

All cables shall be carried overhead using head and loft blocks fitted with precision ball or tapered roller bearings of ample capacity to accommodate the weight at the speeds required. Grooves in the blocks shall be machined properly to cradle and protect the cable. All blocks supporting the proscenium firesafety curtain shall be supported on the proscenium wall by means of steel brackets of suitable size to safely carry the weight, or shall be mounted on structural steel beams and other steel shapes that may be added.

Head and loft blocks shall be installed so as to prevent cable fouling.

For all style curtains using $\frac{1}{4}$-inch-diameter (6.4 mm) 7 by 19 galvanized aircraft cable lift lines, the minimum diameter of loft blocks shall be 8 inches (203 mm) when the height of the proscenium is 20 feet (6096 mm) or less, and 12 inches (305 mm) for all others. Curtains using larger diameter lift lines shall use loft blocks with a minimum diameter 38 times the diameter of the cable. Head blocks shall be at least 4 inches (102 mm) greater in diameter than the loft blocks.

The mechanism and devices for controlling the curtain shall be of simple design and positive in operation. Normal day-to-day operation of straight-lift, braille curtains installed on proscenium openings of 1,500 square feet (139.4 m$^2$) or less may be by manual means as long as operation can be accomplished with relative ease by a single person. Curtains meeting the size criteria in the previous sentence that are difficult for a single person to operate and other curtains not meeting the size criteria shall be operated by electric devices.

Automatic emergency release shall be by gravity obtained by overbalancing the curtain. The emergency control line shall be of minimum $\frac{3}{8}$-inch-diameter (9.5 mm) manila rope, or $\frac{3}{32}$-inch-diameter (2.38 mm) 7 by 19 galvanized aircraft cable, fitted with not less than four 165°F (74°C.) or less nonelectric fusible links. One of these fusible links shall be located on each side of the stage and two overhead. When any link in the series separates, or the emergency control line is burned, the curtain shall automatically lower properly to its deployed position (see Section 4.101 above). This emergency control line shall extend up both sides and above the proscenium opening. As is the case with the manual emergency tripping mechanism detailed below, any attachment to the hand line on any operation machine or device that must be disconnected from the hand line or device for proper curtain deployment shall be a mechanical quick-release device that is easily resettable. The fire curtain emergency-release system shall not be interconnected mechanically, electromechanically, electrically or electronically with the emergency ventilator release system, unless a time delay is incorporated to assure that, in the event of a fire, the fire curtain will be fully deployed before the vents open. The building’s fire alarm system shall not be interconnected with the fire curtain emergency-release system.

Manual emergency deployment of the fire curtain shall be accomplished by the activation of one of two mechanical quick-release assemblies (one on each side of the proscenium opening). Activation of either assembly shall be by pulling a minimum $1\frac{1}{2}$-inch-diameter (38 mm) red (color) ring, attached to a quick-release pin that is normally pinned through two steel plates housing a minimum 1-inch-diameter (25 mm) ring that is securely attached to the emergency-release line; these quick-release mechanisms shall be such that they can quickly (within a few minutes) and easily be reset in the event of erroneous activations. Other similar activation assemblies that are positive in nature and meet the basic criteria of the quick-release system detailed above may be used. Knife, axe and other emergency-release systems shall be allowable only until a new fire curtain is installed.
Appropriate signs in English and other languages prevalent to the facility’s area, shall be prominently displayed near the location of the emergency control line quick-release mechanisms. For the release assembly detailed above, the sign would read IN CASE OF FIRE, PULL RED RING TO LOWER FIRE CURTAIN AUTOMATICALLY! with an arrow pointing to the location of the ring. There shall also be a less prominent sign or instruction pamphlet located on the main control side of the opening only, detailing the procedure required to properly and quickly reset the fire curtain in its raised position (this would include the mechanical quick-release mechanisms mentioned in this paragraph and the paragraph above).

Electric operation shall be from a single station located on either side of the proscenium opening and shall consist of two hold-to-operate-style push buttons, one labeled “Up” and one labeled “Down.” Alternately, three push buttons that function from a single push of a button; one button shall be labeled “Up” for raising the curtain, one labeled “Down” for lowering the curtain, and one labeled “Stop” for stopping the curtain at the point it is located when the button is pushed; a sign stating NONEMERGENCY FIRE CURTAIN OPERATION shall be adjacent to the push-button station. Buttons and sign shall be labeled in English only.

All manually rigged counterweight curtains shall have their minimum 3/4-inch (19 mm) manila endless operation hand line securely fastened to both the top and bottom of the counterweight arbor and shall pass under a minimum 12-inch-diameter (305 mm) floor block which is adjustable for tension.

The top and bottom counterweight sections of the arbor shall be of steel, sufficiently heavy to safely accommodate the loads. The top and bottom sections shall be connected with rods not less than 3/4 inch (19 mm) in diameter, with one tie plate for every 4 feet (1219 mm) of rod. Counterweights may be cast iron or flame cut steel with edges deburred. There shall be smooth grooves on the ends of the top and bottom weights which engage the steel guides. The arbor top and bottom shall be provided with an oilless-type bushing.

Counterweight guide tracks shall be structural tees or angles properly tied together and securely anchored to the proscenium wall. All joints where the counterweight travels shall be ground smooth. These guide tracks shall be caged their entire length.

All proscenium firesafety curtains shall have an approved adjustable checking device or system, whether it be a counterweight arrangement, a hydraulic speed-governing system, a hydraulic dashpot shock-absorbing unit, or some other equivalent device or system that will enable the installation to meet the automatic-closing requirements detailed in Section 4.101.

SECTION 4.106 — TESTS

The complete installation of every proscenium firesafety curtain shall be subjected to a minimum of two successful emergency-type operating tests triggered by release of the end of the emergency control line away from the hand line, winch or motor, and an on-site review of specifications by the building official prior to a new facility being issued an occupancy permit, and an existing facility being allowed the use of the newly renovated facilities.

SECTION 4.107 — NEW DESIGNS

A water curtain or deluge system complying with U.B.C. Standard 9-1 may be used in conjunction with an automatically closing opaque noncombustible curtain in lieu of the proscenium firesafety curtain described in U.B.C. Standard 4-1. Both the deluge system and curtain closure shall be actuated by combination rate-of-temperature-rise and temperature devices located on the stage. The water system shall be designed to completely wet the entire curtain.

Curtains of other designs and materials, when not obviously of greater fire resistance than specified in this standard, shall, before acceptance, be subjected to the standard fire test specified in Chapter 7 of the Building Code as applicable to nonbearing partitions, except that such tests shall be
continued only for a period of five minutes unless failure shall have occurred previously. The unexposed face of the curtain shall not glow within a period of 30 minutes nor shall there be any passage of smoke or flame through the curtain.

FIGURE 4-1-1—BRAILLE-STYLE PROSCENIUM FIRESAFETY CURTAIN
UNIFORM BUILDING CODE STANDARD 7-1

FIRE TESTS OF BUILDING CONSTRUCTION AND MATERIALS


See Sections 405.1.1, 405.3.4, 601.3, 703.2, 703.4, 706, 709.3.2.2, 709.5, 709.6, 710.2, 710.3, 2602.5.2 and Table 7-A, Uniform Building Code

SECTION 7.101 — SCOPE

This standard for fire tests is applicable to assemblies of masonry units and to composite assemblies of structural materials for buildings, including bearing and other walls and partitions, columns, girders, beams, slabs, and composite slab and beam assemblies for floors and roofs. They are also applicable to other assemblies and structural units that constitute permanent integral parts of a finished building.

It is the intent that classifications shall register performance during the period of exposure and shall not be construed as having determined suitability for use after fire exposure.

Control of Fire Tests

SECTION 7.102 — TIME-TEMPERATURE CURVE

The conduct of fire tests of materials and construction shall be controlled by the standard time-temperature curve shown in Figure 7-1-1. The points on the curve that determine its character are:

1,000°F. (538°C.) ........... at 5 minutes
1,300°F. (704°C.) ........... at 10 minutes
1,550°F. (843°C.) ........... at 30 minutes
1,700°F. (927°C.) ........... at 1 hour
1,850°F. (1010°C.) ........... at 2 hours
2,000°F. (1093°C.) ........... at 4 hours
2,300°F. (1260°C.) ........... at 8 hours or over

SECTION 7.103 — FURNACE TEMPERATURES

The temperature fixed by the curve shall be deemed to be the average temperature obtained from the readings of not less than nine thermocouples for a floor, roof, wall or partition and not less than eight thermocouples for a structural column symmetrically disposed and distributed to shown the temperature near all parts of the sample, the thermocouples being enclosed in protection tubes of such materials and dimensions that the time constant of the protected thermocouple assembly lies within the range from 5.0 to 7.2 minutes. The exposed length of the pyrometer tube and thermocouple in the furnace chamber shall not be less than 12 inches (305 mm). Other types of protecting tubes or pyrometers may be used that, under test conditions, give the same indications as the above standard within the limit of accuracy that applies for furnace-temperature measurements. For floors and columns, the junction of the thermocouples shall be placed 12 inches (305 mm) away from the exposed face of the sample at the beginning of the test and, during the test, shall not touch the sample as a result of its deflection. In the case of walls and partitions, the thermocouples shall be placed 6 inches (152 mm) away from the exposed face of the sample at the beginning of the test, and shall not touch the sample during the test in the event of deflection.
The temperatures shall be read at intervals not exceeding five minutes during the first two hours, and thereafter the intervals may be increased to not more than 10 minutes.

The accuracy of the furnace control shall be such that the area under the time-temperature curve, obtained by averaging the results from the pyrometer readings, is within 10 percent of the corresponding area under the standard time-temperature curve shown in Figure 7-1-1 for fire tests of one hour or less duration, within 7.5 percent for those over one hour and not more than two hours, and within 5 percent for tests exceeding two hours in duration.

**FIGURE 7-1-1**

**SECTION 7.104 — TEMPERATURES OF UNEXPOSED SURFACES OF FLOORS, WALLS AND PARTITIONS**

Temperatures at unexposed surfaces shall be measured with thermocouples or thermometers placed under flexible, dry, felted asbestos pads 6 inches square, 0.4 inch (152 mm square, 10.2 mm) in thickness and weighing not less than 1 nor more than 1.4 pounds per square foot (9.6 kg/m$^2$). The pads shall be sufficiently soft so that, without breaking, they may be shaped to contact over the whole surface against which they are placed. The wire leads of the thermocouple or the stem of the
thermometer shall have an immersion under the pad and be in contact with the unexposed surface for not less than 3 1/2 inches (88.9 mm). The hot junction of the thermocouple or the bulb of the thermometer shall be placed approximately under the center of the pad. The outside diameter of protecting or insulating tubes, and of thermometer stems, shall not be more than 5/16 inch (7.9 mm). The pad shall be held firmly against the surface and shall fit closely about the thermocouples or thermometer stems. Thermometers shall be of the partial-immersion type with a length of stem between the end of the bulb and the immersion mark of 3 inches (76.2 mm). The wires for the thermocouple in the length covered by the pad shall not be heavier than No. 18 B.&S. gage (0.04 inch (1.02 mm)) and shall be electrically insulated with heat-resistant and moisture-resistant coatings.

Temperature readings shall be taken at not less than nine points on the surface; five of these shall be symmetrically disposed, one to be approximately at the center of the specimens and four at approximately the center of quarter sections. The other four should be located at the discretion of the testing agency to obtain representative information on the performance of the construction under tests. None of the thermocouples shall be located nearer to the edges of the test specimen that one and one-half times the thickness of the construction or 12 inches (305 mm). An exception can be made in those cases where there is an element of the construction that is not otherwise represented in the remainder of the test specimen. None of the thermocouples shall be located opposite or on top of beams, girders, pilasters or other structural members if temperatures at such points will obviously be lower than at more representative locations. None of the thermocouples shall be located opposite or on top of fasteners such as screws, nails or staples that will be obviously higher or lower in temperature than at more representative locations if the aggregate area of any part of such fasteners projected to the unexposed surface is less than 0.8 percent of the area within any 5-inch square (127 mm). Such fasteners shall not extend through the assembly.

Temperature readings shall be taken at intervals not exceeding 15 minutes until a reading exceeding 212°F. (100°C.) has been obtained at any one point. Thereafter the readings may be taken more frequently at the discretion of the testing body, but the intervals need not be less than five minutes.

Where the conditions of acceptance place a limitation on the rise of temperature of the unexposed surface, the temperature end point of the fire-endurance period shall be determined by the average of the measurements taken at individual points; except that if a temperature rise 30 percent in excess of the specified limit occurs at any one of these points, the remainder shall be ignored and the fire-endurance period judged as ended.

Classification as Determined by Test

SECTION 7.105 — REPORT OF RESULTS

Results shall be reported in accordance with the performance in the tests prescribed in this standard. They shall be expressed in time periods of resistance to the nearest integral minute. Reports shall include observations of significant details of the behavior of the material or construction during the test and after the furnace fire is cut off, including information on deformation, spalling, cracking, burning of the specimen or its component parts, continuance of flaming and production of smoke.

Reports of tests involving wall, floor, beam or ceiling constructions in which restraint is provided against expansion, contraction or rotation of the construction shall describe the method used to provide this restraint.

Reports of tests in which other than maximum load conditions are imposed shall fully define the conditions of loading used in the test and shall be designated in the title of the report of the test as a restricted load condition.

When the indicated resistance period is one-half hour or over, and determined by the average or maximum temperature rise on the unexposed surface or within the test sample, or by failure under load, a correction shall be applied for variation of the furnace exposure from that prescribed where it will affect the classification by multiplying the indicated period by two thirds of the difference in
area between the curve of average furnace temperature and the standard curve for the first three
fourths of the period and dividing the product by the area between the standard curve and a base line
of 68°F. (20°C.) for the same part of the indicated period, the latter area increased by 54 Fahrenheit-
hours (30 centigrade-hours) [3,240 Fahrenheit-minutes (1800 centrigrade-minutes)], to compen-
sate for the thermal lag of the furnace thermocouples during the first part of the test. For fire
exposure in the test higher than standard, the indicated resistance period shall be increased by the
amount of the correction and be similarly decreased for fire exposure below standard.

NOTE: The correction can be expressed by the following formula:

\[ C = \frac{2I (A - A_s)}{3 (A_s + L)} \]

WHERE:
- \( A \) = area under the curve of indicated average furnace temperature for the first three fourths of
  the indicated period.
- \( A_s \) = area under the standard furnace curve for the same part of the indicated period.
- \( C \) = correction in the same units as \( I \).
- \( I \) = indicated fire-resistance period.
- \( L \) = lag correction in the same units as \( A \) and \( A_s \) [54 Fahrenheit-hours (30 centrigrade-hours)
  (3,240 Fahrenheit-minutes (1800 centrigrade-minutes))].

Walls and partitions of nonsymmetrical construction shall be tested with both faces exposed to
the furnace and the report shall indicate the fire-endurance classification applicable to each side.
Subject to the approval of the building official based on data submitted by the applicant justifying a
single-side test only, unsymmetrical wall assemblies may be tested with the least fire-resistive side
exposed in the furnace.

SECTION 7.106 — TEST SPECIMEN

The test sample shall be truly representative of the construction for which classification is desired,
as to materials, workmanship, and details such as dimensions of parts, and shall be built under con-
ditions representative of those obtained as practically applied in building construction and opera-
tion. The physical properties of the materials and ingredients used in the test sample shall be
determined and recorded.

The size and dimensions of the test sample specified herein are intended to apply for rating con-
structions of dimensions within the usual general range employed in buildings. If the conditions of
use limit the construction to smaller dimensions, a proportionate reduction may be made in the di-
mensions of the samples for a test qualifying them for such restricted use.

When it is desired to include a built-up roof covering, the test specimen shall have a roof covering
of three-ply, Type 15 felt not in excess of 120 pounds per square (100 square feet) (6.04 kg/m²) of
hot-mopping asphalt without gravel surfacing. Tests of assemblies with this covering do not pre-
clude the field use of other built-up roof coverings.

Fire Test Procedures

SECTION 7.107 — FIRE-ENDURANCE TEST

The fire-endurance test on the sample with its applied load, if any, shall be continued until failure
occurs, or until the sample has withstood the test conditions for a period equal to that herein speci-
fied in the conditions of acceptance for the given type of construction.

For the purpose of obtaining additional performance data, the test may be continued beyond the
time the fire-endurance classification is determined.
SECTION 7.108 — HOSE STREAM TEST

7.108.1 General. Where required by the conditions of acceptance, a duplicate sample shall be subjected to a fire-exposure test for a period equal to one half of that indicated as the resistance period in the fire-endurance test, but not for more than one hour, immediately after which the sample shall be subjected to the impact, erosion and cooling effects of a hose stream directed first at the middle and then at all parts of the exposed face, changes in direction being made slowly.

7.108.2 Exemption. The hose stream test shall not be required in the case of constructions having a resistance period, indicated in the fire-endurance test, of less than one hour.

7.108.3 Optional Program. The submitter may elect, with the advice and consent of the testing body, to have the hose stream test made on the sample subjected to the fire-endurance test and immediately following the expiration of the fire-endurance test.

7.108.4 Stream Equipment and Details. The stream shall be delivered through a 2 1/2-inch (64 mm) hose discharging through a National Standard Playpipe of corresponding size equipped with a 1 1/8-inch (28.6 mm) discharge tip of the standard-taper smooth-bore pattern without shoulder at the orifice. The water pressure and duration of application shall be as prescribed in Table 7-1-A.

7.108.5 Nozzle Distance. The nozzle orifice shall be 20 feet (6096 mm) from the center of the exposed surface of the test sample if the nozzle is so located that when directed at the center, its axis is normal to the surface of the test sample. If otherwise located, its distance from the center shall be less than 20 feet (6096 mm) by an amount equal to 1 foot (305 mm) for each 10 degrees of deviation from the normal.

<table>
<thead>
<tr>
<th>RESISTANCE PERIOD</th>
<th>WATER PRESSURE AT BASE OF NOZZLE</th>
<th>DURATION OF APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(pounds per square inch)</td>
<td>(minutes per 100 square feet)</td>
</tr>
<tr>
<td></td>
<td>× 6.89 for kPa</td>
<td>× 0.0108 for min/m²</td>
</tr>
<tr>
<td>8 hours and over</td>
<td>45</td>
<td>6</td>
</tr>
<tr>
<td>4 hours and over if less than 8 hours</td>
<td>45</td>
<td>5</td>
</tr>
<tr>
<td>2 hours and over if less than 4 hours</td>
<td>30</td>
<td>2 1/2</td>
</tr>
<tr>
<td>1 1/2 hours and over if less than 2 hours</td>
<td>30</td>
<td>1 1/2</td>
</tr>
<tr>
<td>1 hour and over if less than 1 1/2 hours</td>
<td>30</td>
<td>1</td>
</tr>
<tr>
<td>Less than 1 hour, if desired</td>
<td>30</td>
<td>1</td>
</tr>
</tbody>
</table>

SECTION 7.109 — TIME OF TESTING

The material or construction shall not be tested until a large proportion of its final strength has been attained and, if it contains moisture, until the excess has been removed to achieve an air-dry condition in accordance with the requirements given in this section. Protect the testing equipment and sample undergoing the fire test from any condition of wind or weather that might lead to abnormal results. The ambient air temperature at the beginning of the test shall be within the range of 50°F to 90°F (10°C to 32°C.) The velocity of air across the unexposed surface of the sample, measured just before the test begins, shall not exceed 4.4 feet per second (1.3 m/s) as determined by an anemometer placed at right angles to the unexposed surface. If mechanical ventilation is employed during the test, an airstream shall not be directed across the surface of the specimen.

Prior to fire test, condition constructions with the objective of providing, within a reasonable time, a moisture condition within the specimen approximately representative of that likely to exist in similar construction in buildings. For purposes of standardization, this condition is to be considered as that which would be established at equilibrium resulting from drying in an ambient atmosphere of 50 percent relative humidity at 73°F (23°C.) However, with some constructions, it may be difficult or impossible to achieve such uniformity within a reasonable period of time. Accordingly,
where this is the case, specimens may be tested when the dampest portion of the structure, the portion at 6 inches (152 mm) depth below the surface of massive constructions, has achieved a moisture content corresponding to drying to equilibrium with air in the range of 50 to 75 percent relative humidity at 73°F ± 5°F (20°C ± 3°C). In the event that specimens dried in a heated building fail to meet these requirements after a 12-month conditioning period, or in the event that the nature of the construction is such that it is evident that drying of the specimen interior will be prevented by hermetic sealing, these requirements may be waived, except as to attainment of a large portion of final strength, and the specimen tested in the condition in which it then exists.

If during the conditioning of the specimen it appears desirable or is necessary to use accelerated drying techniques, it is the responsibility of the laboratory conducting the test to avoid procedures which will significantly alter the structural or fire-endurance characteristics of the specimen or both from those produced as the result of drying in accordance with procedures given in this section.

Within 72 hours prior to the fire test, information on the actual moisture content and distribution within the specimen shall be obtained. Include this information in the test report.

**Tests of Bearing Walls and Partitions**

**SECTION 7.110 — SIZE OF SAMPLE**

The area exposed to fire shall not be less than 100 square feet (9.3 m²), with neither dimension less than 9 feet (2743 mm). The test specimen shall not be restrained on its vertical edges.

For construction joints, the area of the test specimen may be less than 100 square feet (9.3 m²) provided the length of the joint is not less than 9 feet (2743 mm). The test specimen shall be of sufficient size so as to produce a representative construction joint for which evaluation is desired.

**SECTION 7.111 — LOADING**

Throughout the fire-endurance and fire and hose stream tests, apply a constant superimposed load to simulate a maximum load condition. The applied load shall be as nearly as practicable the maximum load allowed by design under design criteria set forth in the Building Code. The tests may also be conducted by applying to the specimen a load less than the maximum. Such tests shall be identified in the test report as having been conducted under restricted load conditions. The applied load, and the applied load expressed as a percentage of the maximum allowable design load, shall be included in the report. A double-wall assembly shall be loaded during the test to simulate field-use conditions, with either side loaded separately or both sides together. (Note: The method used shall be reported.)

The choice depends on the intended use and whether the load on the exposed side, after it has failed, will be transferred to the unexposed side. If, in the intended use, the load from the structure above is supported by both walls as a unit and would be or is transferred to the unexposed side in case of collapse of the exposed side, both walls shall be loaded in the test by a single unit. If in the intended use the load from the structure above each wall is supported by each wall separately, the walls shall be loaded separately in the test by separate load sources. If the intended use of the construction system being tested involves situations of both loading conditions described above, the walls shall be loaded separately in the test by separate load sources. In tests conducted with the walls loaded separately, the condition of acceptance requiring the walls to maintain the applied load shall be based on the time at which the first of either of the walls fails to sustain the load.

**SECTION 7.112 — CONDITIONS OF ACCEPTANCE**

The test shall be regarded as successful if the following conditions are met:

1. The wall or partition shall have sustained the applied load during the fire-endurance test without passage of flame or gases hot enough to ignite cotton waste, for a period equal to that for which classification is desired.
2. The wall or partition shall have sustained the applied load during the fire and hose stream test as specified in Section 7.108, without passage of flame, of gases hot enough to ignite cotton waste, or of the hose stream. The assembly shall be considered to have failed the hose stream test if an opening develops that permits a projection of water from the stream beyond the unexposed surface during the time of the hose stream test.

3. Transmission of heat through the wall or partition during the fire-endurance test shall not have been such as to raise the temperature on its unexposed surface more than 250°F (139°C) above its initial temperature.

Tests of Nonbearing Walls and Partitions

SECTION 7.113 — SIZE OF SAMPLE

The area exposed to fire shall not be less than 100 square feet (9.3 m²), with neither dimension less than 9 feet (2734 mm). The test specimen shall be restrained on all four edges.

For construction joints, the area of the test specimen may be less than 100 square feet (9.3 m²) provided the length of the joint is not less than 9 feet (2734 mm). The test specimen shall be of sufficient size so as to produce a representative construction joint for which evaluation is desired.

SECTION 7.114 — CONDITIONS OF ACCEPTANCE

The test shall be regarded as successful if the following conditions are met:

1. The wall or partition shall have withstood the fire-endurance test without passage of flame or gases hot enough to ignite cotton waste, for a period equal to that for which classification is desired.

2. The wall or partition shall have withstood the fire and hose stream test as specified in Section 7.108, without passage of flame, of gases hot enough to ignite cotton waste, or of the hose stream. The assembly shall be considered to have failed the hose stream test if an opening develops that permits a projection of water from the stream beyond the unexposed surface during the time of the hose stream test.

3. Transmission of heat through the wall or partition during the fire-endurance test shall not have been such as to raise the temperature on its unexposed surface more than 250°F (139°C) above its initial temperature.

Tests of Columns

SECTION 7.115 — SIZE OF SAMPLE

The length of the column exposed to fire shall, when practicable, approximate the maximum clear length contemplated by the design, and for building columns shall not be less than 9 feet (2734 mm). The contemplated details of connections, and their protection, if any, shall be applied according to the methods of acceptable field practice.

SECTION 7.116 — LOADING

During the fire endurance test, the column shall be exposed to fire on all sides and shall be loaded in a manner calculated to develop theoretically, as nearly as practicable, the working stresses contemplated by the design. Provision shall be made for transmitting the load to the exposed portion of the column without unduly increasing the effective column length.

If the submitter and the building official jointly so decide, the column may be subjected to one and three-fourths times its designed working load before the fire-endurance test is undertaken. The
fact that such a test has been made shall not be construed as having had a deleterious effect on the fire-endurance test performance.

SECTION 7.117 — CONDITION OF ACCEPTANCE
The test shall be regarded as successful if the column sustains the applied load during the fire-endurance test for a period equal to that for which classification is desired.

Alternate Test of Protection for Structural Steel Columns

SECTION 7.118 — APPLICATION
This test procedure does not require column loading at any time and may be used at the discretion of the testing laboratory to evaluate steel column protections that are not required by design to carry any of the column load.

SECTION 7.119 — SIZE AND CHARACTER OF SAMPLE
The size of the steel column used shall be such as to provide a test specimen that is truly representative of the design, materials and workmanship for which classification is desired. The protection shall be applied according to the methods of acceptable field practice. The length of the protected column shall be at least 8 feet (2438 mm). The column shall be vertical during application of the protection and during the fire exposure.

The applied protection shall be restrained against longitudinal temperature expansion greater than that of the steel column by rigid steel plates or reinforced concrete attached to the ends of the steel column before the protection is applied. The size of the plates or amount of concrete shall be adequate to provide direct bearing for the entire transverse area of the protection.

The ends of the specimen, including the means for restraint, shall be given sufficient thermal insulation to prevent appreciable direct heat transfer from the furnace.

SECTION 7.120 — TEMPERATURE MEASUREMENT
The temperature of the steel in the column shall be measured by at least three thermocouples located at each of four levels. The upper and lower levels shall be 2 feet (610 mm) from the ends of the steel column, and the other two intermediate levels shall be equally spaced. The thermocouples at each level shall be so placed as to measure significant temperatures of the component elements of the steel section.

SECTION 7.121 — EXPOSURE TO FIRE
During the fire-endurance test the specimen shall be exposed to fire on all sides for its full length.

SECTION 7.122 — CONDITIONS OF ACCEPTANCE
The test shall be regarded as successful if the transmission of heat through the protection during the period of fire exposure for which classification is desired does not raise the average (arithmetical) temperature of the steel at any one of the four levels above 1,000°F. (538°C.), or does not raise the temperature above 1,200°F. (649°C.) at any one of the measured points.

Tests of Floors and Roofs

SECTION 7.123 — APPLICATION
This procedure is applicable to floor and roof assemblies with or without attached, furred or suspended ceilings and requires application of fire exposure to the underside of the specimen under test.
Two fire-endurance classifications shall be developed for assemblies restrained against thermal expansion, a restrained assembly classification based upon the conditions of acceptance specified in Section 7.127 and an unrestrained assembly classification based upon the conditions of acceptance specified in Section 7.128.

One fire-endurance classification shall be developed from tests of assemblies not restrained against thermal expansion based upon the conditions of acceptance specified in Section 7.128, Items 1 and 2.

Individual unrestrained classifications may be developed for beams tested in accordance with this test method using the conditions of acceptance specified in Section 7.136.

SECTION 7.124 — SIZE AND CHARACTERISTICS OF SPECIMEN

The area exposed to fire shall not be less than 180 square feet (16.7 m²) with either dimension less than 12 feet (3658 mm). Structural members, if a part of the construction under test, shall lie within the combustion chamber and have a side clearance of not less than 8 inches (203 mm) from its walls.

For construction joints, the area of the test specimen may be less than 180 square feet (16.7 m²) provided the length of the joint is not less than 12 feet (3658 mm). The test specimen shall be of sufficient size so as to produce a representative construction joint for which evaluation is desired.

The specimen shall be installed in accordance with recommended fabrication procedures for the type of construction and shall be representative of the design for which classification is desired. Where a restrained classification is desired, specimens representing forms of construction in which restraint to thermal expansion occurs shall be reasonably restrained in the furnace.

SECTION 7.125 — LOADING

Throughout the fire-endurance test, apply a superimposed load to the specimen. This load, together with the weight of the specimen, shall be as nearly as practicable the maximum theoretical dead and live loads permitted by this code. A fire-endurance test may be conducted applying a restricted load condition to the specimen which shall be identified for a specific load condition other than the maximum allowed load condition.

SECTION 7.126 — TEMPERATURE MEASUREMENT

For specimens employing structural members (beams, open-web steel joists, etc.) spaced at more than 4 feet (1219 mm) on centers, measure the temperature of the steel in these structural members by thermocouples at three or more sections spaced along the length of the members with one section preferably located at midspan, except that in cases where the cover thickness is not uniform along the specimen length, at least one of the sections at which temperatures are measured shall include the point of minimum cover.

For specimens employing structural members (beams, open-web steel joists, etc.) spaced at 4 feet (1219 mm) on center or less, measure the temperature of the steel in these structural members by four thermocouples placed on each member, except that no more than four members shall be so instrumented. Place the thermocouples at significant locations, such as at midspan, over joints in the ceiling, and over light fixtures, etc.

For steel structural members, there shall be four thermocouples at each section, except that where only four thermocouples are required on a member, the thermocouples may be distributed along the member at significant locations as provided for in the preceding paragraph. Locate two on the bottom of the bottom flange or chord, one on the web at the center, and one on the top flange or chord. The recommended thermocouple distribution at each section is shown in Figure 7-1-2.

For reinforced or prestressed concrete structural members, locate thermocouples on each of the tension-reinforcing elements, unless there are more than eight such elements, in which case place
thermocouples on eight elements selected in such a manner as to obtain representative temperatures of all the elements.

For steel floor or roof units, locate four thermocouples on each section (a section to comprise the width of one unit), one on the bottom plane of the unit at an edge joint, one on the bottom plane of the unit remote from the edge, one on the side wall of the unit, and one on the top plane of the unit. The thermocouples should be applied, where practicable, to the surface of the units remote from fire and spaced across the width of the unit. No more than four or less than two sections need be so instrumented in each representative span. Locate the groups of four thermocouples in representative locations. Typical thermocouple locations for a unit section are shown in Figure 7-1-3.

SECTION 7.127 — CONDITIONS OF ACCEPTANCE—RESTRAINED ASSEMBLY

In obtaining a restrained assembly classification, the following conditions shall be met:

1. The specimen shall have sustained the applied load during the classification period without developing unexposed surface conditions which will ignite cotton waste.

2. Transmission of heat through the specimen during the classification period shall not have been such as to raise the average temperature on its unexposed surface more than 250°F (139°C) above its initial temperature.

3. For specimens employing steel structural members (beams, open-web joists, etc.) spaced more than 4 feet (1219 mm) on centers, the assembly shall achieve a fire-endurance classification on the basis of the temperature criteria specified in Section 7.128, Item 3, for assembly classifications up to and including one hour. For classifications greater than one hour, the above temperature criteria shall apply for a period of one half the classification of the assembly or one hour, whichever is greater.

4. For specimens employing steel structural members (beams, open-web steel joists, etc.) spaced 4 feet (1219 mm) or less on centers, the assembly shall achieve a fire-endurance classification on the basis of the temperature criteria specified in Section 7.128, Item 4, for assembly classifications up to and including one hour. For classifications greater than one hour, the above temperature criteria shall apply for a period of one half the classification of the assembly or one hour, whichever is greater.

5. For specimens employing conventionally designed concrete beams, spaced more than 4 feet (1219 mm) on centers, the assembly shall achieve a fire-endurance classification on the basis of the temperature criteria specified in Section 7.128, Item 5, for assembly classifications up to and including one hour. For classifications greater than one hour, the above temperature criteria shall apply for a period of one half the classification of the assembly or one hour, whichever is greater.

SECTION 7.128 — CONDITIONS OF ACCEPTANCE—UNRESTRAINED ASSEMBLY

In obtaining a unrestrained assembly classification, the following conditions shall be met:

1. The specimen shall have sustained the applied load during the classification period without developing unexposed surface conditions which will ignite cotton waste.

2. The transmission of heat through the specimen during the classification period shall not have been such as to raise the average temperature on its unexposed surface more than 250°F (139°C) above its initial temperature.

3. For specimens employing steel structural members (beams, open-web steel joists, etc.) spaced more than 4 feet (1219 mm) on centers, the temperature of the steel shall not have exceeded 1,300°F (704°C) at any location during the classification period nor shall the average temperature recorded by four thermocouples at any section have exceeded 1,100°F (593°C) during the classification period.
4. For specimens employing steel structural members (beams, open-web steel joists, etc.) spaced 4 feet (1219 mm) or less on center, the average temperature recorded by all joist or beam thermocouples shall not have exceeded 1,100°F. (593°C.) during the classification period.

5. For specimens employing conventionally designed concrete structural members (excluding cast-in-place concrete roof or floor slabs having spans equal to or less than those tested), the average temperature of the tension steel at any section shall not have exceeded 800°F. (427°C.) for cold-drawn prestressing steel or 1,100°F. (593°C.) for reinforcing steel during the classification period.

6. For specimens employing steel floor or roof units intended for use in spans greater than those tested, the average temperature recorded by all thermocouples located on any one span of the floor or roof units shall not have exceeded 1,100°F. (593°C.) during the classification period.

SECTION 7.129 — REPORT OF RESULTS
The fire-endurance classification of a restrained assembly shall be reported as that developed by applying the conditions of acceptance specified in Section 7.127.

The fire-endurance classification of an unrestrained assembly shall be reported as that developed by applying the conditions of acceptance specified in Section 7.128 to a specimen tested in accordance with this test procedure.

Tests of Loaded Restrained Beams

SECTION 7.130 — APPLICATION
An individual classification of a restrained beam may be obtained by this procedure and based upon the conditions of acceptance specified in Section 7.133. The fire-endurance classification so derived shall be applicable to the beam when used with a floor or roof construction which has a comparable or greater capacity for heat dissipation from the beam than the floor or roof with which it was tested. The fire-endurance classification developed by this method shall not be applicable to sizes of beams smaller than those tested.

SECTION 7.131 — SIZE AND CHARACTERISTICS OF SPECIMEN
Install the test specimen in accordance with recommended fabrication procedures for the type of construction. It shall be representative of the design for which classification is desired. The length of beam exposed to the fire shall not be less than 12 feet (3658 mm) and the member shall be tested in its normal horizontal position. A section of a representative floor or roof construction not more than 7 feet (2134 mm) wide, symmetrically located with reference to the beam, may be included with the test specimen and exposed to the fire from below. Restrain the beam including that part of the floor or roof element forming the complete beam as designed (such as composite steel or concrete construction) against longitudinal thermal expansion in a manner simulating the restraint in the construction represented. Do not support or restrain the perimeter of the floor or roof element of the specimen, except that part which forms part of a beam as designed.

SECTION 7.132 — LOADING
Throughout the fire-endurance tests, apply a superimposed load to the specimen. This load, together with the weight of the specimen, shall be as nearly as practicable the maximum theoretical dead and live loads permitted by this code.

SECTION 7.133 — CONDITIONS OF ACCEPTANCE
The following conditions shall be met:
I. The specimen shall have sustained the applied load during the classification period.

2. The specimen shall have achieved a fire-endurance classification on the basis of the temperature criteria specified in Section 7.128, Item 3 or 4, of one half the classification of the assembly, or one hour, whichever is greater.

**Alternative Classification Procedure for Loaded Beams**

**SECTION 7.134 — APPLICATION**

Individual unrestrained classifications may be developed for beams tested as part of a floor or roof assembly as described in Sections 7.123 through 7.126 (except for the fourth paragraph of Section 7.123) or for restrained beams tested in accordance with the procedure described in Sections 7.130 through 7.132. The fire-endurance classification so derived shall be applicable to beams when used with a floor or roof construction which has a comparable or greater capacity for heat dissipation from the beam than the floor or roof with which it was tested. The fire-endurance classification developed by this method shall not be applicable to sizes of beams smaller than those tested.

**SECTION 7.135 — TEMPERATURE MEASUREMENT**

Measure the temperature of the steel in structural members by thermocouples at three or more sections spaced along the length of the members with one section preferably located at midspan, except that in cases where the cover thickness is not uniform along the specimen length, at least one of the sections at which temperatures are measured shall include the point of minimum cover.

For steel beams, there shall be four thermocouples at each section; locate two on the bottom of the bottom flange, one on the web at the center, and one on the bottom of the top flange.

For reinforced or prestressed concrete structural members, locate thermocouples on each of the tension-reinforcing elements unless there are more than eight such elements, in which case place thermocouples on eight elements selected in such a manner as to obtain representative temperatures of all the elements.

**SECTION 7.136 — CONDITIONS OF ACCEPTANCE**

In obtaining an unrestrained beam classification, the following conditions shall be met:

1. The specimen shall have sustained the applied load during the classification period.

2. For steel beams, the temperature of the steel shall not have exceeded 1,300°F. (704°C.) at any location during the classification period nor shall the average temperature recorded by four thermocouples at any section have exceeded 1,100°F. (593°C.) during this period.

3. For conventionally designed concrete beams, the average temperature of the tension steel at any section shall not have exceeded 800°F. (427°C.) for cold-drawn prestressing steel or 1,100°F. (593°C.) for reinforcing steel during the classification period.

**Alternate Test of Protection for Solid Structural Steel Beams and Girders**

**SECTION 7.137 — APPLICATION**

Where the loading required in Section 7.125 is not feasible, this alternate test procedure may be used to evaluate the protection of steel beams and girders without application of design load, provided that the protection is not required by design to function structurally in resisting applied loads. The conditions of acceptance of this alternate test are not applicable to tests made under design load as provided under tests for floors and roofs in Sections 7.124, 7.127 and 7.128.
SELECTION 7.138 — SIZE AND CHARACTER OF SAMPLE

The size of the steel beam or girder shall be such as to provide a test specimen that is truly representative of the design, materials and workmanship for which classification is desired. The protection shall be applied according to the methods of acceptable field practice and the projection below the ceiling, if any, shall be representative of the conditions of intended use. The length of beam or girder exposed to the fire shall not be less than 12 feet (3658 mm) and the member shall be tested in horizontal position. A section of a representative floor construction not less than 5 feet (1524 mm) wide, symmetrically located with reference to the beam or girder and extending its full length, shall be included in the test assembly and exposed to fire from below. The rating of performance shall not be applicable to sizes smaller than those tested.

The applied protection shall be restrained against longitudinal expansion greater than that of the steel beam or girder by rigid steel plates or reinforced concrete attached to the ends of the member before the protection is applied. The ends of the member, including the means for restraint, shall be given sufficient thermal insulation to prevent appreciable direct heat transfer from the furnace to the unexposed ends of the member or from the ends of the member to the outside of the furnace.

SELECTION 7.139 — TEMPERATURE MEASUREMENT

The temperature of the steel in the beam or girder shall be measured with not less than four thermocouples at each of four sections equally spaced along the length of the beam and symmetrically disposed and not nearer than 2 feet (610 mm) from the inside face of the furnace. The thermocouples at each section shall be symmetrically placed so as to measure significant temperatures of the component elements of the steel section.

SELECTION 7.140 — CONDITIONS OF ACCEPTANCE

The test shall be regarded as successful if the transmission of heat through the protection during the period of fire exposure for which classification is desired does not raise the average (arithmetical) temperature of the steel at any one of the four sections above 1,000°F. (649°C.), or does not raise the temperature above 1,200°F. (649°C.) at any one of the measured points.

Determining Conditions of Restraint for Floor and Roof Assemblies and for Individual Beams

SELECTION 7.141 — GENERAL

Construction tested in accordance with this standard shall be classified as restrained or unrestrained.

A restrained condition in fire tests, as used in this standard, is one in which expansion at the supports of a load-carrying element resulting from the effects of the fire is resisted by forces external to the element. An unrestrained condition is one in which the load-carrying element is free to expand and rotate at its supports.

For the purpose of this section, restraint in buildings is defined as follows: floor and roof assemblies and individual beams in buildings shall be considered restrained when the surrounding or supporting structure is capable of resisting the thermal expansion throughout the range of anticipated elevated temperatures. Construction not complying with this definition is assumed to be free to rotate and expand and shall be considered as unrestrained.

Restraint may be provided by the lateral stiffness of supports for floor and roof assemblies and intermediate beams forming part of the assembly. In order to develop restraint, connections must adequately transfer thermal thrusts to such supports. The rigidity of adjoining panels or structures shall be considered in assessing the capability of a structure to resist thermal expansion.
Performance of Protective Membranes in Wall, Partition, Floor or Roof Assemblies

SECTION 7.142 — APPLICATION

When the thermal protection afforded by membrane elements in wall, partition, floor or roof assemblies is to be determined, the nonstructural performance of protective membranes shall be obtained by the following procedure. The performance of protective membranes as determined by this procedure is not a substitute for the fire-endurance classification determined by Sections 7.110 through 7.141 of this standard.

SECTION 7.143 — SIZE AND CHARACTER OF SAMPLE

The sample shall conform to the provisions specified in Section 7.106. The size of the sample shall also conform to the provisions specified in Section 7.110 for bearing walls and partitions, Section 7.113 for nonbearing walls and partitions, or Section 7.124 for floors or roofs.

SECTION 7.144 — TEMPERATURE PERFORMANCE OF PROTECTIVE MEMBRANES

The temperature performance of protective membranes shall be measured with thermocouples, the measuring junctions of which are in intimate contact with the exposed surface of the elements being protected. The diameter of the wires used to form the thermo-junction shall not be greater than the thickness of sheet metal framing or panel members to which they are attached, and in no case greater than No. 18 B.&S. gage (0.040 inch (1.02 mm)). The lead shall be electrically insulated with heat-resistant and moisture-resistant coatings.

For each class of elements being protected, temperature readings shall be taken at not less than five representative points. Thermocouples shall not be located nearer to the edges of the test assembly than 12 inches (305 mm). An exception may be made in those cases when there is an element or feature of the construction that is not otherwise represented in the test assembly. Thermocouples shall not be located opposite, on top of or adjacent to fasteners such as screws, nails or staples when such locations are excluded for thermocouple placement on the unexposed surface of the test assembly as specified in the second paragraph of Section 7.104.

Thermocouples shall be located to obtain representative information on the temperature of the interface between the exposed membrane and the substrate or element being protected.

Temperature readings shall be taken at intervals not exceeding five minutes, but the intervals need not be less than two minutes.

SECTION 7.145 — CONDITIONS OF PERFORMANCE

Unless otherwise specified, the performance of protective membranes shall be determined as the time at which the following conditions occur:

1. The average temperature rise of any set of thermocouples for each class of element being protected is more than $250^\circ F$ $(139^\circ C)$ above the initial temperature, or

2. The temperature rise of any one thermocouple of the set for each class of element being protected is more than $325^\circ F$ $(181^\circ C)$ above the initial temperature.

SECTION 7.146 — REPORT OF RESULTS

The protective membrane performance for each class of element being protected shall be reported to the nearest integral minute.
The test report shall identify each class of elements being protected and shall show the location of each thermocouple.

The test report shall show the time-temperature data recorded for each thermocouple and the average temperature for the set of thermocouples on each element being protected.

The test report shall state any visual observations recorded that are pertinent to the performance of the protective membrane.

SECTION A

SECTION B

FIGURE 7-1-2—RECOMMENDED THERMOCOUPLE DISTRIBUTION

FLUTED UNIT

CELLULAR UNIT

FIGURE 7-1-3—TYPICAL LOCATION OF THERMOCOUPLES
UNIFORM BUILDING CODE STANDARD 7-2
FIRE TESTS OF DOOR ASSEMBLIES

See Sections 302.4, 305.2.2.2, 703.4, 713.5, 713.9, 1005.8 and 1009.3,
Uniform Building Code
Part I—Based on Underwriters Laboratories Inc. Standard 10B-1988,
Fire Tests of Door Assemblies

SECTION 7.201 — SCOPE

These methods of fire test are applicable for door assemblies of various materials and types of construction, for use in wall openings to retard the passage of fire.

Tests made in conformity with these test methods will register performance during the test exposure; but such tests shall not be construed as determining suitability for use after exposure to fire.

SECTION 7.202 — TIME-TEMPERATURE CURVE

The fire exposure of door assemblies shall be controlled to conform to the applicable portion of the standard time-temperature curve shown in Figure 7-1-1 of U.B.C. Standard 7-1. The points on the curve that determine its character are:

1,000°F. (538°C.) . . . . . . . . . at 5 minutes
1,300°F. (704°C.) . . . . . . . . . at 10 minutes
1,462°F. (794°C.) . . . . . . . . . at 20 minutes
1,550°F. (843°C.) . . . . . . . . . at 30 minutes
1,638°F. (892°C.) . . . . . . . . . at 45 minutes
1,700°F. (927°C.) . . . . . . . . . at 1 hour
1,792°F. (978°C.) . . . . . . . . . at 1 1/2 hours
1,850°F. (1010°C.) . . . . . . . . . at 2 hours
1,925°F. (1052°C.) . . . . . . . . . at 3 hours

SECTION 7.203 — FURNACE TEMPERATURES

7.203.1 Test Exposure. The temperatures of the test exposure shall be deemed to be the average temperature obtained from the readings of not less than nine thermocouples symmetrically disposed and distributed to show the temperature near all parts of the test assembly. The thermocouples shall be protected by sealed porcelain tubes having 3/4-inch (19.1 mm) outside diameter and 1/8-inch (3.2 mm) wall thickness; or, as an alternate, in the case of base metal thermocouples shall be protected by 1/2-inch (13 mm) wrought steel or wrought-iron pipe of standard weight. The junction of the thermocouples shall be 6 inches (152 mm) from the exposed face of the test assembly or from the masonry in which the assembly is installed during the entire test exposure.

7.203.2 Reading Intervals. The temperatures shall be read at intervals not exceeding five minutes during the first two hours, and thereafter the intervals may be increased to not more than 10 minutes.

7.203.3 Accuracy of Control. The accuracy of furnace control shall be such that the area under the time-temperature curve, obtained by averaging the results from the thermocouple readings, is within 10 percent of the corresponding area under the standard time-temperature curve for fire tests of one hour or less duration, within 7.5 percent of those over one hour and not more than two hours and within 5 percent for tests exceeding two hours in duration.
SECTION 7.204 — UNEXPOSED SURFACE TEMPERATURES

If unexposed surface temperatures are recorded other than for single-layer metal doors, they shall be determined in the following manner:

1. Unexposed surface temperatures shall be taken at not less than three points with at least one thermocouple in each 16-square-foot (1.5 m²) area of the door.

   Thermocouples shall not be located over reinforcements extending through the door, over vision panels or nearer than 12 inches (305 mm) from the edge of the door.

2. Unexposed surface temperatures shall be measured with thermocouples placed under flexible, oven-dry, felted asbestos pads, 6 1/8 inches square (156 mm square), 0.40 inch ± 0.05 inch (10.2 mm ± 1.3 mm) thick and weighing not less than 1.0 (4.9 kg/m²) or more than 1.4 pounds per square foot (6.8 kg/m²). The pads shall be held firmly against the surface of the door and shall fit closely about the thermocouples. The thermocouple leads shall be positioned under the pad for a distance of not less than 3 1/2 inches (88.9 mm) with the hot junction under the center of the pad. The thermocouple leads under the pads shall not be heavier than No. 18 AWG [0.04 inch (1.02 mm)] and shall be electrically insulated with heat-resistant and moisture-resistant coatings.

3. Unexposed-surface temperatures shall be read at the same intervals as those for furnace temperatures in Section 7.203.2.

SECTION 7.205 — TEST ASSEMBLIES

7.205.1 Construction and Size. The construction and size of the test door assembly, consisting of single doors or doors in pairs, special purpose doors (such as dutch doors, double egress doors, etc.) or multisection doors shall be representative of that for which classification or rating is desired.

7.205.2 Sills. A floor structure shall be provided as part of the opening to be protected except where such sill interferes with the operation of the door. The sill shall be of noncombustible material and project into the furnace to a distance approximately twice the thickness of the test door or to the limit of the frame, whichever is greater.

SECTION 7.206 — MOUNTING

7.206.1 Side to Be Exposed. Swinging doors shall be mounted so as to open into the furnace chamber.

   Sliding and rolling doors, except passenger-elevator shaft doors, shall be mounted on the exposed side of the opening in the wall closing the furnace chamber.

   Horizontal slide-type elevator shaft doors shall be mounted on the unexposed side of the opening in the wall closing the furnace chamber.

   Access-type doors and chute-type doors and frame assemblies shall be mounted so as to have one assembly open into the furnace chamber and another assembly open away from the furnace chamber.

   Dumbwaiter and service-counter doors and frame assemblies shall be mounted on the exposed side of the opening in the wall.

7.206.2 Frames. Door frames shall be evaluated when mounted so as to have the doors open either away from, or into, the furnace chamber at the discretion of the testing agency, to obtain representative information on the performance of the construction under test.

7.206.3 Hardware. Surface-mounted hardware (fire-exit devices) for use on fire doors shall be evaluated by being installed on one door assembly swinging into the furnace chamber and another door assembly swinging away from the furnace chamber.
7.206.4 Anchors. Door frame wall anchors, when used, shall be acceptable for the wall or partition construction.

7.206.5 Fit. The mounting of all doors shall be such that they fit snugly within the frame, against the wall surfaces, or in guides, but such mounting shall not prevent free and easy operation of the test door.

7.206.6 Clearances. Clearances for swinging doors shall be as follows: With a minus 1/16-inch (1.6 mm) tolerance—1/8 inch (3.2 mm) along the top, 1/8 inch (3.2 mm) along the hinge and latch jambs, 1/8 inch (3.2 mm) along the meeting edge of doors in pairs, and 3/8 inch (9.5 mm) at the bottom edge of a single swing door, and 1/4 inch (6.4 mm) at the bottom of a pair of doors.

Clearances for horizontal sliding doors not mounted within guides shall be as follows: With a minus 1/8-inch (3.2 mm) tolerance—1/2 inch (12.7 mm) between door and wall surfaces, 3/8 inch (9.5 mm) between door and floor structure, and 1/4 inch (6.4 mm) between the meeting edges of center-parting doors. A maximum lap of 4 inches (101.6 mm) of the door over the wall opening at sides and top shall be provided.

Clearances for vertical sliding doors moving within guides shall be as follows: With a minus 1/8-inch (3.2 mm) tolerance—1/2 inch (12.7 mm) between door and wall surfaces along top and/or bottom door edges with guides mounted directly to the wall surface and 3/16 inch (4.8 mm) between meeting edges of biparting doors or 3/16 inch (4.8 mm) between door and floor structure or sill.

Clearances for horizontal slide-type elevator doors shall be as follows: With a minus 1/8-inch (3.2 mm) tolerance—3/8 inch (9.5 mm) between door and wall surfaces, 3/8 inch (9.5 mm) between multisection door panels and 3/8 inch (9.5 mm) from the bottom of the panel to the sill. Multisection door panels shall overlap 3/4 inch (19.1 mm). Door panels shall lap the wall opening 3/4 inch (19.1 mm) at sides and top.

SECTION 7.207 — CONDUCT OF TEST

7.207.1 Time of Testing. Masonry settings shall have sufficient strength to retain the assembly securely in position throughout the fire and hose stream tests.

7.207.2 Fire-endurance Test. The pressure in the furnace chamber shall be maintained as nearly as equal to the atmospheric pressure as possible.

The test shall be continued until the exposure period of the desired classification or rating is reached unless the conditions of acceptance specified in Section 7.209 are exceeded in a shorter period.

7.207.3 Hose Stream Test. Immediately following the fire-endurance test, the test assembly shall be subjected to the impact, erosion and cooling effects of a hose stream directed first at the middle and then at all parts of the exposed surface, changes in direction being made slowly.

The hose stream shall be delivered through a 2 1/2-inch (63.5 mm) hose discharging through a National Standard Playpipe of corresponding size equipped with a 1 1/2-inch (28.6 mm) discharge tip of standard-taper smoothbore pattern without shoulder at the orifice. The water pressure at the base of the nozzle and the duration of application in seconds per square foot (square meter) of exposed area shall be as set forth in Table 7-2-A.

The tip of the nozzle shall be located 20 feet (6096 mm) from and on a line normal to the center of the test door. If impossible to be so located, the nozzle may be on a line deviating not to exceed 30 degrees from the line normal to the center of the test door.

When so located, the distance from the center shall be less than 20 feet (6096 mm) by an amount equal to 1 foot (305 mm) for each 10 degrees of deviation from the normal.

SECTION 7.208 — REPORT

Results shall be reported in accordance with the performance in the tests prescribed in these test methods. The report shall show the performance under an exposure period chosen from the
following: 20 minutes, 30 minutes, three-fourths hour, one hour, one and one-half hours, or three hours. The report shall include the temperature measurements of the furnace and, if determined, of the unexposed side of the test assembly. It shall also contain a record of all observations having a bearing on the performance of the test assembly including:

1. Any flaming on the unexposed surface of the door leaf.
2. The amount of movement of any portion of the edges of the door adjacent to the door frame from the original position.
3. The materials and construction of the door and frame and the details of the installation, hardware, hangers, guides, trim, finish and clearance or lap shall also be recorded or appropriately referenced to provide positive identification or duplication in all respects.
4. It shall also contain pressure measurements relative to the elevation of the top of the door.

SECTION 7.209 — CONDITIONS OF ACCEPTANCE

7.209.1 General. A door assembly shall be considered as meeting the requirements for acceptable performance when it remains in the opening during the fire-endurance test and hose stream test within the following limitations:

1. The movement of swinging doors shall not permit any portion of the edges to move from the original position more than the thickness of the door, during the first half of the classification period or more than 1 1/2 times the thickness during the entire classification period.
2. An assembly consisting of a pair of swinging doors shall not separate more than 3/4 inch (19.1 mm) or a distance equal to the throw of the latch bolt at the latch location.
3. An assembly consisting of a single swinging door shall not separate more than 1/2 inch (12.7 mm) at the latch location.
4. The lap edges of passenger (horizontal slide-type) elevator doors, including the lap edges of multisection doors, shall not move from the wall or adjacent panel surfaces sufficiently to develop a separation of more than 2 7/8 inches (73.0 mm) during the entire classification period, or immediately following the hose stream test. The meeting edges of center-parting elevator door assemblies, for a fire and hose stream exposure of one and one-half hours or less, shall not move apart more than 1 1/4 inches (31.8 mm) as measured in any horizontal plane during the entire classification period or immediately following the hose stream test.
5. Doors mounted in guides shall not release from guides and guides shall not loosen from fastenings.
6. The test assembly shall have withstood the fire-endurance test and the hose stream test without developing openings anywhere through the assembly; except that dislodging of small portions of glass by the hose stream and within the limits specified in these requirements shall remain in place.
7. An opening is defined as a through hole in the assembly that can be seen from the unexposed side when viewed from the direction perpendicular to the plane of the assembly at the location of the suspected opening.

7.209.2 Specific, All Doors.

1. No flaming shall occur on the unexposed surface of a door assembly during the first 30 minutes of the classification period.
2. After 30 minutes, some intermittent light flames [approximately 6 inches (152.4 mm) long], for periods not exceeding five-minute intervals, may occur along the edges of doors.
3. Light flaming may occur during the last 15 minutes of the classification period on the unexposed surface area of the door, provided it is contained within a distance of 1 1/2 inches (38.1 mm)
from a vertical door edge and within 3 inches (76.2 mm) from the top edge of the door and within 3 inches (76.2 mm) from the top edge of the frame of a vision panel.

4. When hardware is to be evaluated for use on fire doors, it shall hold the door closed in accordance with the conditions of acceptance for the intended door assembly classification period and, in addition, the latch bolt shall remain projected and shall be intact after the test. The hardware need not be operable after test.

7.209.3 Swinging Doors. The movement of swinging doors shall not result in any portion of the edges adjacent to the door frame moving from the original position in a direction perpendicular to the plane of the door more than the thickness of the door during the first half of the classification period, or more than one and one-half times the door thickness during the entire classification period or as a result of the hose stream test.

The movement of swinging doors mounted in pairs shall not result in any portion of the meeting edges moving more than the thickness of the door away from the adjacent door edge in a direction perpendicular to the plane of the doors during the entire classification period or as a result of the hose stream test.

An assembly consisting of a pair of swinging doors incorporating an astragal shall not separate in a direction parallel to the plane of the doors more than \( \frac{3}{4} \) inch (19.1 mm) or a distance equal to the throw of a latch bolt at the latch location.

An assembly consisting of a pair of swinging doors, without an overlapping astragal, for a fire and hose stream exposure of one and one-half hours or less, shall not separate along the meeting edges more than \( \frac{3}{8} \) inch (9.5 mm), including the initial clearance between doors.

An assembly consisting of a single swinging door shall not separate more than \( \frac{1}{2} \) inch (12.7 mm) at the latch location.

Door frames to be evaluated with doors shall remain securely fastened to the wall on all sides and shall not permit through openings between frame and doors or between frame and adjacent wall.

7.209.4 Sliding Doors. Doors mounted on the face of the wall shall not move from the wall sufficiently to develop a separation of more than \( \frac{27}{8} \) inches (73.0 mm) during the entire classification period or as a result of the hose stream test.

Doors mounted in guides shall not release from the guides, and the guides shall not loosen from fastenings.

The bottom bar of rolling steel doors shall not separate from the floor structure more than \( \frac{3}{4} \) inch (19.1 mm) during the entire classification period or as a result of the hose stream test.

The meeting edge of center-parting horizontal sliding doors and biparting vertical sliding doors shall not separate more than the door thickness in a direction perpendicular to the plane of the doors. The meeting edges of center-parting horizontal sliding doors and biparting vertical sliding doors without an overlapping astragal, for a fire and hose stream exposure of one and one-half hours or less, shall not separate in a direction parallel to the plane of the doors more than \( \frac{3}{8} \) inch (9.5 mm) along the meeting edges, including the initial clearance between doors.

The meeting edges of center-parting horizontal sliding doors incorporating an astragal shall not separate in a direction parallel to the plane of the doors more than \( \frac{3}{4} \) inch (19.1 mm) nor a distance equal to the throw of the latch bolt along the meeting edges.

The bottom edge of service-counter doors or single-slide dumbwaiter doors shall not separate from the sill more than \( \frac{3}{8} \) inch (9.5 mm).

A resilient astragal, if provided, shall not deteriorate sufficiently to result in through openings during the fire-endurance test, but small portions may be dislodged during the hose stream test.
TABLE 7-2-A—WATER PRESSURE AT BASE OF NOZZLE AND DURATION OF APPLICATION

<table>
<thead>
<tr>
<th>DESIRED RATING</th>
<th>WATER PRESSURE AT BASE OF NOZZLE (pounds per square inch)</th>
<th>DURATION OF APPLICATION (seconds per square foot of exposed area)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x 6.89 for kPa</td>
<td>x 10.76 for sec./m²</td>
</tr>
<tr>
<td>3 hrs.</td>
<td>45</td>
<td>3</td>
</tr>
<tr>
<td>1 1/2 hrs. and over, if less than 3 hrs.</td>
<td>30</td>
<td>1.5</td>
</tr>
<tr>
<td>1 hr. and over, if less than 1 1/2 hrs.</td>
<td>30</td>
<td>0.9</td>
</tr>
<tr>
<td>Less than 1 hr.</td>
<td>30</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Part II—Test Standard for Smoke- and Draft-control Assemblies of the International Conference of Building Officials

SECTION 7.210 — SMOKE- AND DRAFT-CONTROL DOOR ASSEMBLIES

7.210.1 Fire-endurance Test. The method of test for 20-minute smoke- and draft-control assemblies shall be as required for swinging doors under Part I of this standard. The fire-endurance test for these door assemblies shall be for an exposure period of not less than 20 minutes except that the hose stream test required by Section 7.207.3 need not be applied.

7.210.2 Conditions of Acceptance. A smoke- and draft-control door assembly shall be considered as meeting the requirements for acceptable performance when it remains in the opening during the fire-endurance test and complies with the following:

1. Flaming shall not occur on the unexposed surface of the door assembly during the fire-endurance test.

2. The movement shall not result in any portion of the edges adjacent to the door frame moving from the original position in a direction perpendicular to the plane of the door equivalent to the thickness of the door.

3. Neither the unexposed surface of the door nor the door itself shall emit excessive amounts of smoke during the fire test.

4. Smoke- and draft-control door assemblies shall be provided with a gasket so installed as to provide a seal where the door meets the stop on both sides and across the top. The gasketing need not be installed on the test assembly.
SECTION 7.301 — SCOPE

This standard covers the design and construction of tinclad fire doors which have been shown by fire tests to possess sufficient fire-retardant values to warrant classification as three, one and one-half or three-fourths-hour assemblies, when tested in accordance with the Standard Specification for Fire Tests of Door Assemblies. Doors complying with these requirements are classified in two temperature-rise groups:

1. Temperature rise on the unexposed side at the end of 30 minutes, 250°F. (139°C.) maximum.
2. Temperature rise on the unexposed side at the end of 30 minutes in excess of 650°F. (361°C.)

SECTION 7.302 — REQUIREMENTS

A door conforming to these specifications consists essentially of a core made up of layers of boards nailed to each other, encased in terne or zinc-coated steel in the form of sections jointed together at their edges and nailed through the seams to the core.

SECTION 7.303 — SIZES AND RATINGS

The sizes and ratings for three-ply and two-ply doors are given in Table 7-3-A.

Doors exceeding the sizes in Table 7-3-A have not been subjected to standard fire tests, and certificates on such doors indicate that the units conform to construction requirements of this standard, except in size.

It should be noted that Table 7-3-A pertains to maximum size of opening. Doors limited in size by this table fall into two categories: (1) swinging doors intended to be installed within an opening, and (2) all sliding doors and those swinging doors intended for surface mounting outside of the opening. Swinging doors in the first category are limited in size to the maximum dimensions specified for the opening. Doors in the second category must be larger than the maximum opening dimensions to provide the minimum 4-inch (101.6 mm) lap at each side and the top of the door. Doors exceeding these two basic dimension considerations are termed “Oversize,” the design and construction of which are not necessarily fully covered in these requirements.

SECTION 7.304 — LUMBER

7.304.1 Species and Condition. The following soft woods may be used, provided only one kind of lumber is used in the assembly of a single core:

<table>
<thead>
<tr>
<th>Species</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cedars—All classes</td>
<td>Redwood</td>
</tr>
<tr>
<td>Cypress—All classes</td>
<td>Sitka Spruce</td>
</tr>
<tr>
<td>Douglas Fir</td>
<td>Tupelo Gum</td>
</tr>
<tr>
<td>Eastern Spruce</td>
<td>Yellow Poplar</td>
</tr>
<tr>
<td>Northern White Pine</td>
<td>Western White Pine</td>
</tr>
</tbody>
</table>
Other kinds of lumber may be added to the foregoing list, provided the kind of wood to be used
has properties equivalent to the above species with respect to low resin content, light weight, resistance
to fungus and decay, and ability to withstand nailing without splitting or splintering.

Lumber shall have a moisture content of 19 percent or less at the time of manufacturing door
cores. Tests for moisture content shall be made using the oven-drying or the electrical meter method
in accordance with approved methods for tests for moisture content of wood.

Stocks of lumber shall be stored under cover in the premises of the fire-door manufacturer for at
least one month before being used in the manufacture of fire-door cores and, while in storage, shall
be piled in such a manner that the air has free access to all surfaces of each board. Kiln drying will be
accepted for the 30-day drying period.

7.304.2 Size. The boards shall be nominal 1-inch (25 mm) lumber, surfaced on two sides and
matched. They shall be without beading, beveling, painting or other treatment.

The actual thickness of the boards shall not be less than \( \frac{3}{4} \) inch (19.1 mm).

The boards shall not be less than 4 inches (102 mm) or more than 8 inches (203 mm) in nominal
width.

The nominal width (or stock width) is greater than the actual width over the tongue and groove.

7.304.3 Grading. The boards shall be free from wane (bark), decay, knots or other holes, loose
knots, unsound knots or knots exceeding 2\( \frac{1}{2} \) inches (63.5 mm) in any dimension.

Lumber of a No. 2 Common or Construction grade or better will generally meet these
requirements. However, because some pieces of No. 2 grade could be unacceptable, the kind of lumber
used and its condition shall be judged from characteristic properties of the wood as commonly
known. These characteristics include:

1. Decay—Destruction of the wood substance due to the action of wood destroying fungi.
   NOTE: "Dote" and "rot" are synonymous with "decay" and are any form of decay which may be
evident either as a dark red discoloration, not found in the sound wood, or the presence of white or
red rotten spots.

2. Advanced (typical decay)—The older stage of decay in which the destruction is readily
   recognized because the wood has become punky, soft and spongy, stringy, ring shaped, pitted or
   crumbly.

3. Incipient decay—The early stage of decay which has not proceeded far enough to soften or
   otherwise perceptibly impair the hardness of the wood.

4. Knot—that portion of a branch which has become incorporated in the body of a tree.

5. Loose knot—A knot which is not firmly held in place by growth or position.

6. Tight knot—A knot so fixed by growth or position that it will firmly retain its place in the
   wood piece.

7. Hollow knot—A hollow knot is an apparently sound knot except it contains a hole over \( \frac{1}{4} \) inch
   (6.4 mm) in diameter or a void area behind the knot.

8. Check—A separation along the grain, the greater part of which occurs across the rings of an-
   nual growth.

9. Wane—The lack of wood from any cause, or bark on the surface of lumber.

To permit judging of the several characteristics of knots, oval and circular knots are to be
measured across their lines of growth. For spike knots, the measurement is to be parallel to the lines
of growth. In all cases, the measured distance is to be the visible portion of the knot which is
normally darker or lighter than the coloring of the board.

The following characteristics are to be judged as unacceptable:
1. Oval, circular or spike knots exceeding 2 1/2 inches (63.5 mm) in any direction.
2. Loose knots, open knots or any knot over 1 inch (25.4 mm) in any direction located on the tongue or lip.
3. Loose knots, open knots, through holes and surface pits [deeper than 1/16 inch (1.6 mm)] in the central portion of the boards.
4. Hollow and decayed knots.
5. Checks, advanced (typical) and incipient decay.
6. Warpage which would prevent the boards from being nailed flat or which would affect the flatness of the nailed core.
7. Cluster knots or knots in groups [less than 5/8 inch (15.9 mm) apart].

Tight knots on the lips or tongue of a board may be judged acceptable if, due to manufacturing, the lips or tongue have been chipped, but only to the extent that (1) the dimensions of the damage do not exceed 3/8 inch (9.5 mm) in length and 3/16 inch (4.8 mm) in diameter, and (2) the lip or tongue with a chip cannot be easily broken, such as upon exerting direct hand pressure.

SECTI0N 7.305 — METAL COVERINGS

7.305.1 General. The terne or zinc-coated steel sections shall have straight edges and square corners. A deviation of 1/32 inch per foot (2.6 mm per meter) from square shall be accepted, provided the door manufacturer is able to obtain true, straight joints and to avoid patching the rows of sheets in the covering.

7.305.2 Terne-coated Sheet Steel. Only prime terne plate shall be used. For the purpose of these requirements, “terne” shall be understood as indicating an alloy of tin and lead in the proportion of 80 percent lead and 20 percent tin, hot-dipped applied. The terne coating shall be uniformly applied on both sides of sheet steel having an uncoated thickness of not less than 0.010 inch (0.254 mm). The terne coating shall not crack, peel or flake when formed.

The sheet steel shall be coated with not less than 0.55 ounce per square foot (0.168 kg/m²) average of terne coating (total both sides) by triple spot test and not less than 0.40 oz./sq. ft. (0.122 kg/m²) of terne coating (total both sides) by the single spot test, with not less than 40 percent of the coating of any side, by the single spot test requirement. The weight of terne coating shall be determined by approved nationally recognized methods.

A determination for percent tin shall be made on a portion of the solution containing the stripped terne coating, using standard laboratory analytical methods. The amount of tin in the coating shall not be less than 20 percent.

A determination for percent lead may be made on a portion of the solution containing the stripped terne coating, using standard laboratory analytical methods, or the percent of lead in coating may be determined by subtracting the percent of tin from 100 percent.

7.305.3 Zinc-coated (Galvanized) Sheet Steel. Zinc-coated sheet steel shall have an uncoated thickness of not less than 0.010 inch (0.254 mm). The zinc coating shall not crack or flake when formed.

Finished doors shall be painted with a good grade of corrosion-resisting paint before shipment. Before painting, zinc surfaces shall be thoroughly cleaned and pretreated to provide for adherence of the paint coating.

The protective coating of zinc shall be as applied to hot-dipped, mill galvanized sheet steel, with not less than 40 percent of the zinc on any side, based on the single spot requirement. The weight of zinc coating, minimum 0.5 oz./ft.² (0.153 kg/m²), shall be determined by approved nationally recognized methods.
SECTION 7.306 — NAILS

Core nails shall be cut nails of the clinch type or duck-bill point-type power-driven nails that clinch. For three-ply cores, the nails shall not be less than 2\(\frac{7}{16}\) inches (73.0 mm) or more than 3 inches (76.2 mm) long. For two-ply cores, the nails shall not be less than 1\(\frac{11}{16}\) inches (42.9 mm) or more than 2 inches (50.8 mm) long. The shank diameters of duckbill-point nails shall be 0.130 inch to 0.140 inch (3.3 mm to 3.6 mm) for three-ply doors and 0.100 inch to 0.110 inch (2.5 mm to 2.8 mm) for two-ply doors.

Nails for applying the metal covering shall be wire nails with flat heads. The shank of the nails shall not be less than 0.091 inch (2.3 mm) nor more than 0.109 inch (2.8 mm) in diameter. The nails for three-ply cores shall be 2 inches (50.8 mm) long, and for two-ply cores shall not be less than 1\(\frac{1}{4}\) inches (31.8 mm) or more than 1\(\frac{1}{2}\) inches (38.1 mm) long.

Part III—Construction

SECTION 7.307 — ASSEMBLY OF BOARDS

The details for the assembly of boards are shown in Figures 7-3-1 and 7-3-2.

Only one stock width of board shall be used in any one core, except that the edge board and the stock board immediately adjacent to the edge board may differ in width from the remaining stock boards. Edge boards shall not finish less than 3 inches (76.2 mm) in width and the exposed edges shall not be tongued or grooved.

Boards shall not be less than 1 foot (305 mm) in length, with ends cut square. Not more than two pieces shall be used in any continuous strip in any outside layer of a two-ply or three-ply core, nor more than three pieces in any middle layer strip of a three-ply core. At least alternate strips in outside layers shall be full-length boards.

If glass panels are provided and the panel opening is of such a size that the distance between the opening and the edges of the door is less than 2 feet (609.6 mm), all boards bordering the vertical edges of the opening may be laid vertically, and all boards bordering the horizontal edges of the opening may be laid horizontally.

If glass panels are provided, the boards in the normally vertical layers bordering the sides of the panel opening shall be continuous from top to bottom of the door, and boards in the normally horizontal layer bordering the top or bottom of the panel opening shall be continuous from side to side of the door. The distance between the panel opening and the side of the door shall not be less than 7 inches (177.8 mm). See Figure 7-3-2.

Outside layers in a three-ply core and one layer of a two-ply core shall be vertical, and the other layer horizontal. The several boards in each layer and the ends of pieces of boards in strips shall make tight joints at edges and ends of boards.

The top edge for a sliding door designed to close by gravity shall conform to an incline of 3\(\frac{1}{4}\) inch per foot (62.5 mm per meter). The minimum face width of the top horizontal board of a core having the top edge inclined shall not be less than 3 inches (76.2 mm). See Figures 7-3-3, 7-3-4 and 7-3-5.

SECTION 7.308 — NAILING OF CORES

7.308.1 General. The boards shall be nailed so that the several layers are fastened tightly together, with the points of the nails turning back and clinching thoroughly in the face of the core and with no portion of the nails projecting beyond the surfaces of the core. See Figure 7-3-6.

7.308.2 Two-ply and Three-ply Cores of Boards 3 Inches to 4 Inches (76.2 mm to 101.6 mm) (Inclusive) Stock Width. The details for nailing of boards 3 inches to 4 inches (76.2 mm to 101.6 mm), inclusive, stock width are shown in Figure 7-3-3.
Horizontal rows of nails shall be about the center of each horizontal layer board. Vertical rows of nails shall be about the center of each vertical layer of board. Nails in horizontal and vertical rows shall be spaced not more than five times the face width of each board. Rows of nails at edges of core shall be about 1 1/2 inches (38 mm) from each edge. Nails in vertical edge rows shall be placed not more than the face width of each board and shall be about the center of each horizontal board. Nails in horizontal edge rows shall be spaced not more than the face width of each board and shall be about the center of each vertical board.

7.308.3 Two-ply and Three-ply Cores of Boards 4 1/2 inches to 8 inches (114.3 mm to 203.2 mm) (Inclusive) Stock Width. The details for nailing of boards 4 1/2 inches to 8 inches (114.3 mm to 203.2 mm), inclusive, stock width are shown in Figure 7-3-4.

Horizontal rows of nails shall be about 1 inch (25 mm) from each edge of each horizontal layer board (two horizontal rows of nails through each horizontal board). Vertical rows of nails shall be about 1 inch (25 mm) from each edge of each vertical layer board (two vertical rows of nails through each vertical board). Nails in horizontal and vertical rows shall be spaced not more than twice the face width of each board.

Rows of nails at edges of core shall be about 1 1/2 inches (38 mm) from each edge. Nails in vertical-edge rows shall be spaced not more than the face width of each board and shall be about the center of each horizontal board. Nails in horizontal edge rows shall be spaced not more than the face width of each board and shall be about the center of each vertical board.

7.308.4 Three-ply Cores Only of Boards 4 1/2 inches to 8 inches (114.3 mm to 203.2 mm) (Inclusive) Stock Width. The details for nailing of boards 4 1/2 inches to 8 inches (114.3 mm to 203.2 mm), inclusive, stock width for three-ply core only are shown in Figure 7-3-5.

Horizontal rows of nails shall be about the center of each horizontal layer board. Vertical rows of nails shall be about 1 inch (25 mm) from each edge of each vertical layer board (two vertical rows of nails through each vertical board). Nails in horizontal rows shall be spaced not more than the face width of each board. Nails in vertical rows shall be spaced not more than twice the face width of each board.

Rows of nails at edges of core shall be about 1 1/2 inches (38 mm) from each edge. Nails in vertical edge rows shall be spaced not more than the face width of each board and shall be about the center of each horizontal board. Nails in horizontal edge rows shall be spaced about 1 inch (25 mm) from each edge of each vertical board, except that each vertical edge board shall have only one nail, which should be placed about the center of the board.

SECTION 7.309 — FINISHED CORES

A finished three-ply core shall not be less than 2 1/4 inches (57.2 mm) nor more than 2 5/8 inches (66.7 mm) in thickness, and a finished two-ply core shall not be less than 1 1/2 inches (38.1 mm) nor more than 1 3/4 inches (44.5 mm) in thickness.

EXCEPTION: A finished three-ply core door which is less than 2 1/4 inches (57.2 mm) thick may be marked in accordance with the schedule for two-ply doors.

The cores shall have true corners. All edges shall be finished smooth and square, except that meeting edges of swinging doors may be beveled 1/4 inch (6.4 mm) (not rabbeted).

SECTION 7.310 — SIZES OF STEEL SECTIONS

Coated steel sections shall not be larger than the 14- by 20-inch (355.6 mm by 508 mm) size. Corner sections shall not be over 14 inches (355.6 mm) wide and of any length that will avoid joints with edge sections coming under miter fold. Edge sections (excepting "cap" sections) shall be of the
same width as corner sections and of any convenient length. Cap sections shall be of any convenient length and equal in width to thickness of core plus $3\frac{1}{2}$ inches (88.9 mm).

SECTION 7.311 — FORMING OF STEEL SECTIONS

Turned edges of coated steel sections shall be parallel to cut edges. Turned-up portions of all sections shall be of uniform width.

Face sections, excepting the face sections used in the row forming the closure, shall have one vertical edge turned $\frac{5}{8}$ inch (15.9 mm) and the other vertical edge doubled under $1\frac{3}{16}$ inches (30.2 mm) and the doubled edge then turned up $\frac{5}{8}$ inch (15.9 mm) from cut edge as shown in Figure 7-3-7, Section A-B.

Face sections, excepting face sections forming top horizontal seams, shall have both horizontal seams, shall have both horizontal edges turned $\frac{5}{8}$ inch (15.9 mm) to lock with edge and other face sections shown in Figure 7-3-7, Section C-D.

Face sections forming top horizontal seams, excepting seams formed with a cap, shall have the lower horizontal edge turned $\frac{5}{8}$ inch (15.9 mm) to lock with other face sections, and the other horizontal edge doubled under $1\frac{3}{16}$ inches (30.2 mm) and the doubled edge then turned up $\frac{5}{8}$ inch (15.9 mm) from cut edge.

Face sections forming top horizontal seams with a cap shall have both horizontal edges turned $\frac{5}{8}$ inch (15.9 mm) to lock with cap and other face sections.

Corner sections shall have all edges turned $\frac{5}{8}$ inch (15.9 mm) so as to lock with edge and face sections as shown in Figure 7-3-8.

Edge sections, excepting cap sections, shall have all edges turned $\frac{5}{8}$ inch (15.9 mm) so as to lock with corner, face and other edge sections as shown in Figure 7-3-9.

Cap sections shall have edges forming seams with other cap sections turned $\frac{5}{8}$ inch (15.9 mm). Cap sections shall have edges forming top horizontal seams with face and edge sections doubled under $1\frac{3}{16}$ inches (30.2 mm) and the portion next to the cut edge turned down $\frac{5}{8}$ inch (15.9 mm) so as to lap the edge and face sections as shown in Figure 7-3-10.

SECTION 7.312 — APPLICATION OF STEEL SECTIONS

The sections shall fit the core as flatly and tightly as practicable. Any air space created as the result of bulging shall not exceed $\frac{3}{16}$ inch (4.8 mm).

The sections shall be locked together not less than $\frac{1}{2}$ inch (12.7 mm). Both faces of the core shall be covered with sections laid with their longer sides vertical, except that the sections in one vertical row on each face of the core may be laid horizontally.

Vertical seams formed with face sections shall be hook seams with the upper section having a fold for covering the heads of the nails in the seam as shown in Figure 7-3-11.

Horizontal seams formed with face sections, excepting top horizontal seams, shall be hook seams as shown in Figure 7-3-12. Top horizontal seams, excepting seams formed with a cap, shall have a fold for covering the heads of the nails in the seam as shown in Figure 7-3-11. Top horizontal seams formed with a cap shall be lock seams with the locking portion of the cap having a fold for covering the heads of the nails in the seam as shown in Figure 7-3-10.

The upper ends of vertical seams shall be covered by the doubled edges of the top horizontal seams.

Each bottom corner of the core shall be covered with a section bent over the edges of the core and lapped an equal distance on both faces of the core, making a miter fold (without cutting) on each face, the folds on a door for use at an opening in an exterior wall being arranged to shed water as shown in Figure 7-3-8.
Each upper corner shall be covered the same as bottom corners if a cap is not used for covering the top edge of the core.

The bottom edge and the vertical edges of the core shall be covered with sections bent over edges of the core and lapped an equal distance on both faces. The sections shall be joined to each other and to the corners with hook seams, the seams being made so as to shed water when the door is for use at an opening in an exterior wall as shown in Figures 7-3-7 and 7-3-9.

The top edge of the core shall be covered the same as the bottom and vertical edges if a cap is not used. The top edge of a core shall be covered with a cap when the door is for use at an opening in an exterior wall or when the door has a segmental head. The cap shall be formed of sections joined to each other with hook seams as shown in Figure 7-3-13.

If glass panels are provided and band or angle iron reinforcement for glass grooves is used, the vertical edges of the panel openings shall be covered with terne or zinc-coated steel secured to the face sections by vertical seams. The covering at the horizontal edges of the opening shall be cap seams as shown in Figure 7-3-14.

SECTION 7.313 — NAILING OF STEEL SECTIONS

The nails shall pass straight into the core and as near as possible through the center of the lock in the seams as shown in Figures 7-3-10, 7-3-11 and 7-3-12.

Full-sized face sections shall be held to the core by 18 nails in the seams, with nails near but not in the corners, and with four nails along each short side and five along each long side of each section.

Face sections smaller than 14- by 20-inch (355.6 mm by 508 mm) size shall be held to the core by nails in the seams placed near but not in the corners, with at least two nails along each side and with nails spaced not over 3 inches (76.2 mm) apart in horizontal seams and not over 4 inches (101.6 mm) apart in vertical seams.

Vertical seams formed with face sections shall have nails through two thicknesses of each section as shown in Figure 7-3-11.

Horizontal seams formed with face sections, except top horizontal seams, shall have nails through two thicknesses of lower sections and one thickness of upper section forming the seams as shown in Figure 7-3-12. Top horizontal seams, except seams made with a cap, shall have nails through two thicknesses of each section forming the seams as shown in Figure 7-3-11. Top horizontal seams formed with a cap shall have nails through one thickness of each plate forming the seams as shown in Figure 7-3-10.

Each corner section shall be held to the core with two nails on each side near the edge of the core as shown in Figure 7-3-8.

If glass panels are provided and band or angle-iron reinforcement for glass grooves is used, nails securing seams between face sections and strips covering edges of panel opening shall be spaced at intervals not exceeding 3 inches (76.2 mm) in horizontal seams and 4 inches (101.6 mm) in vertical seams, with one nail near but not in each corner.

SECTION 7.314 — PROTECTION OF NAILHEADS

Heads of nails in vertical seams formed with face sections shall be covered by the doubled edges of face sections as shown in Figure 7-3-11. Heads of nails in horizontal seams formed with face sections, except top horizontal seams, shall be covered by the face sections as shown in Figure 7-3-12. Heads of nails in top horizontal seams formed with face sections shall be covered by the doubled edges of face sections or cap as shown in Figures 7-3-10 and 7-3-11. Heads of nails in corner sections shall be covered by the miter fold as shown in Figure 7-3-8.

SECTION 7.315 — ASTRAGALS

Swinging doors to be mounted in pairs shall be provided with at least one astragal extending the full height of the doors. Sliding doors to be mounted in pairs shall be provided with only one astragal.
extending to within 4 inches (101.6 mm) of the top and bottom of the doors. Astragals shall be of steel not less than \( \frac{3}{16} \) inch (4.8 mm) thick and 3 inches (76.2 mm) wide. The astragal shall be fastened to the door, when installed, by not less than \( \frac{1}{4} \) inch (6.4 mm) carriage or stove bolts spaced at intervals not exceeding 12 inches (304.8 mm). Top bolts shall not be over 5 inches (127 mm) from the end of the astragal and bottom bolts not over 3 inches (76.2 mm). Bolts shall pass through the astragal and be secured by nuts on the opposite side of the door. Washers shall be used under nuts. Bolt holes in the astragal and door shall be located so that the astragal will extend at least \( \frac{3}{4} \) inch (19.1 mm) beyond the edge of the door to which it is attached.

In case the astragal is to be attached in the field, the bolt holes in the astragal shall be drilled by the manufacturer to ensure proper spacings, fit, etc. In such case it will not be necessary to drill the door for the bolts.

SECTION 7.316 — GLASS PANELS

7.316.1 General. The construction details for any one of the following types of glass panel construction shall not be used in or combined with any of the other types described.

7.316.2 Reinforcements for Grooves. In all doors provided with grooves constructed of angles, the opening shall be reinforced either by means of a band-iron strip not less than \( \frac{1}{8} \) inch (3.2 mm) in thickness and equal in width to the thickness of the core or by means of \( \frac{3}{16} \)-by-\( \frac{3}{16} \)-by-\( \frac{3}{8} \)-inch (3.2 mm by 34.9 mm by 22.2 mm) angles bolted together through the door. See Figures 7-3-14, 7-3-15 and 7-3-16.

The band-iron strip shall be secured to the inner edges of the panel opening by not less than two wood screws and shall be provided with threaded holes for receiving the bolts which secure the angles forming the glass grooves.

The \( \frac{3}{16} \)-by-\( \frac{3}{16} \)-by-\( \frac{3}{8} \)-inch (3.2 mm by 34.9 mm by 22.2 mm) angles shall be bolted together through the door by \( \frac{3}{16} \) inch (4.8 mm) stove bolts spaced at intervals not exceeding 12 inches (304.8 mm) and not more than 2 inches (50.8 mm) from each end. They shall be provided with threaded holes for receiving the bolts which secure angles forming the glass groove.

7.316.3 Glass Grooves Constructed of Angles. The angles used in forming the glass grooves shall not be less than \( \frac{1}{8} \) inch (3.2 mm) in thickness and shall be of such other dimensions as to provide a groove not less than \( \frac{3}{4} \) inch (19.1 mm) deep by \( \frac{3}{8} \) inch (9.5 mm) wide as shown by Figures 7-3-14, 7-3-15 and 7-3-16.

Rivets or screws used to secure the groove angles to the reinforcement shall be spaced at intervals not exceeding 12 inches (304.8 mm) and not more than 2 inches (50.8 mm) from each end.

7.316.4 Grooves Constructed of Formed Sheet Metal. Grooves of this type shall be formed of a single piece of galvanized or tere-coated sheet steel having an uncoated thickness of not less than 0.020 inch (0.508 mm) as shown by Figures 7-3-17, 7-3-18 and 7-3-19 and shall not be less than \( \frac{3}{4} \) inch (19.1 mm) deep by \( \frac{3}{8} \) inch (9.5 mm) wide.

The edges of this formed strip shall be secured to the face sections of the door by vertical seams at the vertical edges of the opening as shown by Figure 7-3-19, Section B-B, and by cap seams at the horizontal edges of the opening as shown by Figure 7-3-19, Section D-D.

The edges of this formed strip shall be secured to the face plates of the door by vertical seams at the vertical edges of the opening as shown by Figure 7-3-19, Section B-B, and by cap seams at the horizontal edges of the opening as shown by Figure 7-3-19, Section D-D.

In the case of glass openings employing only one light, the sheet-metal glass groove may be constructed as shown by Figure 7-3-19, Section A-A. In this type of glass groove the reinforcing strip shall be \( \frac{1}{8} \)-inch (3.2 mm) band iron and shall either be continuous for the full length of the groove or consist of individual reinforcing strips not less than 1 inch (25 mm) long for each screw securing the removable molding. The reinforcing strip shall be secured to the fixed part of the glass groove by
rivets or screws, independent of the screws fastening the removable molding. Rivets or screws used to secure the reinforcing strip or the removable molding shall be spaced at intervals not exceeding 12 inches (304.8 mm) and not more than 2 inches (50.8 mm) from each end.

Nails securing seams between molding strips and face sections shall be spaced at intervals not exceeding 3 inches (76.2 mm) in horizontal seams and 4 inches (101.6 mm) in vertical seams, with one nail near, but not in, each corner.

7.316.5 Muntins. Muntins may be of any of the constructions shown by Figures 7-3-12 through 7-3-19. In all cases, fixed parts of muntins shall be firmly secured to glass moldings at ends and at intersections with each other. Rivets, screws, welds or clips may be employed. Rivets, screws, etc., shall be spaced at intervals not exceeding 12 inches (304.8 mm).

When muntins are formed of sheet metal, the reinforcing plate shall be 1/8-inch (3.2 mm) band iron which may be either continuous for the full length of the muntin or may consist of individual reinforcing strips not less than 1 inch (25 mm) long for each screw securing the removable part of the muntin.

7.316.6 Screws and Rivets. Screw sizes shall be 3/16 inch (4.8 mm) (10-24) spaced 10 inches (254 mm) on centers; 1/8 inch (3.2 mm) (either 6-32 or 8-32) spaced 8 inches (203.2 mm) on centers. Rivets shall not be less than 1/8 inch (3.2 mm) in diameter.

7.316.7 Glass Sizes. Individual lights in doors bearing the marking “Rating: 3/4-Hr. (C) or (E)’’ shall not exceed 1,296 square inches (0.836 m²) in exposed area or 54 inches (1371.6 mm) in either dimension.

Area of exposed glass light per door leaf in doors bearing the marking “Rating: 1 1/2-Hr. (B). Temp. Rise—30 Min.—250°F. (139°C.) Max.” shall not exceed 100 square inches (0.064 m²), neither length nor width to exceed 12 inches (304.8 mm).

Glass lights shall not be used in doors bearing the marking “Rating: 3-Hr. (A) or 1 1/2-Hr. (D).’’

SECTION 7.317 — SPICING OF DOORS MADE IN SECTIONS

If doors are made in sections to be assembled as a single unit in the field, each section shall be constructed and marked in accordance with the requirements for a completed door.

Sections less than 10 feet (3048 mm) in height (not more than two) shall be joined together vertically by attaching to each face of the completed door a strip of galvanized sheet steel having a minimum thickness of not less than 0.056 inch (1.42 mm), not less than 6 inches (152.4 mm) in width and of a length corresponding to the height of the door. The splice metal sections shall be attached to each section of the door by not less than 1/8-inch (3.2 mm) not less than 1/8 inch (3.2 mm) in diameter.

Sections over 10 feet (3048 mm) in height (not more than two) may be joined together vertically by attaching to each face of the completed door not more than two strips of sheet steel having a minimum thickness of 0.12 inch (3.05 mm), painted on both sides, or galvanized sheet steel having a minimum thickness of 0.126 inch (3.20 mm) not less than 6 inches (152.4 mm) in width and of a length corresponding to the height of the door. The meeting edges of such splice sections on one side of the door section shall be at least 2 feet (610 mm) higher or lower than those on the opposite side.

On three-ply doors, 2- by 2- by 3/16-inch (50.8 mm by 50.8 mm by 4.8 mm) angles or 2 1/2- by 3/16-inch (63.5 mm by 15.9 mm by 4.8 mm) channels shall be attached horizontally across the width of the door and not to exceed 18 inches (457.2 mm) from the bottom edge and the lowest corner of the top edge by not less than 3/16-inch (9.5 mm) through bolts spaced on not more than 18-inch (457.2 mm) centers and at not more than 6 inches (152.4 mm) from each edge of the assembled door. On two-ply doors, 2- by 1 1/2- by 3/16-inch (50.8 mm by 38.1 mm by 4.8 mm) angles or
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1½- by 5/8- by 3/16-inch (38.1 mm by 15.9 mm by 4.8 mm) channels shall be attached in a like manner.

Angle- and channel-iron reinforcements and both splice plates may be shipped separately, but through bolts shall be secured to them before shipment. Both sections of the door shall be drilled at the factory to receive through bolts for attachment of splice metal sections and angle- and channel-iron reinforcements.

SECTION 7.318 — WICKETS
Doors or door sections shall not be provided with wickets or openings for same.

SECTION 7.319 — APPLIED METALS
Doors or door sections shall not be provided with kick plates or metals applied over the standard construction.

Part IV—Marking

SECTION 7.320 — MARKING

7.320.1 Content. Each door shall be marked with:
1. The manufacturer's or vendor's name or identifying symbol.
2. The words "Tinclad Fire Door."
3. The appropriate hourly rating and temperature rise for the classification and any glass panels.

If a door has been provided with edge notches to clear conveyor rails, for example, it becomes ineligible to carry the marking outlined in Section 7.320, Item 3; but it shall be otherwise identified with the following statement:

"This door(s) violates one of the fundamental principles of wall opening protection in that it (they) does not provide for a continuous lap of the door over the edge of the opening to oppose the passage of flame and therefore cannot be provided with an hourly classification."

If a manufacturer produces doors at more than one factory, each door shall have a distinctive marking to identify it as the product of a particular factory.

7.320.2 Application. Markings shall be permanent to the degree afforded by a lithographed metal plate, a pressure-sensitive label, or stamping. All markings on one door shall be grouped in one location.
TABLE 7-3-A—SIZES AND RATINGS

<table>
<thead>
<tr>
<th>TYPE, METHOD OF OPERATION AND MAXIMUM SIZE OF OPENING</th>
<th>RATING AND CLASS OF OPENING</th>
<th>MAXIMUM EXPOSED GLASS AREA x 645 for mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-ply</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swinging single 6' 0&quot; x 12' 0&quot; (1829 x 3658 mm)</td>
<td>3-hr. (A)¹</td>
<td>None</td>
</tr>
<tr>
<td>Swinging in pairs 10' 0&quot; x 12' 0&quot; (3048 x 3658 mm)</td>
<td>1½-hr. (B)¹</td>
<td>100 square inches per door</td>
</tr>
<tr>
<td>Sliding single and center-parting 120 square feet</td>
<td>¾-hr. (C)²</td>
<td>1,296 square inches per light</td>
</tr>
<tr>
<td>(11.15 m²) with maximum dimension 12' 0&quot; (3658 mm)</td>
<td>1½-hr. (D)¹</td>
<td>None</td>
</tr>
<tr>
<td>Vertically sliding 80 square feet (7.43 m²) with</td>
<td>¾-hr. (E)²</td>
<td>1,296 square inches per light</td>
</tr>
<tr>
<td>maximum dimension 10' 0&quot; (3048 mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two-ply</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swinging single 6' 0&quot; x 10' 0&quot; (1829 x 3048 mm)</td>
<td>1½-hr. (B)¹</td>
<td>100 square inches per door</td>
</tr>
<tr>
<td>Swinging in pairs 10' 0&quot; x 10' 0&quot; (3048 x 3048 mm)</td>
<td>¾-hr. (C)²</td>
<td>1,296 square inches per light</td>
</tr>
<tr>
<td>Sliding single and 80 square feet (7.43 m²)</td>
<td>1½-hr. (D)¹</td>
<td>None</td>
</tr>
<tr>
<td>with maximum dimension 10' 0&quot; (3048 mm)</td>
<td>¾-hr. (E)²</td>
<td>1,296 square inches per light</td>
</tr>
</tbody>
</table>

¹Three-hour (A), one- and one-half-hour (B) and one- and one-half hour (D) doors have a temperature rise of 250°F (139°C.) maximum at 30 minutes.

²Three-fourths-hour (C) and three-fourths-hour (E) doors with large glass lights may permit a temperature rise in excess of 650°F (361°C.) on the unexposed side at 30 minutes.
FIGURE 7-3-1
ASSEMBLY OF BOARDS IN THREE-PLY CORE

FIGURE 7-3-2
ASSEMBLY OF BOARDS IN THREE-PLY CORE WITH GLASS OPENINGS

FIGURE 7-3-3
NAILING FOR 3- TO 4-INCH (76.2 to 101.6 mm) STOCK
FIGURE 7-3-4
NAILING FOR 4\(\frac{1}{2}\) TO 8-INCH
(114.3 to 203.2 mm) STOCK

FIGURE 7-3-5
NAILING FOR THREE-PLY CORES
ONLY 4\(\frac{1}{2}\) TO 8-INCH
(114.3 to 203.2 mm) STOCK

FIGURE 7-3-6
NAILING IN THREE-PLY
CORE SHOWING CLINCHING
FIGURE 7-3-7
APPLICATION OF METAL SECTIONS ON FACE OF CORE

FIGURE 7-3-8
APPLICATION OF METAL SECTIONS AT CORNER OF CORE
FIGURE 7-3-9
APPLICATION OF METAL SECTIONS AT EDGES OF CORE

FIGURE 7-3-10
APPLICATION OF CAP METAL SECTIONS AT TOP EDGE OF CORE
FIGURE 7-3-11—VERTICAL SEAMS OF FACE SECTIONS (TOP VIEW)

FIGURE 7-3-12—HORIZONTAL SEAMS OF FACE SECTIONS (SIDE VIEW)

FIGURE 7-3-13—SEAMS BETWEEN CORNER AND EDGE SECTIONS
FIGURE 7-3-14—GLASS OPENING DETAILS

FIGURE 7-3-15—GLASS OPENING DETAILS

FIGURE 7-3-16
GLASS OPENING DETAILS
FIGURE 7-3-17—ASSEMBLY—GLASS GROOVES, FORMED SHEET METAL

FIGURE 7-3-18—GLASS OPENING DETAILS
Section B-B

NOTE—For sash having more than one light in width.

Section A-A

NOTE—For sash having one light in width.

FIGURE 7-3-19—GLASS OPENING DETAILS
UNIFORM BUILDING CODE STANDARD 7-4
FIRE TESTS OF WINDOW ASSEMBLIES


See Sections 703.4, 713.5 and 713.9, Uniform Building Code

SECTION 7.401 — SCOPE
These methods of fire tests are applicable to window assemblies, including glass block and other light-transmitting assemblies, for use in wall openings to retard the passage of fire. Test methods in this standard are intended to evaluate the ability of a window or other light-transmitting assembly to remain in an opening during a predetermined test exposure of 45-minute duration.

Tests made in conformity with these test methods will register performance during the test exposure and develop data to determine the suitability of window assemblies for use in wall openings where fire protection is required. Such tests shall not be construed as determining suitability of window assemblies for continued use after fire exposure.

SECTION 7.402 — CONTROL OF FIRE TESTS

7.402.1 Time-temperature Curve. The fire exposure of window assemblies shall be controlled to conform to the standard time-temperature curve shown in Figure 7-1-1.

7.402.2 Furnace Temperatures. The temperatures of the test exposure shall be the average temperature obtained from the readings of not less than nine thermocouples symmetrically disposed and distributed to show the temperature near all parts of the test assembly. The thermocouples shall be protected by sealed porcelain tubes having \( \frac{3}{4} \)-inch (19.1 mm) outside diameter and \( \frac{1}{8} \)-inch (3.2 mm) wall thickness or, as an alternate, in the case of base metal thermocouples, protected by sealed \( \frac{1}{2} \)-inch (12.7 mm) wrought-steel or wrought-iron pipe of standard weight. The exposed length of the thermocouple protection tube in the furnace chamber shall not be less than 12 inches (304.8 mm). The junction of the thermocouples shall be 6 inches (152.4 mm) from the exposed face of the test assembly or from the masonry in which the assembly is installed during the entire test exposure.

The temperature shall be read at intervals not exceeding five minutes.

The furnace shall be controlled so that the maximum temperature at individual points shall not exceed 1,650°F (899°C.) and the area under the time-temperature curve, obtained by averaging the results from the temperature readings, is within 10 percent of the corresponding area under the standard time-temperature curve.

SECTION 7.403 — TEST ASSEMBLIES

7.403.1 Construction and Size. The design, construction, material, workmanship and hardware of the test window assembly shall be representative of that for which approval is desired. A record of materials and construction details adequate for identification shall be made.

The area of the test assembly shall not be less than 100 square feet (9.29 m²), with neither dimension less than 9 feet (2743 mm). If the conditions of use limit the construction to smaller dimensions, a proportionate reduction may be made in the dimensions of the test assembly for tests qualifying them for such restricted use.

*NOTE: In case the temperature at any point does exceed 1,650°F (899°C.), the performance of the glass in that area shall be disregarded.
7.403.2 Mounting. The test assembly shall be installed in the manner in which it is to be used. It shall be mounted so that the latches and fasteners other than hinges shall be on the unexposed side, and the mounting shall not prevent the free and easy operation of all openable components such as ventilators and sash.

SECTION 7.404 — CONDUCT OF TESTS: TIME OF TESTING

Masonry settings shall be allowed to season at least seven days, and reinforced concrete settings at least 28 days, before fire tests are made.

SECTION 7.405 — FIRE-ENDURANCE TEST

The pressure in the furnace chamber shall be maintained as nearly equal to the atmospheric pressure as possible.

The test shall be continued for 45 minutes unless the conditions of acceptance specified in Section 7.407 are exceeded in a shorter period.

SECTION 7.406 — HOSE STREAM TEST

Immediately following the fire-endurance test and within one and one-half minutes, the fire-exposed side of the test assembly shall be subjected to the impact, erosion and cooling effects of the hose stream.

The hose stream shall be delivered through a 2 1/2-inch (63.5 mm) hose discharging through a National Standard Playpipe of corresponding size equipped with a 1 1/8-inch (28.6 mm) discharge tip of the standard-taper, smooth-bore pattern without shoulder at the orifice.

The tip of the nozzle shall be located 20 feet (6.1 m) from and on a line normal to the center of the test assembly. If impossible to be so located, the nozzle may be on a line deviating not to exceed 30 degrees from the line normal to the center of the test assembly. When so located, the distance from the plane of the surface of the test assembly shall be less than 20 feet (6.1 m) by an amount equal to 1 foot (304.8 mm) for each 10 degrees of deviation from the normal.

The hose stream shall be directed around the periphery of the test assembly starting upward from a lower corner. When the circuit is about 1 foot (304.8 mm) from the starting point, the hose stream shall be applied in paths about 1 foot (304.8 mm) apart up and down the assembly across the entire width and then back and forth horizontally across the entire height.

The water pressure at the base of the nozzle shall be 30 psi (207 kPa) and the hose stream shall be applied 6/10 second for each square foot (0.0929 m²) of area of the test assembly.

SECTION 7.407 — CONDITIONS OF ACCEPTANCE

7.407.1 Window Assemblies. A window assembly shall be considered as meeting the requirements for acceptable performance when it remains in the opening during the fire-endurance and hose stream tests within the following limitations:

1. The window assembly shall not be loosened from its fastenings.
2. Movement at the perimeter of openable components, from the initial closed position, shall not exceed the thickness of the frame member at any point.
3. At least 70 percent of the edges of each individual glass light shall remain in position through the hose stream test. The dislodging of small fragments from the central areas of individual lights shall be disregarded.

7.407.2 Glass Block Assemblies. A glass block assembly shall be considered as meeting the requirements for acceptable performance when it remains in the opening during the fire-endurance and hose stream tests within the following limitations:

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1. The glass block assembly shall not be loosened from the frame.
2. At least 70 percent of the glass blocks shall not develop through openings.
UNIFORM BUILDING CODE STANDARD 7-5
FIRE TESTS OF THROUGH-PENETRATION FIRE STOPS


See Section 714, Uniform Building Code

Part I—General

SECTION 7.501 — SCOPE

This method is applicable to penetration fire stops as defined in this code. Part I of this standard is applicable to both through-penetration and membrane-penetration fire stops. Part II contains additional criteria applicable to through-penetration fire stops.

In addition to evaluating the fire-resistant characteristics of penetration fire stops, this test method considers the resistance of penetration fire stops to an external force simulated by a hose stream. However, this method shall not be construed as determining the performance of the fire stop during actual fire conditions when subjected to forces such as failure of support systems and falling debris.

SECTION 7.502 — SIGNIFICANCE AND USE

This method is used to determine the performance of a penetration fire stop with respect to exposure to a standard temperature-time fire test and hose stream test. The performance of a penetration fire stop is dependent upon the specific assembly of materials tested, including the number, type and size of penetrations and the floors or walls in which it is installed.

SECTION 7.503 — DEFINITIONS

For the purpose of this standard, certain terms are defined as follows:

TEST ASSEMBLY is the wall or floor into which the test sample is mounted or installed.

TEST SAMPLE is the fire stop being tested.

SECTION 7.504 — CONTROL OF FIRE TESTS

7.504.1 Temperature-time Curve. The fire environment within the furnace shall be in accordance with the standard temperature-time curve shown in U.B.C. Standard 7-1, Figure 7-1-1. The points on the curve that determine its character are set forth in Section 7.504.2.

7.504.2 Furnace Temperatures. The temperature fixed by the curve shall be the average temperature obtained from the readings of thermocouples symmetrically disposed and distributed within the test furnace to show the temperature near all parts of the assembly. Use a minimum of three thermocouples, with not fewer than five thermocouples per 100 square feet (9.29 m²) of floor surface, and not fewer than nine thermocouples per 100 square feet (9.29 m²) of wall specimen surface.

Enclose the thermocouples in sealed protection tubes of such materials and dimensions that the time constant of the protected thermocouple assembly lies within the range from 300 to 400 seconds. The exposed length of the pyrometer tube and thermocouple in the furnace chamber shall not be less than 12 inches (300 mm). Other types of protection tubes of pyrometers may be used, provided that temperature measurements obtained in accordance with Figure 7-1-1 are within the limit of accuracy that applies for furnace temperature measurements.
For floors, place the junction of the thermocouples 12 inches (300 mm) away from the exposed face of the assembly. In the case of walls, place the thermocouples 6.0 inches (150 mm) away from the exposed face.

Read the temperature at intervals not exceeding five minutes during the first 120 minutes. Thereafter, the intervals may be increased to not more than 10 minutes.

The accuracy of the furnace control shall be such that the area under the temperature-time curve, obtained by averaging the results from the pyrometer or thermoelectric device readings, is within 10 percent of the corresponding area under the standard temperature-time curve shown in Figure 7-1-1 for fire tests of 60 minutes or less duration; within 7.5 percent for those over 60 minutes and not more than 120 minutes; and within 5 percent for tests exceeding 120 minutes in duration.

7.504.3 Unexposed Surface Temperatures. Measure temperatures on the unexposed surface of the test sample and assembly with thermocouples placed under flexible pads.

The pads shall be of suitable inorganic material and shall exhibit the following properties:

1. **Length and width:** 2.00 ± 0.04 inch (50 ± 1.02 mm).
2. **Thickness:** 0.04 ± 0.05 inch (10.2 ± 1.27 mm).
3. **Density:** 31.2 ± 0.6 pounds/cubic feet (499.2 ± 9.6 kg/m³).
4. **Thermal conductivity (k) at 150°F. (65.6°C.):** 0.380 ± 0.027 Btu x inches/hour x square feet °F. [0.0548 ± 0.0039 W/(m•k)].

The pads shall be sufficiently soft so that, without breaking, they may be shaped to contact over the whole surface against which they are placed. The pads shall be held firmly against the surface; they shall fit closely about the thermocouples. The thermocouple junction shall be located under the center of the pads. The thermocouple leads under the pads shall not be heavier than No. 18 B.&S. gage (0.040 inches) (1.02 mm) and shall be electrically insulated with heat-resistant, moisture-resistant coverings.

Read temperatures at intervals not exceeding 15 minutes until a reading exceeding 212°F. (100°C.) has been obtained at any one point. Thereafter, the readings may be taken more frequently, but the intervals need not be less than five minutes.

For specific locations of thermocouples, see Part II.

Additional temperature measurements may be made at the discretion of the testing agency to obtain representative information on the performance of the test sample.

7.504.4 Differential Pressure. Measure the pressure differential between the exposed and unexposed surfaces of the test assembly required in Section 7.507.2 at three points 0.78 inch (20 mm) from the surface and locate as follows:

1. **Walls**—At the center and quarter points on the vertical center line.
2. **Floors**—At the center and quarter points along the longitudinal center line.

The pressure-measuring probe tip shall be as shown in Figure 7-5-2, manufactured from stainless steel or other suitable material.

Measure the pressure by means of a manometer or equivalent transducer. The manometer or transducer shall be capable of reading 0.01-inch H₂O (2.5 Pa) increments.

**SECTION 7.505 — TEST SAMPLE**

The construction of the test sample shall be of sufficient size and include all conduits, pipes, cables (jacket types, sizes, conductor types, percent fills), required supports or other penetrating items so as to produce a representative penetration fire stop for which evaluation is desired. Penetration fire stops shall be installed and tested in each representative construction for which ratings are desired.
The periphery of the test sample shall not be closer than one and one-half times the thickness of the test assembly or a minimum of 12 inches (300 mm) to the furnace edge, whichever is greater.

The distance between test sample periphery and furnace edge may be reduced if the testing agency demonstrates and reports that the edge effects do not affect the results.

SECTION 7.506 — PROTECTING AND CONDITIONING

Prior to fire test, condition the floor or wall assembly and test samples to provide, within a reasonable time, a moisture condition approximately representative of that likely to exist in similar construction in buildings. This moisture condition is considered as that which would be established at equilibrium resulting from drying in an ambient atmosphere of 50 percent relative humidity at 73°F. (23°C.). However, with some assemblies and test samples it may be difficult or impossible to achieve the equilibrium moisture condition within a reasonable period of time. Therefore, floor or wall assemblies and test samples may be tested when their dampest portion has achieved a moisture content corresponding to drying to equilibrium with air in the range from 50 to 75 percent relative humidity at 73°F ± 5°F. (23°C. ± 3°C.). If the assembly or test sample dried in a heated building fails to meet these requirements after a 12-month conditioning period, or if the nature of the construction is such that drying of the assembly or test sample interior will be prevented by hermetic sealing, these requirements may be waived, except as to attainment of the required strength as described in Section 7.507.1, and the assembly or test sample may be tested in the condition in which it then exists.

Protect the testing equipment, sample and assembly undergoing the fire test from any condition of wind or weather that might lead to abnormal results. The ambient air temperature at the beginning of the test shall be within the range from 50°F. to 90°F. (10°C. to 32°C.). The velocity of air across the unexposed surface measured just before the test begins shall not exceed 4.4 feet/seconds (1.3 m/s) as determined by an anemometer placed at right angles to the unexposed surface. If mechanical ventilation is employed during the test, an airstream shall not be directed across the surface of the sample.

SECTION 7.507 — CONDUCT OF TESTS

7.507.1 Time of Testing. The test sample shall not be tested until the test assembly has developed sufficient strength to retain the test sample securely in position.

7.507.2 Fire Test. After the first 10 minutes, the test sample shall be subject to a minimum positive pressure differential of 0.01 inch of water (2.5 Pa).

Continue the test until the desired evaluation period is reached or until the rating criteria are satisfied.

7.507.3 Hose Stream Test. Subject a duplicate test sample to a fire exposure test for a period equal to one half of that indicated as the resistance period in the fire test, but not more than 60 minutes, immediately after which subject the sample to the impact, erosion and cooling effects of a hose stream as described in Table 7-5-A directed first at the middle and then at all parts of the exposed face, with changes in direction being made slowly.

The test sponsor may elect, with the advice and consent of the testing body, to have a hose stream test made on the sample subjected to the fire test immediately following the fire test.

The stream shall be delivered through a 2 1/2-inch (63.5 mm) hose and discharged through a National Standard Playpipe of corresponding size equipped with a 1 1/8-inch (28.6 mm) discharge tip of the standard-taper, smooth-bore pattern without a shoulder at the orifice. The water pressure shall be 30 psi ± 2 psi as (207 kPa ± 13.8 kPa) measured at the base of the nozzle.

The nozzle orifice shall be 20 feet (6096 mm) from the center of the exposed surface of the test sample if the nozzle is so located that when directed at the center its axis is normal to the surface of
the test sample. If otherwise located, its distance from the center shall be less than 20 feet (6096 mm) by an amount equal to 1 foot (300 mm) for each 10 degrees of deviation from the normal.

SECTION 7.508 — REPORT

Results expressed as F and T ratings, as appropriate, shall be reported in accordance with the performance in the tests prescribed in this method. They shall be expressed in hours and minutes to the nearest integral minute. Reports shall include the following:

1. The assembly, materials and penetrating items of the tested penetration fire stop, clearly identified and described. Drawings depicting geometry, exact size (length, width, thickness) and location of penetration fire stops within the test assembly.

2. The relative humidities of the test assembly and test sample materials, if applicable.

3. The furnace and the unexposed side temperatures for the duration of the standard fire test.

4. The measurement of differential pressure between the exposed and unexposed test assembly surface during the fire test.

5. Observations of significant details of the behavior of the test sample during the test and after the furnace fire is extinguished. These shall include cracks, deformation, flaming and smoke issuance. Also, these include continued burning within the test sample after termination of the fire test.

When the indicated, penetration fire-stop rating period is 60 minutes or over, a correction shall be applied for variation of the furnace exposure from that prescribed, where it will affect the rating, by multiplying the indicated period by two thirds of the difference in area between the curve of average furnace temperature and the standard curve for the first three fourths of the period, and dividing the product by the area between the standard curve above a base line of 68°F (20°C.) for the same part of the indicated period, the latter areas increased by 54°F. × hours (30°C. × hours) [3,240°F. × minutes (1800°C. × minutes)], to compensate for the thermal lag of the furnace thermocouples during the first part of the test. For higher-than-standard fire exposure in the test, the indicated rating period shall be increased by the amount of the correction and similarly decreased for fire exposure below surface. The correction can be expressed as follows:

\[ C = \frac{2I(A - A_s)}{3(A_s + L)} \]

WHERE:

- \( A \) = area under the curve of indicated average furnace temperature for the first three fourths of the indicated period.
- \( A_s \) = area under the standard furnace curve for the same part of the indicated period.
- \( C \) = correction in the same units as \( I \).
- \( I \) = indicated fire-resistance period.
- \( L \) = lag correction in the same units as \( A \) and \( A_s \) [54°F. × hours (30°C. × hours); 3,240°F. × minutes (1800°C. × minutes)].

Part II—Through-penetration Fire Stops

SECTION 7.509 — SCOPE

This part of this standard contains specific criteria for testing and rating through-penetration fire stops.

Two ratings are established for each through-penetration fire stop. An F rating is based on flame occurrence on the unexposed surface, while the T rating is based on the temperature rise on the unexposed side of the through-penetration fire stop.
SECTION 7.510 — UNEXPOSED SURFACE AND PENETRATION TEMPERATURES

Measurements shall be made at the locations on the unexposed surface of the test sample and floor or wall assembly as shown in Figure 7-5-1 and as described in the following:

Measure temperatures of each type and size of penetrating item with at least one thermocouple located 1 inch (25.4 mm) from the unexposed surface of the test sample. Where a thermal protection assembly is used to wrap around the penetrating items on the unexposed side, an additional thermocouple shall be located on the penetrating items 1 inch (25.4 mm) from the end of the thermal-protection assembly. The thermocouple lead shall be held firmly against the penetrating item. The thermocouple leads shall not be heavier than No. 22 B.&S.gage (0.0253 inches) (300 mm) and shall be electrically insulated with heat-resistant and moisture-resistant coverings. The pads as described in Part I shall be held firmly against the penetrating item and shall fit closely about the thermocouples.

SECTION 7.511 — INSTALLATION OF PENETRATING ITEMS

Penetrating items shall be installed so that they extend a minimum of 12 inches (300 mm) on the exposed side and a minimum of 36 inches (900 mm) on the unexposed side. The extended portion of the penetrating items on the unexposed side shall be supported in the same manner as methods employed in field installation. When the end use of the penetrating items precludes the minimum projections specified, the penetrating items shall be installed in the end-use configuration.

Individual ends of the penetrating items shall be covered and sealed by suitable means on the exposed side to prevent excessive transfer of gases through the test sample. When the penetrating item is intended to be representative of a closed system that is not normally vented or open to the atmosphere, the penetrating item may also be capped or sealed on the unexposed side. Otherwise, the penetrating items shall not be capped or sealed on the unexposed side.

SECTION 7.512 — RATING CRITERIA

7.512.1 F Rating. A through-penetration fire stop shall be considered as meeting the requirements for an F rating when it remains in the test assembly during the fire test and hose stream test within the following limitations:

1. The through-penetration fire stop shall have withstood the fire test for the rating period without permitting the passage of flame through openings or the occurrence of flaming on any element of the unexposed side of the test sample.

2. During the hose stream test, the test sample shall not develop any opening that would permit a projection of water from the stream beyond the unexposed side.

7.512.2 T Rating. A through-penetration fire stop shall be considered as meeting the requirements for a T rating when it remains in the test assembly during the fire test and hose stream test so as to meet the requirements for an F rating and it performs within the following limitations:

1. The transmission of heat through the test sample during the rating period shall not have been such as to raise the temperature of any thermocouple on the unexposed surface of the test sample or any penetrating item more than 325°F. (181°C.) above its initial temperature.

SECTION 7.513 — REPORT

In addition to the information required in Section 7.508, the following shall be included in the report:

1. The F and T ratings for each through-penetration fire stop in the time period of resistance.

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### TABLE 7-5-A—HOSE STREAM TEST PRESSURE AND DURATION

| RESISTANCE PERIOD                                   | DURATION OF APPLICATION (seconds per square foot of exposed area)
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>120 minutes and over</td>
<td>( \times 10.76 \text{ for sec} \cdot \text{m}^2 )</td>
</tr>
<tr>
<td>90 minutes and over if less than 120 minutes</td>
<td>1.5</td>
</tr>
<tr>
<td>Less than 90 minutes</td>
<td>0.9</td>
</tr>
</tbody>
</table>

1The exposed area shall be calculated using the area of the wall or floor assembly in which the penetration fire stop is mounted.

![Diagram of Wall or Floor Assembly](image)

**FLOOR ASSEMBLY—PLAN**

**WALL ASSEMBLY—ELEVATION**

![Diagram of Floor Assembly—Sectional View](image)

**FLOOR ASSEMBLY—SECTIONAL VIEW**

**WALL ASSEMBLY—ELEVATION**

**FIGURE 7-5-1—TEMPERATURE MEASUREMENT LOCATIONS**
LEGEND FOR FIGURE 7-5-1:

A—At a point on the surface of the fire stop 1 in. (25.4 mm) from one through-penetrating item for each type of penetrating item employed in the field of the fire stop. If the grouping of penetrating items through the test sample prohibits placement of the thermocouple pad, the thermocouple shall not be required.

B—At a point on the fire stop surface at the periphery of the fire stop.

C—At a minimum of three points on the fire stop surface approximately equidistant from a penetrating item or group of penetrating items in the field of the fire stop and the periphery.

D—At one point on any frame that is installed about the perimeter of the opening.

E—At one point on the unexposed surface of the wall or floor that is not less than 12 inches (300 mm) from any opening.

F—At one point on each type of through-penetrating item, 1 inch (25.4 mm) beyond test sample or thermal protective assembly.

G—At one point on the surface of thermal protective assembly, 1 inch (25.4 mm) beyond test sample.

SECTION

ELEVATION

FIGURE 7-5-2—STATIC PRESSURE-MEASURING DEVICE
DIMENSIONS IN MILLIMETERS
SECTION 7.601 — SCOPE

These methods cover procedures for obtaining the thickness and density for sprayed fibrous and cementitious fire-resistive materials. In addition, provisions for field inspection procedures by an approved agency on a random sample basis are included.

SECTION 7.602 — APPLICATIONS

These test methods require that the application of the field-applied, sprayed, fire-resistive material be in accordance with the manufacturer's published instructions. The apparatus, materials and procedure used to apply the fire-resistive material shall be the same as the procedure used to prepare the test specimens which were subjected to the fire tests set forth in U.B.C. Standard 7-1.

SECTION 7.603 — TEST METHODS FOR THICKNESS

7.603.1 General. The following tests based on samplings as described in this standard shall be conducted by an approved agency.

7.603.2 Substrate Condition. The condition of the substrate on each floor shall be inspected prior to application of the spray-applied fireproofing material. The substrate shall be prepared in accordance with the manufacturer's instructions and shall be free of dirt, grease, oil, loose scale, loose paint or primer and other materials which may prevent adequate adhesion.

7.603.3 Thickness Measurement and Acceptance Criteria. The thickness of the spray-applied fireproofing shall be measured by either of the following methods:

1. A steel rule graduated in at least $\frac{1}{16}$-inch (1 mm) increments, a depth gage consisting of a moveable needle or pin and a disc perpendicular to the needle as shown in Figure 7-6-1.

   The pin shall be of sufficient length to penetrate the material to be measured. The disc shall be perpendicular to the needle at all times and shall have a friction device to grip the pin unless purposely moved. The disc shall have a diameter of $\frac{1}{16}$ inches (28.6 mm) to permit complete contact with the surface of the specimen to be measured. In materials not readily penetrated by the depth gage, other suitable approved measuring devices may be used.

   The thickness shall be determined by inserting the penetrating pin of the depth gage perpendicular to and through the sprayed fire-resistive material to the substrate. When the point of the pin touches the substrate, the disc shall be moved against the fire-resistive material with sufficient force on the disc to register the average plane of the surface. The gage shall be withdrawn to read the thickness in $\frac{1}{16}$-inch (1.6 mm) increments as shown by the position of the sliding clip indicator. The acceptance of measurements with a minus tolerance greater than $\frac{1}{4}$ inch (6.4 mm) shall not be permitted. If design thickness is less than 1 inch (25.4 mm), no more than 25 percent less thickness shall be permitted. Measurements greater than $\frac{1}{4}$ inch (6.4 mm) for thickness over 1 inch (25.4 mm), or 25 percent for thickness less than 1 inch (25.4 mm) above the required thickness, shall not be used to determine the thickness average.

2. As an alternate to the method described above, the thickness of the spray-applied fireproofing may be measured by a fixed probe with a $\frac{1}{16}$-inch-diameter (28.6 mm) disc set to the required thickness. If any measurement is less than that required, the thickness shall be increased or measurement shall be taken as required in Method 1.
Where thickness is less than that required, the condition shall be corrected. The location of any uncorrected areas shall be reported to the building official.

7.603.4 Thickness Determination for Structural Frame Members. Twenty-five percent of the structural frame, columns and beams as defined in Section 601.4 of this code in each story shall be inspected for thickness determination. Five measurements at a single cross section shall be made and averaged on structural frame beams, and six measurements shall be made and averaged at a single cross section on columns as shown in Figure 7-6-2.

Where open flutes or valley of steel deck sections occur over beams, they shall be filled solid unless the flutes were unfilled in the fire-tested assembly.

7.603.5 Thickness Determination for Beams Other than Structural Frame. Ten percent of beams (other than structural frame members) on each floor shall be selected at random and shall be measured for thickness as required for structural frame members in Section 7.603.4.

7.603.6 Thickness Determination for Floor Sections. Ten floor thickness measurements for each prescribed thickness shall be made on a random basis for each 10,000 square feet (929 m$^2$). At each area selected, a rectangle having an area of 144 square inches (0.0929 m$^2$) and a minimum width of 6 inches (152.4 mm) where possible shall be laid out, and a thickness measurement shall be taken at the center and at each corner. The five measurements shall be averaged and shall be reported as a single measurement of the area. The average thickness as determined by Section 7.603.3, Item 1, shall not be less than that specified. If the method for thickness determination as described in Section 7.603.3, Item 2 is used, the thickness at any location shall not be less than the required thickness.

SECTION 7.604 — TEST METHODS FOR DENSITY

7.604.1 General. The test to determine the density of spray-applied fireproofing shall be conducted by an approved agency.

7.604.2 Density Sample Groups. There shall be density test specimens taken from a column, a beam and a deck for each 10,000 square feet (929 m$^2$) of floor area or fraction thereof, or from each floor if the floor area is smaller than 10,000 square feet (929 m$^2$).

7.604.3 Density Determination. The density of each sample shall be determined as follows:

1. Utilizing a rectangular template as described in Section 7.603.6, a known area of the test sample shall be marked off.

2. Utilizing the procedure described in Section 7.603.6 and Section 7.603.3, Method 1, at least five thickness measurements shall be taken. One measurement shall be taken at the center of the specimen and one at each of the four corners approximately 1 1/2 (38 mm) inches from adjacent sides. The thickness measurement shall be determined prior to removing the sample, and the average of these five measurements shall be considered as the thickness of the specimen.

3. The specimen shall be cut along the perimeter of the template. All of the in-place material shall be carefully removed from the substrate and dried at 120°F. (49°C.) at a relative humidity of not less than 50 percent until a constant weight is obtained. The constant weight of the dried material shall be measured.

4. The density shall be calculated in accordance with the following formula:

Density in pounds per cubic foot:

\[ \frac{W \times 1,728}{l \times w \times t} \]

For SI: (Density in kilograms per cubic meter)

\[ \frac{W \times (10^3)}{l \times w \times t} \]

WHERE:

\[ l = \text{length of the specimen, inches (mm)}. \]
7.604.4 Density Acceptance Criteria. No sample shall have a density less than 5 percent below the specified density. Where the density is less than the 5 percent tolerance allowed above, the work shall be corrected to the satisfaction of the building official.

FIGURE 7-6-1—THICKNESS GAGE

FIGURE 7-6-2
SECTION 7.701 — SCOPE

This part of this standard contains procedures by which the fire resistance of steel columns, beams, girders and trusses protected by specific materials or combinations of materials can be established by calculations. These procedures apply to the material contained in this part only.

SECTION 7.702 — DEFINITION

CERAMIC FIBER BLANKET is a mineral wool insulation material made of alumina-silica fibers and weighing 4 to 10 pounds per cubic foot (64 to 160 kg/m³).

SECTION 7.703 — STRUCTURAL STEEL COLUMN PROTECTION

7.703.1 Procedures. These procedures establish a basis for determining the fire resistance of column assemblies as a function of the thickness of fire-protection material, the weight (W) or cross-sectional area (A) of steel columns and the heated perimeter (D or P) of steel columns. As used in these sections, W is the average weight of a structural steel column in pounds per linear foot (kg/m) and A is the cross-sectional area of a structural steel column in square inches (mm²). The heated perimeter (D) is the inside perimeter of the fire-protection material in inches (mm) as illustrated in Figure 7-7-S-1.

Application of these procedures shall be limited to column assemblies in which the fire-protection material is not designed to carry any of the load acting on the column. In the absence of substantiating fire-endurance test results, ducts, conduit, piping and similar mechanical, electrical and plumbing installations shall not be embedded in any required fire-protection materials of assemblies designed in accordance with this standard. Table 7-7-S-A1 contains weight-to-heated-perimeter ratios (W/D) for both contour and box fire-protection profiles for the wide-flange shapes most often used as columns. For different fire-protection profiles or column cross sections, the weight-to-heated-perimeter ratios (W/D) and cross-sectional-area-to-heated-perimeter ratios (A/P) shall be determined in accordance with the definitions given in this section.

7.703.2 Gypsum Wallboard (Wide-flange, Pipe and Tubular Columns). The fire resistance of structural steel columns with weight-to-heated-perimeter ratios (W/D) less than or equal to 3.65 (0.215) and which are protected with Type X gypsum wallboard may be determined from the following expression:

$$R = 130 \left( \frac{h (W/D)}{2} \right)^{0.75}$$

For SI:

$$R = 96 \left( \frac{h (W/D)}{2} \right)^{0.75}$$
FOR SI:

\[ W = W + 0.0008 h D \]

The gypsum wallboard shall be supported and fastened as illustrated in either Figure 7-7-S-2 for fire-resistance ratings of four hours or less, or Figure 7-7-S-3 for fire-resistance ratings of three hours or less. The fire resistance of structural steel columns can be determined from Figure 7-7-S-4 for various thicknesses of gypsum wallboard as a function of the weight-to-heated-perimeter ratio \((W/D)\) of the column. For structural steel columns with weight-to-heated-perimeter ratios \((W/D)\) greater than 3.65 (0.215), the thickness of gypsum wallboard required for specified fire-resistance ratings shall be the same as the thickness determined for a W14 x 233-wide (W 360 x 347) flange shape.

### 7.703.3 Spray-applied Materials (Wide-flange Columns)

The fire resistance of wide-flange structural steel columns protected with spray-applied fire-protection materials, as illustrated in Figure 7-7-S-5, may be determined from the following expression:

\[ R = \left( C_1 \frac{W}{D} + C_2 \right) h \]

WHERE:

- \( C_1 \) and \( C_2 \) = material-dependent constants.
- \( D \) = heated perimeter of the structural steel column, inches (mm).
- \( h \) = thickness of spray-applied fire protection, inches (mm).
- \( R \) = fire resistance, minutes.
- \( W \) = average weight of steel column, pounds per linear foot (kglm).

The material-dependent constants, \( C_1 \) and \( C_2 \), shall be determined for specific fire-protection materials on the basis of standard fire-endurance tests in accordance with Section 703.2. These constants shall be determined from results of at least four fire-endurance tests in accordance with requirements set forth in U.B.C. Standard 7-1. At least two tests shall be conducted on the largest and two on the smallest columns which establish the limits of applicability to the resulting equation. Test data shall be evaluated with respect to the assumption that the ratio of fire endurance to fire-protection thickness \((R/h)\) is reasonably constant for a given column shape \((W/D)\) ratio. The tests conducted on columns of the same shape shall be designed so that the resulting fire-endurance times are approximately one and one-half hours and three and one-half hours. In evaluating the \(R/h\) ratios resulting from tests on the same column shape, differences in the range of 10 percent are typical. Differences greater than 20 percent may, however, suggest that the equation is not applicable to the specific fire-protection material under consideration and further examination of the test data is warranted.

Unless evidence is submitted to the building official substantiating a broader application, this expression shall be limited to determining the fire resistance of structural steel columns with weight-to-heated-perimeter ratios \((W/D)\) between the largest and smallest columns for which standard fire-endurance test results are available.

### 7.703.4 Spray-applied Fire-protection Materials (Pipe and Tubular Columns)

The fire resistance of pipe and tubular steel columns protected with spray-applied fire-protection materials may be determined from the following expressions:
WHERE:

\[ R = C_3 (A/P) h + C_4 \]

\[ A = \text{cross-sectional area of the structural steel column, square inches (square millimeters).} \]

\[ C_3, C_4 = \text{material-dependent constants.} \]

\[ h = \text{thickness of spray-applied fire protection, inches (millimeters).} \]

\[ P = \text{heated perimeter of the structural steel column, inches (millimeters).} \]

\[ R = \text{fire resistance, hours.} \]

The material-dependent constants \((C_3, C_4)\) shall be determined for specific fire-protection materials on the basis of standard fire-resistance tests in accordance with Section 703.2. These constants shall be determined from the results of at least four fire-endurance tests in accordance with requirements set forth in U.B.C. Standard 7-1. At least two tests shall be conducted on each of two different column sizes as follows:

1. For the smaller of the two columns, one of the test specimens shall be protected so as to develop the minimum desired fire-resistance rating, and the second specimen shall be protected with the maximum intended thickness of fire-protection material.

2. For the larger of the two columns, one of the test specimens shall be protected with the minimum intended thickness of fire-protection material, and the second specimen shall be protected so as to develop the maximum desired fire-resistance rating.

These four tests shall establish limits governing the use of the resulting equation. These limits shall define the minimum and maximum permitted thicknesses of protection and the minimum and maximum fire-resistance ratings. Additional tests may be conducted to modify any of these four limits and these additional tests may involve different column sizes. The material-dependent constants shall be determined based on all applicable test data using a linear, least-squares curve-fitting technique or similar statistical analysis.

Unless evidence is submitted to the building official substantiating a broader application, this expression shall be limited to determining the fire resistance of structural steel columns with cross-sectional-area-to-heated-perimeter ratios \((A/P)\) between the largest and smallest columns for which standard fire-endurance test results are available.

Table 7-7-S-A2 contains area-to-heated-perimeter ratios \((A/P)\) for circular, square and rectangular tubes most often used as columns.

### 7.703.5 Concrete

The fire-resistance rating of structural steel columns protected with concrete, as illustrated in Figure 7-7-S-6, may be determined from the following expression:

\[ R = R_o (1 + 0.03m) \]

\[ R_o = 10 \left( \frac{W}{D} \right)^{0.7} + 17 \frac{h^{1.6}}{k_c^{0.2}} \left[ 1 + 26 \left( \frac{H}{\rho_c c_h (L + h)} \right)^{0.8} \right] \]

For SI:

\[ R_o = 73 \left( \frac{W}{D} \right)^{0.7} + 0.16 \frac{h^{1.6}}{k_c^{0.2}} \left[ 1 + 30984 \left( \frac{H}{\rho_c c_h (L + h)} \right)^{0.8} \right] \]

WHERE:

\[ c_c = \text{ambient temperature specific heat of concrete, Btu/\text{lbf} \cdot ^\circ\text{F}. (kJ/\text{kg} \cdot \text{K}).} \]
For wide-flange steel columns completely encased in concrete with all reentrant spaces filled (Figure 7-7-S-6, Detail C), the thermal capacity of the concrete with the reentrant spaces may be added to the thermal capacity of the steel column, and the total thermal capacity may be determined by the expression:

\[
H = 0.11W + \frac{p_c c_c \left(b_f d - A_s\right)}{144} + \frac{1,000,000}{A_s} \frac{p_c c_c \left(b_f d - A_s\right)}{144}
\]

WHERE:

- \( A_s \) = cross-sectional area of the steel column, square inches (mm²).
- \( b_f \) = flange width of the steel column, inches (mm).
- \( d \) = depth of the steel column, inches (mm).

If specific data on the properties of concrete or concrete masonry are not available, the values given in Table 7-7-S-B may be used.

For structural steel columns encased in concrete with all reentrant spaces filled (Figure 7-7-S-6, Detail C), Tables 7-7-S-C and 7-7-S-D give the thickness of concrete cover required for various fire-resistance ratings for typical wide-flange sections. The thicknesses of concrete given in these tables also apply to structural steel columns larger than those listed.

For structural steel columns protected with precast concrete column covers (Figure 7-7-S-6, Detail A), Tables 7-7-S-E and 7-7-S-F give the thickness of the column covers required for various fire-resistance ratings for typical wide-flange sections. The thicknesses of concrete given in these tables also apply to structural steel columns larger than those listed.

For structural steel columns protected with concrete masonry (Figure 7-7-S-7), Tables 7-7-S-G and 7-7-S-H give the equivalent thickness of concrete masonry required for various fire-resistance ratings for typical wide-flange shapes. The equivalent thicknesses given in these tables also apply to structural steel columns larger than those listed.

Head and bed joints shall be fully mortared. Design and anchorage of concrete masonry shall be in accordance with Chapter 21. The thickness of column units (Figure 7-7-S-7) shall not be less than \( 1\frac{1}{2} \) inches (38 mm). The nominal thickness of hollow or solid units (Figure 7-7-S-7) shall not be less than 4 inches (102 mm).

**7.703.6 Concrete Masonry.** The fire-resistance rating of structural steel columns protected with concrete masonry, as illustrated in Figure 7-7-S-7, may be determined in accordance with the following expression:

\[
R = 0.401 \left( A_s / p_c \right)^{0.7} + 0.285 \left( T_{cw} ^{1.6} / K^{0.2} \right) \times \left[ 1.0 + 42.7 \left( A_s / DT_{cw} \right) / \left( 0.25p + T_{cw} \right) \right]^{0.8}
\]
For SI:
\[ R = 0.042\left(\frac{A_s}{p_s}\right)^{0.7} + 0.0018\left(\frac{T_{es}^{1.9}/K^{0.2}}{1.0 + \frac{384\left(\frac{A_s}{DT_{es}}\right)}{0.25p + T_{es}}\right)^{0.8}} \]

**WHERE:**
- \( A_s \) = cross-sectional area of the steel column, square inches (mm²).
- \( D \) = density of the concrete masonry protection, pounds per cubic foot (kg/m³).
- \( K \) = ambient thermal conductivity of concrete masonry. See Table 7-7-S-J, Btu/hr.ft.°F/(W/m•k).
- \( p \) = inner perimeter of concrete masonry protection, inches (mm).
- \( p_s \) = heated perimeter of steel column, inches (mm).
- \( R \) = fire-resistance rating of the column assembly, hours.
- \( T_{es} \) = equivalent thickness of concrete masonry protection assembly, inches (mm).

**SECTION 7.704 — PROTECTED STEEL BEAMS, GIRDERS AND TRUSSES**

7.704.1 Beams and Girders.

7.704.1.1 General. These procedures establish a basis for determining the fire resistance of structural steel beams and girders which differ in size from that specified in approved fire-resistant assemblies as a function of the thickness of fire-protection material and the weight \( W \) and heated perimeter \( D \) of the beam or girder. The use of the methodology in this section is limited to unstrained conditions. As used in these sections, \( W \) is the average weight of a structural steel member in pounds per linear foot (kg/m). The heated perimeter \( D \) is the inside perimeter of the fire-protection material in inches (mm) as illustrated in Figure 7-7-S-8. The weight-to-heated-perimeter ratios \( \left(\frac{W}{D}\right) \) for both contour and box fire-protection profiles for the wide-flange shapes most often used as beams or girders are given in Table 7-7-S-1. For different shapes, the weight-to-heated-perimeter ratios \( \left(\frac{W}{D}\right) \) shall be determined in accordance with the definitions given in this section. Except as provided for in Section 7.704.1, structural steel beams in approved fire-resistant assemblies shall be considered the minimum permissible size. Other beam or girder shapes may be substituted, provided that the weight-to-heated-perimeter ratio \( \left(\frac{W}{D}\right) \) of the substitute beam is equal to or greater than that of the beam specified in the approved assembly.

7.704.1.2 Spray-applied fire-protection materials. The provisions in this section apply to structural steel beams and girders protected with spray-applied cementitious or mineral fiber materials. Larger or smaller beam and girder shapes may be substituted for beams specified in approved fire-resistant assemblies, provided that the thickness of fire-protection material is adjusted in accordance with the following expression:

\[ h_2 = \left[ \frac{W_1/D_1 + 0.60}{W_2/D_2 + 0.60} \right] h_1 \]

For SI:

\[ h_2 = \left[ \frac{W_1/D_1 + 0.036}{W_2/D_2 + 0.036} \right] h_1 \]

**WHERE:**
- \( D \) = heated perimeter of the structural steel beam or girder, in inches (mm).
- \( h \) = thickness of spray-applied fire protection, in inches (mm).
- \( W \) = weight of the structural steel beam or girder in pounds per linear foot (kg/m).

Subscript 1 refers to the beam and fire-protection thickness in the approved assembly.

Subscript 2 refers to the substitute beam or girder and the required thickness of fire-protection materials.
This equation is limited to beams with a weight-to-heated-perimeter ratio \((W/I)\) of 0.37 (0.022) or greater. The thickness of protection shall not be less than \(3/8\) inch (9.5 mm).

7.704.2 Structural Steel Trusses. The fire resistance of structural steel trusses protected with cementitious or mineral fiber materials spray applied to each of the individual truss elements may be determined in accordance with this section. The thickness of protection shall be determined in accordance with Section 7.703.3. The weight-to-heated-perimeter ratio \((W/I)\) of truss elements which can be simultaneously exposed to fire on all sides shall be determined on the same basis as columns, as specified in Section 7.703.1. The weight-to-heated-perimeter ratio \((W/I)\) of truss elements which directly support floor or roof construction shall be determined on the same basis as beams and girders, as specified in Section 7.704.1.1.
<table>
<thead>
<tr>
<th>STRUCTURAL SHAPE</th>
<th>CONTOUR PROFILE (W/D)</th>
<th>BOX PROFILE (W/D)</th>
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<td>\times 0.059 for metric W/D</td>
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### TABLE 7-7-S-A1—WEIGHT-TO-HEATED-PERIMETER RATIOS (W/D)
FOR TYPICAL STRUCTURAL STEEL WIDE FLANGE COLUMNS—(Continued)

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<td>In. x lb./ft.</td>
<td>× 0.059 for metric W/D</td>
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1See Section 7.703.2 for W/D limitations for gypsum wallboard protected assemblies.
### TABLE 7-7.S-A2—AREA-TO-HEATED-PERIMETER RATIOS (\(A/P\)) FOR TYPICAL ROUND AND SQUARE STRUCTURAL TUBING

#### ROUND PIPE COLUMNS

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<th>Thickness (mm)</th>
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#### EXTRA-STRONG STEEL PIPE COLUMNS

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#### DOUBLE EXTRA-STRONG STEEL PIPE COLUMNS

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### TABLE 7-7-S-A2—AREA-TO-HEATED-PERIMETER RATIOS (A/P)
FOR TYPICAL ROUND AND SQUARE STRUCTURAL TUBING—(Continued)

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### TABLE 7-7-S-A2—AREA-TO-HEATED-PERIMETER RATIOS (A/P)
FOR TYPICAL ROUND AND SQUARE STRUCTURAL TUBING—(Continued)

#### RECTANGULAR STRUCTURAL TUBING

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TABLE 7-7-S-B—PROPERTIES OF CONCRETE

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<th>Concrete Masonry</th>
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<td>(kg/m)</td>
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1 The tabulated thicknesses are based on the assumed properties of normal-weight concrete given in Table 7-7-S-B.
### TABLE 7-7-S-D—THICKNESS OF LIGHTWEIGHT CONCRETE\(^1\) FOR VARIOUS FIRE-RESISTANCE RATINGS FOR TYPICAL WIDE-FLANGE STRUCTURAL STEEL COLUMNS ENCASED IN CONCRETE [INCHES (MM)] (FIGURE 7-7-S-6, DETAIL C)

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\(^1\)The tabulated thicknesses are based on the assumed properties of structural lightweight concrete given in Table 7-7-S-B.
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1 The tabulated thicknesses are based on the assumed properties of normal-weight concrete given in Table 7-7-S-B.
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1The tabulated thicknesses are based on the assumed properties of structural lightweight concrete given in Table 7-7-S-B.
### TABLE 7-7-S-G—EQUIVALENT THICKNESS OF NORMAL-WEIGHT CONCRETE MASONRY FIRE PROTECTION FOR TYPICAL WIDE-FLANGE STRUCTURAL STEEL COLUMNS¹, ²

[Inches (mm)] (See Figure 7-7-S-7)

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¹The tabulated thicknesses are based on the assumed properties of normal-weight concrete masonry given in Table 7-7-S-B.

²The thicknesses of concrete masonry units shall not be less than set forth in Section 7.703.4.
## TABLE 7-7-S-H—EQUIVALENT THICKNESS OF LIGHTWEIGHT CONCRETE MASONRY FIRE PROTECTION FOR TYPICAL WIDE-FLANGE STRUCTURAL STEEL COLUMNS¹,²

**[Inches (mm)] (See Figure 7-7-S-7)**

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¹The tabulated thicknesses are based on the assumed properties of normal-weight concrete masonry given in Table 7-7-S-B.

²The thicknesses of concrete masonry units shall not be less than set forth in Section 7.703.4.
### TABLE 7-7-S—WEIGHT-TO-HEATED-PERIMETER RATIOS W/D FOR TYPICAL WIDE-FLANGE BEAM AND GIRDER SHAPES

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<th>( \times 0.059 ) for metric W/D</th>
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(Continued)
### TABLE 7-7-S-I—WEIGHT-TO-HEATED-PERIMETER RATIOS W/D FOR TYPICAL WIDE-FLANGE BEAM AND GIRDER SHAPES—(Continued)

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(Continued)
### TABLE 7-7-S-I—WEIGHT-TO-HEATED-PERIMETER RATIOS W/D FOR TYPICAL WIDE-FLANGE BEAM AND GIRDER SHAPES—(Continued)

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<th>BOX PROFILE</th>
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<tr>
<td>in. x lb./ft.</td>
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<td>0.59</td>
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<td>x 19</td>
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<table>
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<tr>
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<tr>
<td>x 58</td>
<td>x 86</td>
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<td>0.66</td>
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<td>x 27</td>
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<td>0.84</td>
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<td>x 22</td>
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<td>0.74</td>
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<tr>
<td>x 13</td>
<td>x 19</td>
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<td>0.65</td>
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<tr>
<td>x 10</td>
<td>x 15</td>
<td>0.37</td>
<td>0.51</td>
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<tr>
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<tr>
<td>x 20</td>
<td>x 30</td>
<td>0.67</td>
<td>1.09</td>
</tr>
<tr>
<td>x 16</td>
<td>x 24</td>
<td>0.66</td>
<td>0.96</td>
</tr>
<tr>
<td>x 15</td>
<td>x 22</td>
<td>0.51</td>
<td>0.83</td>
</tr>
<tr>
<td>x 12</td>
<td>x 18</td>
<td>0.51</td>
<td>0.75</td>
</tr>
<tr>
<td>x 9</td>
<td>x 13</td>
<td>0.39</td>
<td>0.57</td>
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</table>

<table>
<thead>
<tr>
<th>W5 x 19</th>
<th>W130 x 28</th>
<th>0.76</th>
<th>1.24</th>
</tr>
</thead>
<tbody>
<tr>
<td>x 16</td>
<td>x 24</td>
<td>0.65</td>
<td>1.07</td>
</tr>
</tbody>
</table>

<p>| W4 x 13 | W100 x 19 | 0.65 | 1.05 |</p>
<table>
<thead>
<tr>
<th>DENSITY ((D)) (pcf) (\times 16) for (kg/m^3)</th>
<th>THERMAL CONDUCTIVITY ((K)) (\times 1.73) for (W/m\cdot K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>0.207</td>
</tr>
<tr>
<td>85</td>
<td>0.228</td>
</tr>
<tr>
<td>90</td>
<td>0.252</td>
</tr>
<tr>
<td>95</td>
<td>0.278</td>
</tr>
<tr>
<td>100</td>
<td>0.308</td>
</tr>
<tr>
<td>105</td>
<td>0.340</td>
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<tr>
<td>110</td>
<td>0.376</td>
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<td>115</td>
<td>0.416</td>
</tr>
<tr>
<td>120</td>
<td>0.459</td>
</tr>
<tr>
<td>125</td>
<td>0.508</td>
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<tr>
<td>130</td>
<td>0.561</td>
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<tr>
<td>135</td>
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<tr>
<td>140</td>
<td>0.685</td>
</tr>
<tr>
<td>145</td>
<td>0.758</td>
</tr>
<tr>
<td>150</td>
<td>0.837</td>
</tr>
</tbody>
</table>
FIGURE 7-7-S-1—DETERMINATION OF THE HEATED PERIMETER OF STRUCTURAL STEEL COLUMNS

\[ D = 4b_I + 2d - 2t_w \]
\[ D = 2(a + b) \]
\[ D = 2(b_I + d) \]
Notes:

1. Structural steel column, either wide-flange or tubular shapes.

2. Type X gypsum wallboard. For single-layer applications, the wallboard shall be applied vertically with no horizontal joints. For multiple-layer applications, horizontal joints are permitted at a minimum spacing of 8 feet (2438 mm), provided that the joints in successive layers are staggered at least 12 inches (305 mm). The total required thickness of wallboard shall be determined on the basis of the specified fire-resistance rating and the weight and heated perimeter of the column. For fire-resistance ratings of two hours or less, one of the required layers of gypsum wallboard may be applied to the exterior of the sheet steel column covers with 1-inch-long (25.4 mm) Type S screws spaced 1 inch (25.4 mm) from the wallboard edge and 8 inches (203.2 mm) on center. For such installations, 0.016-inch-minimum-thickness (0.4 mm) galvanized steel corner beads with 1 1/2-inch (38.1 mm) legs shall be attached to the wallboard with Type S screws spaced 12 inches (305 mm) on center.

FIGURE 7-7-S-2—GYPSUM WALLBOARD PROTECTED STRUCTURAL STEEL COLUMNS WITH SHEET STEEL COLUMN COVERS (FOUR HOURS OR LESS)
3. For fire-resistance ratings of three hours or less, the column covers shall be fabricated from 0.024-inch-minimum-thickness (0.6 mm) galvanized or stainless steel. For four-hour fire-resistance ratings, the column covers shall be fabricated from 0.024-inch-minimum-thickness (0.6 mm) stainless steel. The column covers shall be erected with the snap lock or Pittsburgh joint details.

For fire-resistance ratings of two hours or less, column covers fabricated from 0.027-inch-minimum-thickness (0.7 mm) galvanized or stainless steel may be erected with lap joints. The lap joints may be located anywhere around the perimeter of the column cover. The lap joints shall be secured with 1/2-inch-long (12.7 mm) No. 8 sheet metal screws spaced 12 inches (305 mm) on center.

The column covers shall be provided with a minimum expansion clearance of 1/8 inch (10.4 mm) per linear foot (m) between the ends of the cover and any restraining construction.
Notes:

1. Structural steel column, either wide-flange or tubular shapes.

2. One and five-eighths-inch-deep (41.3 mm) studs fabricated from 0.021-inch-minimum-thickness (0.5 mm) galvanized steel with 1/16- or 1/16-inch (33.3 mm or 36.5 mm) legs and 1/4-inch (6.4 mm) stiffening flanges. The length of the steel studs shall be 1/2 inch (12.7 mm) less than the height of the assembly.

3. Type X gypsum wallboard. For single-layer applications, the wallboard shall be applied vertically with no horizontal joints. For multiple-layer applications, horizontal joints are permitted at a minimum spacing of 8 feet (2438 mm), provided that the joints in successive layers are staggered at least 12 inches (305 mm). The total required thickness of wallboard shall be determined on the basis of the specified fire-resistance rating and the weight and heated perimeter of the column.

4. Galvanized steel corner beads [0.016-inch (0.4 mm) minimum thickness] with 1/2-inch (38.1 mm) legs attached to the wallboard with 1-inch-long (25.4 mm) Type S screws spaced 12 inches (305 mm) on center.

5. No. 18 SWG steel tie wires spaced 24 inches (610 mm) on center.

6. Sheet metal angles with 2-inch (50.8 mm) legs fabricated from 0.021-inch-minimum-thickness (0.5 mm) galvanized steel.

7. Type S screws 1-inch (25.4 mm) long shall be used for attaching the first layer of wallboard to the steel studs and the third layer to the sheet metal angles at 24 inches (610 mm) on center. Type S screws 13/4 inches (44.5 mm) long shall be used for attaching the second layer of wallboard to the steel studs and the fourth layer to the sheet metal angles at 12 inches (305 mm) on center. Type S screws 21/4 inches (57.1 mm) long shall be used for attaching the third layer of wallboard to the steel studs at 12 inches (305 mm) on center.

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**FIGURE 7-7-S-3—GYPSUM WALLBOARD PROTECTED STRUCTURAL STEEL COLUMNS WITH STEEL STUD/SCREW ATTACHMENT SYSTEM (THREE HOURS OR LESS)**

<table>
<thead>
<tr>
<th>Layers</th>
<th>Description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 layer = 5/8&quot; OR 1/2&quot; (15.9 mm or 12.7 mm)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2 layers = 1 1/4&quot; OR 1&quot; (31.8 mm or 25.4 mm)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3 layers = 1 7/8&quot; OR 1 1/2&quot; (47.6 mm or 38.1 mm)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4 layers = 2 1/2&quot; OR 2&quot; (63.5 mm or 50.8 mm)</td>
<td></td>
</tr>
</tbody>
</table>

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NOTE: The W/D ratios for typical wide-flange columns are listed in Table 7-7-S-A1. For other column shapes, the W/D ratios shall be determined in accordance with Section 7.703.

FIGURE 7-7-S-4—FIRE RESISTANCE OF STRUCTURAL STEEL COLUMNS PROTECTED WITH VARIOUS THICKNESSES OF TYPE X GYPSUM WALLBOARD

FIGURE 7-7-S-5—WIDE-FLANGE STRUCTURAL STEEL COLUMN WITH SPRAY-APPLIED FIRE PROTECTION
NOTE: When the inside perimeter of the concrete protection is not square, \( L \) shall be taken as the average of \( L_1 \) and \( L_2 \). When the thickness of concrete cover is not constant, \( h \) shall be taken as the average of \( h_1 \) and \( h_2 \).

*Joints shall be protected with a minimum 1-inch (25.4 mm) thickness of ceramic fiber blanket, but in no case less than one half the thickness of the column cover. The joint width shall not exceed 1 inch (25.4 mm) maximum.

FIGURE 7-7-S-6—CONCRETE-PROTECTED STRUCTURAL STEEL COLUMNS
FIGURE 7-7-S-7—CONCRETE MASONRY PROTECTED STRUCTURAL STEEL COLUMNS
FIGURE 7-7-S-8—DETERMINATION OF THE HEATED PERIMETER OF STRUCTURAL STEEL BEAMS AND GIRDER
Part II—Method for Calculating the Fire Resistance of Concrete Construction
See Section 703.3, Uniform Building Code

SECTION 7.705 — SCOPE
This part of this standard contains procedures by which the fire resistance of concrete of specific materials or combinations of materials can be established by calculations. These procedures apply to the material contained in this part only. Procedures shown in this standard for calculating the fire resistance of concrete construction shall apply to all cast-in-place and precast concrete, conventionally reinforced or prestressed. The procedures shall not apply to single or double “T” precast, prestressed (pretensioned) units in wall or floor-roof assemblies.

SECTION 7.706 — DEFINITIONS

CARBONATE AGGREGATE CONCRETE is concrete made with aggregates consisting mainly of calcium or magnesium carbonate, e.g., limestone or dolomite.

CELLULAR CONCRETE is a lightweight insulating concrete made by mixing a preformed foam with portland cement slurry and having a dry unit weight of approximately 30 pounds per cubic foot (pcf).

CERAMIC FIBER BLANKET is a mineral wool insulation material made of alumina-silica fibers and weighing 4 to 10 pcf (64 to 160 kg/m³).

GLASS FIBER BOARD is fibrous glass roof insulation consisting of inorganic glass fibers formed into rigid boards using a binder. The board has a top surface faced with asphalt and kraft paper reinforced with glass fibers.

LIGHTWEIGHT AGGREGATE CONCRETE is concrete made with aggregates of expanded clay, shale, slag or slate or sintered fly ash and weighing 85 to 115 pcf (1362 to 1842 kg/m³).

MINERAL BOARD is a rigid felted thermal insulation board consisting of either felted mineral fiber or cellular beads of expanded aggregate formed into flat rectangular units.

PERLITE CONCRETE is a lightweight insulating concrete having a dry unit weight of approximately 30 pcf (482 kg/m³) made with perlite concrete aggregate. Perlite aggregate is produced from a volcanic rock which, when heated, expands to form a glass-like material of cellular structure.

SAND-LIGHTWEIGHT CONCRETE is concrete made with a combination of expanded clay, shale, slag or slate or sintered fly ash and natural sand. Its unit weight is generally between 105 and 120 pcf (1682 to 1930 kg/m³).

SILICEOUS AGGREGATE CONCRETE is concrete made with normal-weight aggregates consisting mainly of silica or compounds other than calcium or magnesium carbonate.

VERMICULITE CONCRETE is a lightweight insulating concrete made with vermiculite concrete aggregate, which is laminated micaceous material produced by expanding the ore at high temperatures. When added to a portland cement slurry, the resulting concrete has a dry unit weight of approximately 30 pcf (482 kg/m³).

SECTION 7.707 — CONCRETE WALLS

7.707.1 Walls, Cast-in-place or Precast.
1. The minimum equivalent thicknesses of cast-in-place or precast concrete walls for fire-resistance ratings from one to four hours are shown in Table 7-7-C-A. For solid walls with flat vertical surfaces, the equivalent thickness is the same as the thickness. The values in Table 7-7-C-A apply to plain, reinforced or prestressed concrete walls.
2. For hollow-core precast concrete wall panels in which the cores are of constant cross section throughout the length, the equivalent thickness may be calculated by dividing the net cross-sectional area (the gross cross section minus the area of the cores) of the panel by its width.

3. Where all of the core spaces of hollow-core wall panels are filled with loose-fill material, such as expanded shale, clay or slag, or vermiculite or perlite, the fire-resistance rating of the wall is the same as that of a solid wall of the same concrete type and of the same overall thickness.

4. The thickness of panels with tapered cross sections shall be that determined at a distance $2t$ or 6 inches (152 mm), whichever is less, from the point of minimum thickness, where $t$ is the minimum thickness.

5. The equivalent thickness of panels with ribbed or undulating surfaces shall be determined by one of the following expressions, whichever is applicable:

   - for $s \geq 4t$, the thickness to be used shall be $t$
   - for $s \leq 2t$, the thickness to be used shall be $t_e$
   - for $4t > s > 2t$, the thickness to be used shall be

   $$ t + \left( \frac{4t}{s} - 1 \right) (t_e - t) $$

   WHERE:

   - $s = $ spacing of ribs or undulations.
   - $t = $ minimum thickness.
   - $t_e = $ equivalent thickness of the panel calculated as the net cross-sectional area of the panel divided by the width in which the maximum thickness used in the calculation shall not exceed $2t$. 

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7.707.2 Multiwythe Walls.

1. For walls which consist of two wythes of different types of concrete, the fire-resistance ratings may be determined from Figure 7-7-C-1.

2. The fire-resistance rating for wall panels consisting of two or more wythes may be determined by the formula:

\[ R = (R_1^{0.59} + R_2^{0.59} + \ldots + R_n^{0.59})^{1.7} \]

Formula (7-1) can also be expressed as:

\[ R^{0.59} = R_1^{0.59} + R_2^{0.59} + \ldots + R_n^{0.59} \]

WHERE:

- \( R \) = the fire endurance of the assembly, minutes.
- \( R_1 \), \( R_2 \), and \( R_n \) = the fire endurances of the individual wythes, minutes.

Values of \( R_n^{0.59} \) for use in Formula (7-1) are given in Table 7-7-C-B.

<table>
<thead>
<tr>
<th>( R_1 ) MINUTES</th>
<th>( R_1^{0.59} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>11.20</td>
</tr>
<tr>
<td>90</td>
<td>14.22</td>
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<tr>
<td>120</td>
<td>16.85</td>
</tr>
<tr>
<td>180</td>
<td>21.41</td>
</tr>
<tr>
<td>240</td>
<td>25.37</td>
</tr>
</tbody>
</table>

3. The fire-resistance ratings of precast concrete wall panels consisting of a layer of foam plastic insulation sandwiched between two wythes of concrete may be determined by use of Formula (7-1). Foam plastic insulation with a total thickness of less than 1 inch (25 mm) shall be disregarded. The \( R_n \) value for thickness of foam plastic insulation of 1 inch (25 mm) or greater, for use in the calculation, is five minutes; therefore, \( R_n^{0.59} = 2.5 \).
7.707.3 Joints between Precast Concrete Wall Panels. Where openings in exterior walls are required to be protected, or where openings are not permitted in walls, the provisions of this section shall be used to determine the amount of joint insulation required.

Figure 7-7-C-2 shows thicknesses of ceramic fiber blankets to be used to protect joints between precast concrete wall panels for various panel thicknesses. For joint widths of 3/8 inch and 1 inch (10 mm and 25 mm) for fire-resistance ratings of one hour to four hours for joint widths between 3/8 inch and 1 inch (10 mm and 25 mm), the thickness of ceramic fiber blanket may be determined by direct interpolation. Other approved tested and labeled materials may be used in place of ceramic fiber blankets.

SECTION 7.708 — CONCRETE FLOOR AND ROOF SLABS

7.708.1 Reinforced and Prestressed Concrete Floor and Roof Slabs.

1. The minimum thickness of reinforced and prestressed concrete floor or roof slabs for fire-resistance ratings from one to four hours are shown in Table 7-7-C-C.

2. For hollow-core prestressed concrete slabs in which the cores are of constant cross section throughout the length, the equivalent thickness may be obtained by dividing the net cross-sectional area of the slab, including grout in the joints, by its width.

3. The thickness of slabs with sloping soffits shall be determined at a distance of 2t or 6 inches (152 mm), whichever is less, from the point of minimum thickness, where t is the minimum thickness.

4. The thickness of slabs with ribbed or undulating soffits shall be determined by one of the following expressions, whichever is applicable:

   for \( s \geq 4t \), the thickness to be used shall be \( t \)

   for \( s \leq 2t \), the thickness to be used shall be \( t_e \)

   for \( 4t > s > 2t \), the thickness to be used shall be

\[
 t + \left( \frac{4t}{s} - 1 \right) (t_e - t)
\]

WHERE:

\( s \) = spacing of ribs or undulations.

\( t \) = minimum thickness.

\( t_e \) = equivalent thickness of the panel calculated as the net cross-sectional area of the panel divided by the width in which the maximum thickness used in the calculation shall not exceed 2t.
7.708.2 Multicourse Floors and Roofs.

1. Figure 7-7-C-3A gives information on the fire-resistance ratings of floors which consist of a base slab of concrete with a topping (overlay) of a different type of concrete.

2. Figure 7-7-C-3B gives information on the fire-resistance ratings of roofs which consist of a base slab of concrete with a topping (overlay) of an insulating concrete or with an insulating board and built-up roofing. Three-ply built-up roofing contributes 10 minutes to the fire-resistance rating; therefore, 10 minutes can be added to the assemblies shown in Figure 7-7-C-3B, Details (a), (b) and (c), but not to those shown in Figure 7-7-C-3B, Details (d) and (e).

7.708.3 Joints in Precast Slabs. Joints between adjacent precast concrete slabs may be ignored in calculating the slab thickness, provided that a concrete topping at least 1 inch (25 mm) thick is used. Where no concrete topping is used, joints must be grouted to a depth of at least one third the slab thickness at the joint, but not less than 1 inch (25 mm), or the joints must be made fire resistive by other approved methods.

SECTION 7.709 — MINIMUM CONCRETE COVER REQUIREMENTS

7.709.1 Slabs. The minimum thickness of concrete cover to the positive moment reinforcement is given in Table 7-7-C-D for reinforced concrete and Table 7-7-C-E for prestressed concrete. Tables 7-7-C-D and 7-7-C-E are applicable for solid- or hollow-core one-way or two-way slabs with flat undersurfaces. Slabs may be cast-in-place or precast.

7.709.2 Beams.

1. The minimum thickness of concrete cover to the positive moment reinforcement (bottom steel) for reinforced concrete beams is shown in Table 7-7-C-F for fire-resistance ratings from one to four hours.

2. The minimum thickness of concrete cover to the positive moment prestressing tendon (bottom steel) for prestressed concrete beams is shown in Table 7-7-C-G for fire-resistance ratings from one to four hours.

SECTION 7.710 — CONCRETE COLUMNS

7.710.1 Minimum Size. Table 7-7-C-H shows the minimum overall dimensions of reinforced concrete columns for fire-resistance ratings from one to four hours.

7.710.2 Minimum Cover for Reinforced Concrete Columns. The minimum cover to the main reinforcement in columns for fire-resistance ratings of one hour, one and one-half hours, two hours
and three hours shall be $1\frac{1}{2}$ inches (38 mm); for a four-hour rating, the minimum cover to the main reinforcement shall be 2 inches (51 mm) for siliceous aggregate concrete and $1\frac{1}{2}$ inches (38 mm) for carbonate aggregate concrete or sand-lightweight concrete.
### TABLE 7-7-C-A—MINIMUM EQUIVALENT THICKNESS, INCHES, OF CAST-IN-PLACE OR PRECAST CONCRETE WALLS, LOAD BEARING OR NONLOAD BEARING

<table>
<thead>
<tr>
<th>CONCRETE TYPE</th>
<th>MINIMUM WALL THICKNESS (INCHES) FOR FIRE-RESISTANCE RATING OF x 25.4 for mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Hr.</td>
</tr>
<tr>
<td>Siliceous(^1)</td>
<td>3.5</td>
</tr>
<tr>
<td>Carbonate</td>
<td>3.2</td>
</tr>
<tr>
<td>Sand-lightweight</td>
<td>2.7</td>
</tr>
<tr>
<td>Lightweight concrete</td>
<td>2.5</td>
</tr>
</tbody>
</table>

\(^1\)The equivalent thickness may include the thickness of portland cement plaster or 1.5 times the thickness of gypsum plaster applied in accordance with the requirements of Chapter 25.

### TABLE 7-7-C-B—VALUES OF R\(_0\)^0.59 FOR USE IN FORMULA 1

<table>
<thead>
<tr>
<th>TYPE OF MATERIAL</th>
<th>VALUES OF R(_0)^0.59 FOR USE IN EQUATION 1 FOR THICKNESS OF:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 1/2 in.</td>
</tr>
<tr>
<td></td>
<td>(38 mm)</td>
</tr>
<tr>
<td>Siliceous aggregate concrete</td>
<td>5.3</td>
</tr>
<tr>
<td>Carbonate aggregate concrete</td>
<td>5.5</td>
</tr>
<tr>
<td>Sand-lightweight concrete</td>
<td>6.5</td>
</tr>
<tr>
<td>Lightweight concrete(^1)</td>
<td>6.6</td>
</tr>
<tr>
<td>Insulating concrete(^1)</td>
<td>9.3</td>
</tr>
<tr>
<td>Air space(^2)</td>
<td>—</td>
</tr>
</tbody>
</table>

\(^1\)Dry unit weight of 35 pcf (563 kg/m\(^3\)) or less and consisting of cellular, perlite or vermiculite concrete.

\(^2\)The R\(_0\)^0.59 value for 1/2 inch to 3/4 inches (13 mm to 89 mm) air space is 3.3. The R\(_0\)^0.59 value for 2 1/2 inches to 3 1/2 inches (64 mm to 89 mm) air space is 6.7.

\(^3\)The fire-resistance rating for this thickness exceeds four hours.

### TABLE 7-7-C-C—MINIMUM SLAB THICKNESS FOR CONCRETE FLOORS OR ROOFS

<table>
<thead>
<tr>
<th>CONCRETE TYPE</th>
<th>MINIMUM WALL THICKNESS (INCHES) FOR FIRE-RESISTANCE RATING OF x 25.4 for mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Hr.</td>
</tr>
<tr>
<td>Siliceous(^1)</td>
<td>3.5</td>
</tr>
<tr>
<td>Carbonate</td>
<td>3.2</td>
</tr>
<tr>
<td>Sand-lightweight</td>
<td>2.7</td>
</tr>
<tr>
<td>Lightweight concrete</td>
<td>2.5</td>
</tr>
</tbody>
</table>

\(^1\)The equivalent thickness may include the thickness of portland cement plaster or 1.5 times the thickness of gypsum plaster applied in accordance with the requirements of Chapter 25.
### TABLE 7-7-C-D—COVER THICKNESS FOR REINFORCED CONCRETE FLOOR OR ROOF SLABS

<table>
<thead>
<tr>
<th>CONCRETE AGGREGATE TYPE</th>
<th>1 Hr.</th>
<th>1 1/2 Hr.</th>
<th>2 Hr.</th>
<th>3 Hr.</th>
<th>4 Hr.</th>
<th>1 Hr.</th>
<th>1 1/2 Hr.</th>
<th>2 Hr.</th>
<th>3 Hr.</th>
<th>4 Hr.</th>
</tr>
</thead>
</table>

1 See Section 7.141 of U.B.C. Standard 7-1 for guidance on restrained and unrestrained assemblies.

### TABLE 7-7-C-E—COVER THICKNESS FOR PRESTRESSED CONCRETE FLOOR OR ROOF SLABS

<table>
<thead>
<tr>
<th>CONCRETE AGGREGATE TYPE</th>
<th>1 Hr.</th>
<th>1 1/2 Hr.</th>
<th>2 Hr.</th>
<th>3 Hr.</th>
<th>4 Hr.</th>
<th>1 Hr.</th>
<th>1 1/2 Hr.</th>
<th>2 Hr.</th>
<th>3 Hr.</th>
<th>4 Hr.</th>
</tr>
</thead>
</table>

1 See Section 7.141 of U.B.C. Standard 7-1 for guidance on restrained and unrestrained assemblies.

### TABLE 7-7-C-F—MINIMUM COVER TO MAIN REINFORCING BARS FOR REINFORCED CONCRETE BEAMS (APPLICABLE TO ALL TYPES OF STRUCTURAL CONCRETE)

<table>
<thead>
<tr>
<th>RESTRAINED OR UNRESTRAINED</th>
<th>BEAM WIDTH² (inches)</th>
<th>COVER THICKNESS (INCHES) FOR FIRE-RESISTANCE RATING OF</th>
<th>1 Hr.</th>
<th>1 1/2 Hr.</th>
<th>2 Hr.</th>
<th>3 Hr.</th>
<th>4 Hr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>REINFORCED</td>
<td></td>
<td>× 25.4 for mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unrestrained</td>
<td>5</td>
<td>3/4</td>
<td>3/4</td>
<td>11/4</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Unrestrained</td>
<td>≥ 10</td>
<td>3/4</td>
<td>3/4</td>
<td>11/4</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

1 See Section 7.141 of U.B.C. Standard 7-1 for guidance on restrained and unrestrained assemblies. Tabulated values for restrained assemblies apply to beams spaced more than 4 feet (1219 mm) on centers; for restrained beams spaced 4 feet (1219 mm) or less on centers, minimum cover of 3/4 inch (19.1 mm) is adequate for ratings of four hours or less.

2 For beam widths between the tabulated values, the minimum cover thickness can be determined by direct interpolation.
### TABLE 7-7-C-G—MINIMUM COVER FOR PRESTRESSED CONCRETE BEAMS

<table>
<thead>
<tr>
<th>RESTRAINED OR UNRESTRAINED</th>
<th>CONCRETE AGGREGATE TYPE</th>
<th>BEAM WIDTH(^4) (INCHES)</th>
<th>COVER THICKNESS(^5) (INCHES) FOR FIRE-RESISTANCE RATING OF 1 Hr.</th>
<th>1(\frac{1}{2}) Hr.</th>
<th>2 Hr.</th>
<th>3 Hr.</th>
<th>4 Hr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restrained</td>
<td>Carb or Sil</td>
<td>8</td>
<td>(1\frac{1}{2})</td>
<td>(1\frac{1}{2})</td>
<td>(1\frac{1}{2})</td>
<td>(1\frac{3}{4})</td>
<td>(2\frac{1}{2})</td>
</tr>
<tr>
<td>Restrained</td>
<td>Carb or Sil</td>
<td>(\geq 12)</td>
<td>(1\frac{1}{2})</td>
<td>(1\frac{1}{2})</td>
<td>(1\frac{1}{2})</td>
<td>(1\frac{3}{4})</td>
<td>(2\frac{1}{2})</td>
</tr>
<tr>
<td>Restrained</td>
<td>Sand LW</td>
<td>8</td>
<td>(1\frac{1}{2})</td>
<td>(1\frac{1}{2})</td>
<td>(1\frac{1}{2})</td>
<td>(1\frac{3}{4})</td>
<td>(2\frac{1}{2})</td>
</tr>
<tr>
<td>Restrained</td>
<td>Sand LW</td>
<td>(\geq 12)</td>
<td>(1\frac{1}{2})</td>
<td>(1\frac{1}{2})</td>
<td>(1\frac{1}{2})</td>
<td>(1\frac{3}{4})</td>
<td>(2\frac{1}{2})</td>
</tr>
<tr>
<td>Unrestrained</td>
<td>Carb or Sil</td>
<td>8</td>
<td>(1\frac{1}{2})</td>
<td>(1\frac{3}{4})</td>
<td>(2\frac{1}{2})</td>
<td>(5)</td>
<td></td>
</tr>
<tr>
<td>Unrestrained</td>
<td>Carb or Sil</td>
<td>(\geq 12)</td>
<td>(1\frac{1}{2})</td>
<td>(1\frac{3}{4})</td>
<td>(2\frac{1}{2})</td>
<td>(5)</td>
<td></td>
</tr>
<tr>
<td>Unrestrained</td>
<td>Sand LW</td>
<td>8</td>
<td>(1\frac{1}{2})</td>
<td>(1\frac{1}{2})</td>
<td>(2)</td>
<td>(3\frac{1}{4})</td>
<td></td>
</tr>
<tr>
<td>Unrestrained</td>
<td>Sand LW</td>
<td>(\geq 12)</td>
<td>(1\frac{1}{2})</td>
<td>(1\frac{1}{2})</td>
<td>(2)</td>
<td>(3\frac{1}{4})</td>
<td></td>
</tr>
</tbody>
</table>

1 This table shall not apply to I-shaped beams.

2 See Section 7.141 of U.B.C. Standard 7-1 for guidance on restrained and unrestrained assemblies. Tabulated values for restrained assemblies apply to beams spaced more than 4 feet on center.

3 Carb = carbonate aggregate concrete; Sil = siliceous aggregate concrete; Sand LW = sand lightweight concrete.

4 For beam widths between 8 inches and 12 inches (203 mm and 305 mm), minimum cover thickness can be determined by direct interpolation.

5 The cover for an individual tendon is the minimum thickness of concrete between the surface of the tendon and the fire-exposed surface of the beam, except that the ungrouted ducts the assumed cover thickness is the minimum thickness of concrete between the surface of the duct and the surface of the beam. For beams in which several tendons are used, the cover is assumed to be the average of the minimum cover of the individual tendons. The cover for any individual tendon must not be less than one half of the value given in this table or less than 1 inch (25 mm).

6 Not practical for 8-inch-wide (203 mm) beam, but shown for purposes of interpolation.

### TABLE 7-7-C-H—MINIMUM SIZES OF CONCRETE COLUMNS

<table>
<thead>
<tr>
<th>TYPE OF CONCRETE</th>
<th>MINIMUM COLUMN DIMENSION (INCHES) FOR FIRE-RESISTANCE RATING OF 1 Hr.</th>
<th>1(\frac{1}{2}) Hr.</th>
<th>2 Hr.</th>
<th>3 Hr.</th>
<th>4 Hr.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\times 25.4 \text{ for mm})</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silicous</td>
<td>8</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>Carbonate</td>
<td>8</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>Sand-lightweight</td>
<td>8</td>
<td>8</td>
<td>9</td>
<td>10.5</td>
<td>12</td>
</tr>
</tbody>
</table>
Thickness of Inside Wythe of Carbonate or Siliceous Aggregate Concrete, in. ($\times 25.4$ for mm)

Thickness of Inside Wythe of Sand-Lightweight Concrete, in. ($\times 25.4$ for mm)

FIGURE 7-7-C-1—FIRE-RESISTANCE RATINGS OF TWO-WYTHE CONCRETE WALLS CONSISTING OF WYTHES OF DIFFERENT TYPES OF CONCRETE
FIGURE 7-7-C-2—MINIMUM THICKNESS OF CERAMIC FIBER BLANKET REQUIRED BETWEEN PRECAST CONCRETE WALL PANELS TO PROVIDE FIRE-RESISTANCE RATINGS OF ONE HOUR TO FOUR HOURS
Symbols: Carb = carbonate aggregate concrete; Sil = siliceous aggregate concrete

FIGURE 7-7-C-3A—FIRE-RESISTANCE RATINGS FOR TWO-COURSE CONCRETE FLOORS
Symbols: Carb = carbonate aggregate concrete; Sil = siliceous aggregate concrete; SLW = sand-lightweight concrete

(1 in. = 25.4 mm)

(a) CELLULAR CONCRETE

(b) PERLITE CONCRETE

(c) VERMICULITE CONCRETE

FIGURE 7-7-C-3B—FIRE-RESISTANCE RATINGS FOR CONCRETE ROOF ASSEMBLIES

(Continued)
FIGURE 7-7-C-3B—FIRE-RESISTANCE RATINGS FOR CONCRETE ROOF ASSEMBLIES—(Continued)

(d) STANDARD 3-PLY BUILT-UP ROOFING

THICKNESS OF CONCRETE BASE SLAB, IN. (x 25.4 for mm)

(e) STANDARD 3-PLY BUILT-UP ROOFING

THICKNESS OF CONCRETE BASE SLAB, IN. (x 25.4 for mm)
Part III—Methods for Calculating the Fire-resistance Rating of Concrete Masonry

SECTION 7.711 — SCOPE
This part of this standard contains procedures by which the fire-resistance rating of concrete masonry assemblies can be established by calculations. It is applicable to concrete masonry walls, concrete masonry columns, concrete masonry lintels and steel columns protected with concrete masonry.

SECTION 7.712 — MATERIAL REQUIREMENTS
Materials used in accordance with this standard shall comply with the following:

7.712.1 Concrete Masonry Units.
   U.B.C. Standard 21-3, Standard Specification for Concrete Building Brick
   U.B.C. Standard 21-4, Standard Specification for Hollow and Solid Load-bearing Concrete Masonry Units

7.712.2 Mortar.
   U.B.C. Standard 21-15, Standard Specifications for Mortar for Unit Masonry and Reinforced Masonry Other Than Gypsum

7.712.3 Grout.

7.712.4 Material for Filling Cells of Units.
   Sand or slag having a maximum particle size of \( \frac{3}{8} \) inch (9.5 mm).
   ASTM C 33-86, Standard Specification for Aggregate
   ASTM C 144-89, Standard Specification for Aggregate for Masonry Mortar
   ASTM C 330-85 and C 332-83, Standard Specifications for Lightweight Aggregates for Structural and Insulating Concrete
   ASTM C 549-81, Perlite Loose-fill Insulation (Type II)
   ASTM C 516-80, Vermiculite Loose-fill Insulation (Type I and Type II)

7.712.5 Material for Surface Coverings.
   ASTM C 28-76a, Gypsum Plasters
   ASTM C 36-76a, Gypsum Wallboard

SECTION 7.713 — CONCRETE MASONRY WALLS

7.713.1 General. The fire-resistance rating of concrete masonry walls shall be determined in accordance with this section. The wall shall have the minimum equivalent thickness for the desired fire-resistive rating as specified in Table 7-7-M-A. The equivalent thickness of the wall may be increased by adding finishes in accordance with Section 7.713.3 and may be modified by combining more than one type of aggregate in the manufacture of the concrete masonry units in accordance with Section 7.713.4.
7.713.2 Determining Equivalent Thickness. Equivalent thickness of concrete masonry walls shall be determined in accordance with Formula (13-1) for units composed of a single aggregate and by Formula (13-2) for units composed of combined aggregates. When a plaster or gypsum wallboard finish material is applied over an entire face of a concrete masonry wall, the equivalent thickness of the wall assembly shall be determined in accordance with Formula (13-1). Equivalent thickness of units filled with grout or 100 percent solid units shall be the specified thickness.

\[ T_E = \frac{V}{(L \times H)} + T_F \]  

(13-1)

WHERE:
- \( H \) = height of block or brick using specified dimensions as defined in Chapter 21, inches (mm).
- \( L \) = length of block or brick using specified dimensions as defined in Chapter 21, inches (mm).
- \( T_E \) = equivalent thickness of wall, inches (mm).
- \( T_F \) = equivalent thickness of finishes in Table 7-7-M-B.
- \( V \) = net volume of unit, cubic inch (mm³) (U.B.C. Standard 21-6).

7.713.3 Finishes. When a plaster or gypsum wallboard finish is applied over an entire face of the concrete masonry wall, the equivalent thickness of finish shall be determined in accordance with Table 7-7-M-B. The calculated equivalent thickness of the finish can then be added to the calculated equivalent thickness of the concrete masonry wall to determine the total equivalent thickness in accordance with Formula (13-1).

7.713.4 Minimum Required Equivalent Thickness for a Combination of Aggregates. The fire-resistance rating of concrete masonry units composed of a combination of aggregate types shall be based on equivalent thickness values determined as follows:

Determine equivalent thickness values for each tabular column of the desired fire-resistance rating in Table 7-7-M-A by interpolating between equivalent thickness values for aggregate types in proportion to the percentage by volume of each aggregate used in accordance with Formula (13-2).

\[ T_R = T_1 \times V_1 + T_2 \times V_2 + \ldots + T_n \times V_n \]  

(13-2)

WHERE:
- \( T_1, T_2, \ldots, T_n \) = equivalent thickness for each aggregate Type 1, 2, \ldots, n, respectively, used as indicated in Table 7-7-M-A for the desired fire-resistance rating.
- \( T_R \) = minimum required equivalent thickness corresponding to the desired fire-resistance rating as listed in Table 7-7-M-A for concrete masonry units manufactured with a particular combination of aggregate types.
- \( V_1, V_2, \ldots, V_n \) = percentage by volume of each aggregate Type 1, 2, \ldots, n, respectively, which is used in the manufacture of the concrete masonry unit.

7.713.5 Fire-resistance Increase. When the calculated fire-resistance rating of the concrete masonry wall without fill materials or finishes is not less than two hours, the fire-resistance rating may be increased to four hours provided the cells are completely filled with any of the materials specified in the Building Code and the minimum specified thickness of the concrete masonry units is \( \frac{77}{8} \) inches (193.7 mm) as determined in accordance with Chapter 21 of the Building Code.

7.713.6 Framing into Wall. Combustible members framed into a wall shall be protected at their ends by not less than one half the required equivalent thickness of such wall.

7.713.7 Multiwythe. The fire-resistance rating of multiwythe walls, such as illustrated in Figure 7-7-M-1, shall be based on the fire-resistance rating of each wythe and the continuous air space between each wythe in accordance with Formula (13-3).
WHERE:
\[ A_1, A_2, \ldots, A_n = 0.30, \text{ factor for each continuous air space (1, 2, \ldots, n, respectively) having a depth of } \frac{1}{2}\text{ inch or more between wythes.} \]
\[ R_1, R_2, \ldots, R_n = \text{ fire-resistance rating of wythe 1, 2, \ldots, n (hours), respectively.} \]

SECTION 7.714 — CONTROL JOINTS

7.714.1 Design. Control joints installed in fire-resistance-rated concrete masonry walls may be designed in accordance with this section to maintain the fire-resistance rating of the wall in which they are installed.

7.714.2 Materials. The control joints shall be sealed with approved caulk, grout or gaskets in accordance with the details provided in Figure 7-7-M-2.

SECTION 7.715 — STEEL COLUMNS PROTECTED BY CONCRETE MASONRY

7.715.1 The fire-resistance rating of steel columns illustrated in Figure 7-7-S-7, protected by concrete masonry shall be determined in accordance with Part 1 of this standard.

SECTION 7.716 — CONCRETE MASONRY COLUMNS

7.716.1 Concrete masonry columns shall be designed and reinforced in accordance with the requirements of this code. The fire-resistance rating of concrete masonry columns shall be determined based on the least dimension of the column faces in accordance with the requirements of Table 7-7-M-C.

SECTION 7.717 — CONCRETE MASONRY LINTELS

7.717.1 The fire-resistance rating of concrete lintels shall be determined based on the nominal thickness of the lintel and the minimum thickness of concrete or concrete masonry or any combination thereof, covering the reinforcing steel as determined in accordance with Table 7-7-M-D.

### Table 7-7-M-A—FIRE-RESISTANCE RATING OF CONCRETE MASONRY WALLS

<table>
<thead>
<tr>
<th>AGGREGATE TYPE</th>
<th>MINIMUM REQUIRED EQUIVALENT THICKNESS, ( T_{eq} ) (Inches) ( \times 25.4 \text{ for mm} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4 Hours</td>
</tr>
<tr>
<td>Calcareous or siliceous gravel</td>
<td>6.2</td>
</tr>
<tr>
<td>Limestone, cinders or slag</td>
<td>5.9</td>
</tr>
<tr>
<td>Expanded clay, shale or slate</td>
<td>5.1</td>
</tr>
<tr>
<td>Expanded slag or pumice</td>
<td>4.7</td>
</tr>
</tbody>
</table>

Note: The minimum required equivalent thickness of concrete masonry units made with a combination of aggregates shall be determined by linear interpolation of the values shown for each aggregate type in accordance with Formula (13-2) and Section 7.713.4.
### TABLE 7-7-M-B—EQUIVALENT THICKNESS FOR EACH INCH OF FINISH THICKNESS (inches)

<table>
<thead>
<tr>
<th>FINISH</th>
<th>AGGREGATE TYPE</th>
<th>Siliceous or Calcareous Gravel</th>
<th>Limestone or Expanded Shale, Expanded Slag or Clay or Slate</th>
<th>Expanded Slag or Pumice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portland cement-sand plaster</td>
<td></td>
<td>1.00</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Gypsum-sand plaster or gypsum wallboard</td>
<td></td>
<td>1.25</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Gypsum-vermiculite or perlite plaster</td>
<td></td>
<td>1.75</td>
<td>1.50</td>
<td>1.25</td>
</tr>
</tbody>
</table>

### TABLE 7-7-M-C—MINIMUM SIZES OF CONCRETE MASONRY COLUMNS

<table>
<thead>
<tr>
<th>MINIMUM COLUMN DIMENSIONS, INCHES, FOR FIRE-RESISTANCE RATING OF:</th>
<th>1 Hour</th>
<th>2 Hours</th>
<th>3 Hours</th>
<th>4 Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>x 25.4 for mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>10</td>
<td>12</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 7-7-M-D—MINIMUM COVER ON MAIN REINFORCING BARS FOR REINFORCED CONCRETE MASONRY LINTELS

<table>
<thead>
<tr>
<th>LINTEL THICKNESS (inches) (Nominal)</th>
<th>COVER THICKNESS (inches) FOR FIRE-RESISTANCE RATING OF:</th>
</tr>
</thead>
<tbody>
<tr>
<td>x 25.4 for mm</td>
<td>1 Hour</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>10 or more</td>
<td>1</td>
</tr>
</tbody>
</table>

Wythe \( (R_1) \)

Continuous Air Space \[ 1\frac{1}{2}" \text{ (13 mm) or greater} \] \( A_1 \)

\[ R_1 = \text{Fire-resistance rating of wythe 1} \]
\[ R_2 = \text{Fire-resistance rating of wythe 2} \]
\[ A_1 = \text{Fire-resistance rating factor of air space} \]

FIGURE 7-7-M-1—MULTI-WYTHE WALL
1994 UNIFORM BUILDING CODE

For ratings up to and including 4 hours

Caulk
Grout Key
Asphalt Bond Breaker or Asphalt Coating

Mortar [min. depth \( \frac{1}{2}\)" (13 mm)]

For ratings up to and including 4 hours

Caulk
Mortar [min. depth \( \frac{1}{2}\)" (13 mm)]

\( \frac{1}{2}\)" (13 mm) Maximum control joint width

For ratings up to and including 4 hours

Caulk
Joint backing
Ceramic fiber blanket

\( \frac{1}{2}\)" (13 mm) Maximum control joint width

For ratings up to and including 4 hours

FIGURE 7-7-M-2—TYPES OF CONTROL JOINTS FOR FIRE-RESISTANCE-RATED CONCRETE MASONRY WALLS
For ratings up to and including 2 hours

FIGURE 7-7-M-2—TYPES OF CONTROL JOINTS FOR
FIRE-RESISTANCE-RATED CONCRETE MASONRY WALLS—(Continued)
Part IV—Methods of Calculating the Fire-resistance Rating of Clay Masonry

SECTION 7.718 — SCOPE

This standard provides methods for calculating the fire-resistance-rating periods of clay and shale masonry. This standard is applicable to clay and tile masonry walls.

SECTION 7.719 — GENERAL

Clay masonry construction shall comply with the applicable requirements of this code.

SECTION 7.720 — CLAY MASONRY WALLS

7.720.1 General. The rated fire-resistant period of clay masonry walls shall be determined in accordance with this section. The fire-resistance periods of clay masonry units shall be determined from Tables 7-7-B-A, 7-7-B-B and 7-7-B-C. When sanded gypsum plaster is applied over the entire face of the clay masonry wall, the rated fire-resistant period shall be determined in accordance with Section 7.720.2. When continuous air spaces separate multiwythe walls, the rated fire-resistant period shall be determined in accordance with Section 7.720.4. The rated fire-resistant period of multiwythe walls shall be determined in accordance with Section 7.720.4. Hollow clay masonry walls shall have a minimum equivalent thickness for the desired fire-resistant rating as specified in Section 7.720.5.

7.720.2 Plaster Finishes. The fire-resistant rating period of sanded gypsum plastered clay masonry walls shall be based in accordance with Formula (20-1).

\[
R = (R_n^{0.59} + P_l)^{1.7}
\]  

(20-1)

WHERE:

- \( P_l \) = thickness coefficient of sanded gypsum plaster.
- \( R \) = fire-resistant rating of the assembly, hours.
- \( R_n \) = fire-resistant period of wythe, hours.

Coefficients for thickness of sanded gypsum plaster shall be selected from Table 7-7-B-D, based on the actual thickness of plaster applied to the clay masonry wall and whether one or two sides of the wall are plastered.

7.720.3 Continuous Air Spaces. The fire-resistant rating period of multiwythe clay masonry walls separated by a continuous air space between each wythe shall be based in accordance with Formula (20-2).

\[
R = (R_1^{0.59} + R_2^{0.59} + \ldots + R_n^{0.59} + A_s)^{1.7}
\]  

(20-2)

WHERE:

- \( A_s = 0.30 \) factor for each continuous air space having a depth of \( 1/2 \) inch to \( 3 1/2 \) inches (12.7 mm to 88.9 mm) between wythes.
- \( R \) = fire-resistant rating of the assembly, hours.
- \( R_1, R_2, R_n \) = fire-resistant period of each individual wythe, hours.

7.720.4 Multiwythe Walls. The fire-resistant rating period of multiwythe walls consisting of two or more dissimilar wythes shall be based on the fire-resistant periods of each wythe and shall be based in accordance with Formula (20-3).

\[
R = (R_1^{0.59} + R_2^{0.59} + R_n^{0.59})^{1.7}
\]  

(20-3)
WHERE:

\[ R = \text{fire-resistive rating of the assembly, hours.} \]
\[ R_1, R_2, \ldots, R_n = \text{fire-resistive period of each individual wythe, hours.} \]

For walls which consist of two or more wythes of dissimilar materials (concrete or concrete masonry units) in combination with clay masonry units, the fire-resistive period of the dissimilar materials shall be based in accordance with Table 7-7-C-B for concrete, Table 7-7-M-A for concrete masonry units or Table 7-7-B-A, 7-7-B-B or 7-7-B-C for clay masonry units.

### 7.720.5 Hollow Clay Masonry Walls

The rated fire-resistive period of hollow clay masonry units shall be based on the equivalent thickness in accordance with Formula (20-4).

\[
T_E = \frac{V_n}{L \times H}
\]

WHERE:

\[ H = \text{height of brick using the specified dimensions as defined in Chapter 21 of the Building Code, inches (mm).} \]
\[ L = \text{length of brick using the specified dimensions as defined in Chapter 21 of the Building Code, inches (mm).} \]
\[ T_E = \text{equivalent thickness of wall, inches (mm).} \]
\[ V_n = \text{net volume of unit, cubic inches (mm}^3). \]

The fire-resistive rating for hollow clay brick shall be determined from Table 7-7-B-C based on the equivalent thickness. The fire-resistive rating determined from Table 7-7-B-C may be used in the calculated fire-resistance procedure of Sections 7.720.1, 7.720.2, 7.720.3 and 7.720.4.
<table>
<thead>
<tr>
<th>WALL OR PARTITION ASSEMBLY, MINIMUM NOMINAL THICKNESS</th>
<th>FIRE-RESISTIVE PERIOD (HOURS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;= 25.4 for mm x 0.993 for m²</td>
<td></td>
</tr>
<tr>
<td>CLAY OR SHALE, SOLID</td>
<td></td>
</tr>
<tr>
<td>4-inch brick</td>
<td>1.25</td>
</tr>
<tr>
<td>6-inch brick</td>
<td>2.55</td>
</tr>
<tr>
<td>8-inch brick</td>
<td>4.00</td>
</tr>
<tr>
<td>CLAY OR SHALE, HOLLOW</td>
<td></td>
</tr>
<tr>
<td>8-inch brick, 71% solid</td>
<td>3.00</td>
</tr>
<tr>
<td>12-inch brick, 64% solid</td>
<td>4.00</td>
</tr>
<tr>
<td>8-inch brick, 60% solid, cells filled with loose fill insulation</td>
<td>4.00</td>
</tr>
<tr>
<td>CLAY OR SHALE, ROLOK</td>
<td></td>
</tr>
<tr>
<td>8-inch Hollow Rolok</td>
<td>2.50</td>
</tr>
<tr>
<td>12-inch Hollow Rolok</td>
<td>4.00</td>
</tr>
<tr>
<td>CAVITY WALLS, CLAY OR SHALE</td>
<td></td>
</tr>
<tr>
<td>8-inch wall; two 3-inch (actual) brick wythes separated by 2-inch air space; masonry joint reinforcement spaced 16 inches on center vertically</td>
<td>3.00</td>
</tr>
<tr>
<td>10-inch wall; two nominal 4-inch wythes separated by 2-inch air space; 1/4-inch metal ties for each 3 square feet of wall area</td>
<td>4.00</td>
</tr>
<tr>
<td>CLAY OR SHALE BRICK, METAL FURRING CHANNELS</td>
<td></td>
</tr>
<tr>
<td>5-inch wall, 4-inch nominal brick (75% solid) backed with a hat-shaped metal furring channel 1/4 inch thick formed from 0.021 inch sheet metal attached to brick wall on 24 inch centers with approved fasteners; and 1/2-inch Type X gypsum board attached to the metal furring strips with 1-inch-long Type S screws spaced 8 inches on center</td>
<td>2.00</td>
</tr>
<tr>
<td>HOLLOW CLAY TILE, BRICK FACING</td>
<td></td>
</tr>
<tr>
<td>8-inch wall; 4-inch units (40% solid)² plus 4-inch solid brick</td>
<td>3.50</td>
</tr>
<tr>
<td>12-inch wall; 8-inch units (40% solid)² plus 4-inch solid brick</td>
<td>4.00</td>
</tr>
</tbody>
</table>

1Units shall comply with the requirements of U.B.C. Standard 21-1 or ASTM C 126.
2Units shall comply with the requirements of ASTM C 34.
TABLE 7-7-B-B—FIRE-RESISTIVE PERIODS FOR NONLOAD-BEARING AND LOAD-BEARING CLAY TILE MASONRY WALLS¹

<table>
<thead>
<tr>
<th>WALL OR PARTITION ASSEMBLY, MINIMUM NOMINAL THICKNESS</th>
<th>FIRE-RESISTIVE PERIOD (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>× 25.4 for mm</td>
<td></td>
</tr>
</tbody>
</table>

HOLLOW CLAY TILE

- 8-inch unit; 2 cells in wall thickness, 40% solid
- 8-inch unit; 2 cells in wall thickness, 46% solid
- 8-inch unit; 2 cells in wall thickness, 49% solid
- 8-inch unit; 3 or 4 cells in wall thickness, 40% solid
- 8-inch unit; 3 or 4 cells in wall thickness, 43% solid
- 12-inch unit; 3 or 4 cells in wall thickness, 48% solid
- 8-inch unit; 3 or 4 cells in wall thickness, 53% solid

CLAY TILE

- 4-inch unit; 1 cell in wall thickness, 40% solid²,³
- 6-inch unit; 1 cell in wall thickness, 30% solid²,³
- 6-inch unit; 2 cell in wall thickness, 45% solid⁴
- 4-inch unit; 1 cell in wall thickness, 40% solid¹⁴
- 6-inch unit; 1 cell in wall thickness, 40% solid¹⁴

HOLLOW STRUCTURAL CLAY TILE

- 8-inch unit; 2 cells in wall thickness, 40% solid
- 8-inch unit; 2 cells in wall thickness, 49% solid
- 8-inch unit; 3 or 4 cells in wall thickness, 53% solid
- 8-inch unit; 3 cells in wall thickness, 46% solid
- 12-inch unit; 3 cells in wall thickness, 49% solid
- 12-inch wall; 2 units with 3 cells in wall thickness, 40% solid
- 12-inch wall; 2 units with 3 or 4 cells in wall thickness, 45% solid
- 12-inch wall; 2 units with 3 or 4 cells in wall thickness, 53% solid
- 16-inch wall; 2 or 3 units with 4 or 5 cells in wall thickness, 40% solid

¹Units shall comply with the requirements of ASTM C 34, C 56, C 212 or C 530.
²Ratings are for dense hard-burned clay or shale tile.
³Cells filled with tile, stone, slag, cinders or sand mixed with mortar.
⁴Ratings are for medium-burned clay tile.

TABLE 7-7-B-C—MINIMUM EQUIVALENT THICKNESS¹ (inches) OF LOAD-BEARING OR NONLOAD-BEARING HOLLOW CLAY MASONRY WALLS²,³,⁴

<table>
<thead>
<tr>
<th>TYPE OF MATERIAL</th>
<th>FIRE-RESISTIVE PERIOD (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>× 25.4 for mm</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Brick of clay or shale, unfilled</td>
<td>2.3</td>
</tr>
<tr>
<td>Brick of clay or shale, grouted or filled with perlite, vermiculite or expanded shale aggregate</td>
<td>3.0</td>
</tr>
</tbody>
</table>

¹Equivalent thickness as determined for U.B.C. Standard 7-7, Section 7.720.5.
²Values between those shown can be determined by direct interpolation.
³Where combustible members are framed in the wall, the thickness of solid material between the end of each member and the opposite face of the wall, or between members set in from opposite sides, shall not be less than 93 percent of the thickness shown in the table.
⁴Units shall comply with the requirements of U.B.C. Standard 21-1, Section 21.107.
TABLE 7-7-B-D—COEFFICIENTS FOR PLASTER (PI)\textsuperscript{1}

<table>
<thead>
<tr>
<th>THICKNESS OF PLASTER (inch)</th>
<th>ONE-SIDE</th>
<th>TWO-SIDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\times 25.4) for mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\frac{1}{5})</td>
<td>0.30</td>
<td>0.60</td>
</tr>
<tr>
<td>(\frac{3}{8})</td>
<td>0.37</td>
<td>0.75</td>
</tr>
<tr>
<td>(\frac{1}{4})</td>
<td>0.45</td>
<td>0.90</td>
</tr>
</tbody>
</table>

\textsuperscript{1}Values listed are for 1.3 sanded gypsum plaster.

Part V—Methods for Calculating One-hour Fire-resistive Ratings of Wood-framed Walls, Floors and Roofs

See Section 703.3, Uniform Building Code

SECTION 7.721 — SCOPE
This part establishes acceptable calculation methods for determining the fire-resistive classification of structural parts, walls and partitions and floor-ceiling or roof-ceiling assemblies. It is intended for use in cases where fire test results specified in U.B.C. Standard 7-1 are not available and the specific assembly of materials is not among those listed in Tables 7-A, 7-B and 7-C.

Wood-framed Walls, Floors and Roofs

SECTION 7.722 — GENERAL
These procedures apply to both load-bearing and nonbearing construction. The calculated fire-resistive ratings shall only apply to one-hour construction. When the wall construction is nonsymmetrical, the provisions of Section 709.5 of the Building Code apply.

SECTION 7.723 — PROCEDURES
The fire-resistive rating of wood-framed construction is equal to the sum of the time assigned to the membrane on the fire-exposed side (Table 7-7-W-A), the time assigned to the framing members (Table 7-7-W-C), and the time assigned for other protective measures, such as insulation (Table 7-7-W-D). The membrane on the unexposed side shall not be included in determining the fire resistance of the assembly. When more than one membrane is installed on the wall surface exposed to fire, ratings of each membrane may be added.

SECTION 7.724 — WALLS AND PARTITIONS
Table 7-7-W-A lists the time of fire resistance accredited to the materials used on the fire-exposed side of walls and partitions.

SECTION 7.725 — ROOF-CEILING AND FLOOR-CEILING ASSEMBLIES
Table 7-7-W-B specifies the various acceptable membranes and limits the structural frame to wood joists installed on no more than 16-inch (406 mm) spacings. Ratings for roof-ceiling and floor-ceiling assemblies are based on the membranes listed in Table 7-7-W-A being installed on the fire-exposed side in combination with membranes listed in Table 7-7-W-B being installed on the side not exposed to furnace temperatures.

SECTION 7.726 — MEMBRANE FASTENING
Fastening the membrane to the supporting construction shall be as specified in Tables 7-B, 7-C and 23-I-Q of the Building Code for corresponding membrane materials.
### Table 7-7-W-A—Time Assigned to Wallboard Membranes\(^1,2,4\)

<table>
<thead>
<tr>
<th>Description of Finish</th>
<th>Time, Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\frac{3}{8})-inch (9.5 mm) Exterior-glue plywood</td>
<td>5</td>
</tr>
<tr>
<td>(\frac{1}{2})-inch (12.7 mm) Exterior-glue plywood</td>
<td>10</td>
</tr>
<tr>
<td>(\frac{5}{8})-inch (15.9 mm) Exterior-glue plywood</td>
<td>15</td>
</tr>
<tr>
<td>(\frac{3}{8})-inch (9.5 mm) gypsum wallboard</td>
<td>10(^3)</td>
</tr>
<tr>
<td>(\frac{1}{2})-inch (12.7 mm) gypsum wallboard</td>
<td>15</td>
</tr>
<tr>
<td>(\frac{5}{8})-inch (15.9 mm) gypsum wallboard</td>
<td>30</td>
</tr>
<tr>
<td>(\frac{1}{2})-inch (12.7 mm) Type X gypsum wallboard</td>
<td>25</td>
</tr>
<tr>
<td>(\frac{5}{8})-inch (15.9 mm) Type X gypsum wallboard</td>
<td>40</td>
</tr>
<tr>
<td>Double (\frac{3}{8})-inch (9.5 mm) gypsum wallboard</td>
<td>25</td>
</tr>
<tr>
<td>(\frac{1}{2}) + (\frac{3}{8})-inch (12.7 + 9.5 mm) gypsum wallboard</td>
<td>35</td>
</tr>
<tr>
<td>Double (\frac{1}{2})-inch (12.7 mm) gypsum wallboard</td>
<td>40</td>
</tr>
</tbody>
</table>

\(^1\) All wall panels shall be installed with the long dimension parallel to framing members or shall be backed with at least 2-inch-thick (51 mm) framing and gypsum panels.

\(^2\) These values apply only when framing members are spaced a maximum of 16 inches (406 mm) on center.

\(^3\) Membrane rating combined with stud rating is 25.

\(^4\) Plywood membranes shall be limited to nonbearing applications. Other membranes shall be limited to the design stress for studs shown by Footnote 19 to Table 7-B.

### Table 7-7-W-B—Flooring or Roofing Over Wood Framing

<table>
<thead>
<tr>
<th>Assembly</th>
<th>Structural Members</th>
<th>Subfloor or Roof Deck</th>
<th>Finish Flooring or Roofing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor</td>
<td>Wood joists</td>
<td>(\frac{1}{2})-inch (12.7 mm) plywood or (\frac{1}{2})-inch (17.5 mm) tongue-and-groove softwood</td>
<td>Hard or softwood flooring on building paper. Resilient flooring, parquet floor, felted-synthetic-fiber floor coverings, carpeting or ceramic tile on (\frac{3}{8})-inch-thick (15.9 mm) panel-type underlay. Ceramic tile on (\frac{1}{2})-inch (32 mm) mortar bed.</td>
</tr>
<tr>
<td>Roof</td>
<td>Wood joists</td>
<td>(\frac{1}{2})-inch (12.7 mm) plywood or (\frac{1}{2})-inch (17.5 mm) tongue-and-groove softwood</td>
<td>Finish roofing material with or without insulation. See Section 710.1 for the addition of insulation.</td>
</tr>
</tbody>
</table>

### Table 7-7-W-C—Time Assigned for Contribution of Wood Frame\(^1,2\)

<table>
<thead>
<tr>
<th>Description of Frame</th>
<th>Time Assigned to Frame, Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood studs 16 inches (406 mm) on center</td>
<td>20</td>
</tr>
<tr>
<td>Wood floor and roof joists 16 inches (406 mm) on center</td>
<td>10</td>
</tr>
</tbody>
</table>

\(^1\) This table does not apply to studs or joists spaced more than 16 inches (406 mm) on center.

\(^2\) All studs shall be nominal 2 inches by 4 inches (51 mm by 102 mm) and all joists shall have a nominal thickness of at least 2 inches (51 mm).

### Table 7-7-W-D—Time Assigned for Additional Protection

<table>
<thead>
<tr>
<th>Description of Additional Protection</th>
<th>Fire Resistance, Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add to the fire-resistance rating of wood stud walls if the spaces between the studs are filled with rock-wool batts weighing not less than 1.0 lb./ft.(^2) (4.9 kg/m(^2)) ([3.3 \text{ lb. ft.}^2 (52.8 \text{ kg/m}^2)] ) or glass-wool batts at 0.6 lb./ft.(^2) (2.9 kg/m(^2)) ([2.0 \text{ lb. ft.}^2 (32 \text{ kg/m}^2)] ) wall surface.</td>
<td>15</td>
</tr>
</tbody>
</table>
Part VI—Method for Design of One-hour Fire-resistive Exposed Wood Member [6-inch (152 Mm) Nominal or Greater]

See Section 703.3, Uniform Building Code

SECTION 7.727 — SCOPE

Part IV of this standard applies to the design of one-hour fire-resistive exposed solid-sawn and glued-laminated timbers described in Chapter 23. The timbers shall have a minimum nominal thickness of 6 inches (152 mm).

This design method for one-hour fire-resistive exposed wood members is an accepted method of determining fire-resistive construction as specified in Section 703.3 of the Building Code.

SECTION 7.728 — DESIGN PROCEDURES

Design procedures, loads and allowable design stresses shall be as specified in Chapters 16 and 23. In addition, the column or beam shall be analyzed to determine the size required to sustain the design load at the end of a one-hour fire. This design procedure is specified in Section 7.729.

SECTION 7.729 — CALCULATION OF TIMBER SIZE

The following procedure shall be used to establish the fire rating of columns or beams and to determine the size required to be treated as one hour.

The fire-resistance rating, in minutes, of timber beams and columns with a minimum nominal dimension of 6 inches (152 mm) is equal to:

Beams—
1. $2.54 \times Z_b \left[ 4 - 2 \left( \frac{b}{d} \right) \right]$ (For SI: $0.10 \times Z_b \left[ 4 - 2 \left( \frac{b}{d} \right) \right]$) for beams which may be exposed to fire on four sides.
2. $2.54 \times Z_b \left[ 4 - \left( \frac{b}{d} \right) \right]$ (For SI: $0.10 \times Z_b \left[ 4 - \left( \frac{b}{d} \right) \right]$) for beams which may be exposed on three sides.

Columns—
3. $2.54 \times Z_d \left[ 3 - \left( \frac{d}{b} \right) \right]$ (For SI: $0.10 \times Z_d \left[ 3 - \left( \frac{d}{b} \right) \right]$) for columns which may be exposed to fire on four sides.
4. $2.54 \times Z_d \left[ 4 - \left( \frac{d}{2b} \right) \right]$ (For SI: $0.10 \times Z_d \left[ 4 - \left( \frac{d}{2b} \right) \right]$) for columns which may be exposed on three sides. (Applies only when the smaller side of the column is the exposed face.)

WHERE:
- $b$ = the breadth (width) of a beam or larger side of a column before exposure to fire, inches (mm).
- $d$ = the depth of a beam or smaller side of a column before exposure to fire, inches (mm).
- $K_e$ = the effective length factor (Figure 7-7-2).
- $l$ = the unsupported length of column, inches (mm) (Figure 7-7-1).
- $Z$ = the load factor (Figure 7-7-1).

If a column is recessed into a wall and protected, its minimum dimension need not be calculated using this procedure.

SECTION 7.730 — ACCEPTANCE CRITERIA OF CONSTRUCTION

In addition to sizing the timber, the following conditions shall be met:

1. The minimum nominal width or thickness is 6 inches (152 mm).
2. Connectors and fasteners relating to the support of the member shall be protected for equivalent fire resistance. When the minimum one-hour fire resistance is required, connectors and fasteners shall be protected from fire exposure by not less than 1 1/2 inches (38 mm) of wood, appropriate thickness or layers of Type X gypsum board, or any coating approved for one-hour rating.

3. For structural integrity of glued-laminated timbers, one additional lamination of 2-inch (51 mm) thickness shall be placed on the tension face of the beam and shall be equivalent in quality to that required by the design for the outer tensile lamination. The additional lamination on the tension face shall replace a core lamination to maintain the same design depth required in Section 7.729.

4. Glued-laminated timber shall be marked “Fire-rated One-hour” by the manufacturer to indicate compliance with Item 3.

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![Figure 7-7-1—Load Factor](image-url)
FIGURE 7-7-2—EFFECTIVE COLUMN LENGTH

1. For columns having a \( K_e/d \leq 11 \), \( Z \) shall be determined as follows:
   Where the ratio of applied load to allowable load is equal to or less than 50, \( Z = 1.5 \).
   Where the ratio of applied load to allowable load is greater than 50, \( Z \) shall be determined in accordance with the following formula:
   \[ Z = 0.9 + \frac{30}{r} \]
   where \( r \) = ratio of applied load to allowable load expressed as a percent of allowable.

2. For columns having a \( K_e/d > 11 \), \( Z \) shall be determined as follows:
   Where the ratio of applied load to allowable load is equal to or less than 50, \( Z = 1.3 \).
   Where the ratio of applied load to allowable load is greater than 50, \( Z \) shall be determined in accordance with the following formula:
   \[ Z = 0.7 + \frac{30}{r} \]
   where \( r \) = ratio of applied load to allowable load expressed as a percent of allowable.
SECTION 7.801 — SCOPE
This standard covers performance criteria and conditions for horizontal sliding fire doors in exits.

SECTION 7.802 — APPLICATION
Compliance with these conditions permits use of horizontal fire doors in areas specifically authorized by the code.

SECTION 7.803 — GENERAL
Installation shall be in accordance with manufacturer's instructions and nationally recognized standards.

SECTION 7.804 — CONSTRUCTION
Door assemblies shall be fire rated in accordance with U.B.C. Standard 7-2, and shall have a Class I interior finish rating. The door's power operating system shall be approved and listed. The power operating system shall be housed in a fire-resistive enclosure of the same rating as the door.

SECTION 7.805 — OPERATION
The door shall be power operated, be capable of manual operation in the event of power failure and be self-closing or smoke-detector-activated automatic closing. The door's power supply shall be capable of being electrically supervised at a constantly attended location and the door shall have an emergency power supply. Actuating devices shall be installed on both sides of the door and shall be inhibited from opening the door if the temperature on either side exceeds 500°F (260°C). The door shall be equipped with sensors capable of detecting obstructions in its closing path and of signaling such detection at the door location or at a constantly attended location. Automatic closing of the door or trouble conditions shall cause an audible alarm to be sounded at the door location. The alarm shall also be capable of being sounded at a constantly attended location. Operation of the activating device while the door is opening shall cause it to return to the closed position.

SECTION 7.806 — PERFORMANCE
7.806.1 Power Operation. The power operating system shall be examined in accordance with nationally recognized standards and shall be listed. The test report shall contain engineering data relative to tests for normal operation, electrical supervision, input and output, jarring, temperature, charging current, battery charger, undervoltage and overvoltage, standby operating power, variable ambient temperature, humidity, leakage current, transient, overload, endurance, dielectric withstand and abnormal operation. The report shall describe the mechanical operation of the power operating system in sequence as the door opens and closes under both normal and emergency conditions. It shall set forth the tests performed in accordance with nationally recognized standards and the results thereof. Additionally, the report shall contain an analysis comparing each feature of the design against the performance test procedures.
7.806.2 **Automatic-closing Test.** Upon receipt of the initiating device signal, the power operating system shall move the door to the closed position. The door shall begin closing within 10 seconds of receiving the signal. Closing speed shall not be less than 6 inches (152 mm) or more than 24 inches (610 mm) per second.

7.806.3 **Ease of Operation Test.** Manufacturers shall provide a test report from an approved independent authority that the door is easily recognized and operable for its intended usage without a key, special knowledge or effort.

The actuating device shall be subjected to a measurable force load. The force shall be applied to the actuating device in the direction of egress travel (perpendicular to the door). The force causing the actuating device to signal the power operating system to open the door shall not be more than 15 pounds (67 N).

7.806.4 **Self-contained Power Test.** Doors equipped with a self-contained power supply shall be subjected to cycle testing. One cycle shall be defined as the time to completely close the door from the open position and return it to the open position. The self-contained power supply shall have sufficient capacity to operate the door 50 cycles without the aid of outside power.

7.806.5 **Manual Operation Test.** With all power disconnected, and with the door in the closed position, 30 pounds (134 N) of force or less shall be applied in the direction of door travel to initiate the door opening. With a sustained force of 15 pounds (67 N) or less, the door shall open to the specified open distance but not less than 44 inches (1118 mm).

7.806.6 **Temperature Override Test.** The door shall include temperature-sensing devices installed at the leading edge approximately 12 inches (305 mm) from the top of the door. These devices shall be subjected to a measurable temperature. When the temperature exceeds 500°F. (260°C.), the actuating devices shall be deactivated and shall not cause the door to open.

7.806.7 **Lateral Load Test.** A lateral load shall be applied to the door in the direction of egress travel. The total load shall be equivalent to 250 pounds (1113 N) of force distributed over a minimum of five points over the total area of the closed door at locations at least 3 feet (914 mm), but not more than 6 feet (1829 mm), from the floor. Under this condition, the door must meet the conditions of the ease of operation test outlined in Section 7.806.3.

7.806.8 **Opening Speed.** The door shall open to a distance of 88 inches (2235 mm) within 10 seconds after activation of the actuating device.

SECTION 7.807 — CONDITIONS OF ACCEPTANCE

A door shall be considered as meeting the requirements for acceptable performance when it conforms to the tests under Section 7.806.

SECTION 7.808 — MARKING

7.808.1 **Label.** Doors shall bear fire-rating labels issued by a listing agency showing compliance with U.B.C. Standards 7-2 and 7-8. The label shall be of metal attached to the assembly by welding, brazing, riveting or contact adhesive.

7.808.2 **Label Markings.** The markings on the label shall include the following:

1. Name and address of the listee.
2. Model number or type.
3. Symbol, serial or issue number issued by the listing agency.
UNIFORM BUILDING CODE STANDARD 8-1

TEST METHOD FOR SURFACE-BURNING CHARACTERISTICS OF BUILDING MATERIALS


See Sections 201.2; 207; 216; 217; 405.1; 405.3.4; 601.3; 707.2; 707.3; 801.1, Items 1 and 2; 802.2; 2602.3; 2602.5.2 and 2602.6, Uniform Building Code; Section 216, Table 3-A, and Appendix B Section 1201.1, Uniform Mechanical Code; and Sections 202 and 211, Uniform Sign Code

SECTION 8.101 — SCOPE

This method for surface-burning characteristics of building materials is applicable to any type of building material that, by its own structural quality or the manner in which it is applied, is capable of supporting itself in position or may be supported in the test furnace to a thickness comparable to its recommended use.

The purpose of the test is to determine the comparative burning characteristics of the material under test by evaluating the flame spread over its surface when exposed to a test fire and thus to establish a basis on which surface-burning characteristics of different materials may be compared, without specific consideration of all the end-use parameters that might affect the surface-burning characteristics.

Smoke density as well as the flame-spread rate are recorded in this test. However, there is not necessarily a relationship between these measurements.

It is the intent of this method to register performance during the period of exposure, and not to determine suitability for use after the test exposure.

This standard shall be used to measure and describe the properties of materials, products or assemblies in response to heat and flame under controlled laboratory conditions and is not to describe or appraise the fire hazard or fire risk of materials, products or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use.

This method is intended to provide only comparative measurements of surface flame-spread and smoke-density measurements with that of Select grade red oak and asbestos-cement board surfaces under the specific fire exposure conditions described herein.

The test exposes a nominal 24-foot-long (7315 mm) by 20-inch-wide (508 mm) specimen to a controlled airflow and flaming fire exposure adjusted to spread the flame along the entire length of the Select grade red oak specimen in 5 1/2 minutes.

The test method does not provide for the following:

- Measurement of heat transmission through the tested surface.
- The effect of aggravated flame-spread behavior of an assembly resulting from the proximity of combustible walls and ceilings.
- Classifying or defining a material as noncombustible, by means of a flame-spread index by itself.

SECTION 8.102 — FIRE TEST CHAMBER

The fire test chamber, Figures 8-1-1 and 8-1-2, shall consist of a horizontal duct having an inside width of 17 3/4 inches ± 1/4 inch (451 mm ± 6.3 mm) measured at ledge location along side walls and
17\(\frac{1}{8}\) inches ± 3\(\frac{1}{8}\) inch (448 mm ± 10 mm) at all other points; a depth of 12 inches ± 1\(\frac{1}{2}\) inch (305 mm ± 13 mm) measured from the bottom of the test chamber to the ledge of the inner walls on which the sample is supported [including the 1\(\frac{1}{8}\)-inch (3.2 mm) thickness of asbestos fabric gasketing tape]; and a length of 25 feet (7620 mm). The sides and base of the duct are to be lined with insulating masonry as illustrated in Figure 8-1-2 consisting of A. P. Green, G-26 refractory firebrick. The operation and calibration of this equipment is based on the use of A. P. Green Refractories. One side is to be provided with a double window with the inside pane flush mounted (see Figure 8-1-2) pressure tight as described in Section 8.104. Exposed inside glass shall be 2\(\frac{1}{4}\) inches ± 3\(\frac{1}{8}\) inch by 11 inches plus 1 inch minus 2 inches (70 mm ± 10 mm by 279 mm ± 25 mm – 50 mm). The center line of the exposed area of the inside glass shall be in the upper half of the furnace wall, with the upper edge not less than 2.5 inches (63 mm) below the furnace ledge. The window shall be located such that not less than 12 inches (305 mm) of the specimen width can be observed. Multiple windows shall be located along the tunnel so that the entire length of the test sample may be observed from outside the fire chamber.

The ledges shall be fabricated of structural material capable of withstanding the abuse of continuous testing, level with respect to length and width of the chamber and each other and maintained in a state of repair commensurate with the frequency, volume and severity of testing occurring at any time.

To provide air turbulence for proper combustion, turbulence baffling is to be provided as necessary by positioning six A. P. Green, G-26, refractory firebricks [long dimension vertical 4\(\frac{1}{2}\)-inch (114 mm) dimension along the wall] along the sidewalls of the chamber at distances of 7 feet, 12 feet and 20 feet ± 0.5 foot (2.1 m, 3.7 m and 6.1 m ± 0.2 m) on the window side and 4\(\frac{1}{2}\) feet, 9\(\frac{1}{2}\) feet and 16 feet, ± 0.5 foot (1.3 m, 2.9 m and 4.9 m ± 0.2 m) on the opposite side. The top shall consist of a removable noncombustible (metal and mineral composite) structure, insulated with nominal 2-inch-thick (51 mm) mineral composition material as shown in Figure 8-1-2 and of a size necessary to completely cover the fire test chamber and the test samples. The mineral composition material shall have physical characteristics comparable to the following:

- Maximum effective temperature—1,200°F. (650°C.)
- Bulk density—12.5 ± 1.5 lb./ft.\(^3\) (200 ± 24 kg/m\(^3\))
- Thermal conductivity—0.45-0.65 Btu in./h. ft.\(^2\) °F at 300-700°F. (0.065 – 0.094 W/m•k at 149 – 371°C.)

The entire lid assembly shall be protected with flat sections of high density [nominal 110 lb./ft.\(^3\) (1761 kg/m\(^3\))] 1\(\frac{1}{4}\)-inch (6.3 mm) asbestos-cement board maintained in an unwarped and uncracked condition through continued replacement. When in place, the top is to be completely sealed against the leakage of air into the fire test chamber during the test.

One end of the test chamber, designated as the “fire end,” shall be provided with two gas burners delivering flames upward against the surface of the test sample. The burners are to be spaced 12 inches (305 mm) from the fire end of the test chamber sample and 7\(\frac{1}{2}\) inches ± 1\(\frac{1}{2}\) inch (190 mm ± 13 mm) below the under surface of the test sample. The air intake shutter is to be located 54 inches ± 5 inches (1372 mm ± 127 mm) upstream of the burner, as measured from the burners’ center line to the outside surface of the shutter. Gas to the burners shall be provided through a single inlet pipe, distributed to each port burner through a tee section. The outlet shall be a 3\(\frac{1}{4}\)-inch (19 mm) elbow. The plane of the port shall be parallel to the furnace floor, such that the gas is directed upward toward the specimen. Each part shall be positioned transversely approximately 4 inches ± 1\(\frac{1}{2}\) inch (102 mm ± 13 mm) on each side of the center line of the furnace so that the flame is evenly distributed over the width of the exposed sample surface. See Figure 8-1-2. The controls used to assure constant flow of gas to the burners during periods of use are to consist of a pressure regulator, a gas meter calibrated to read in increments of not more than 0.1 ft.\(^3\) (2.8 L), a manometer to indicate gas pressure in inches of water, a quick-acting gas shutoff valve, a gas-metering valve and an orifice plate in combination with a water manometer to assist in maintaining uniform gas-flow conditions.
An air intake fitted with a vertically sliding shutter extending the entire width of the test chamber is to be provided at the fire end. The shutter is to be positioned so as to provide an air-inlet port 3 inches ± 1/16 inch (76 mm ± 2 mm) high measured from the floor level of the test chamber at the air-intake point.

The other end of the test chamber, designated as the “vent end,” is to be fitted with a gradual rectangular-to-round transition piece, not less than 20 inches (508 mm) in length with a minimum cross-sectional area of 200 square inches (0.129 m²) at any point. The transition piece shall in turn be fitted to a 16-inch-diameter (406 mm) flue pipe. The movement of air is to be by induced draft system, and the draft-inducing system is to have a total draft capacity of at least 0.15-inch (3.8 mm) water column with the sample in place, the shutter at the fire end open to normal 3 inches ± 1/16 inch (76 mm ± 2 mm), and the damper in the wide-open position. A draft gage tap to indicate static pressure shall be inserted through the top at the midwidth of the tunnel, 1 inch ± 0.5 inch (25 mm ± 12 mm) below the ceiling, 15 inches ± 0.5 inch (381 mm ± 13 mm) downstream from the inlet shutter.

A light source shall be mounted on a horizontal section of the 16-inch-diameter (406 mm) horizontal vent pipe at a point where it will be preceded by a straight run of pipe [at least 12 diameters or 16 feet (4880 mm) and not more than 30 diameters or 40 feet (12 190 mm)], from the vent end of the chamber, with the light beam directed upward along the vertical axis of the vent pipe. The vent pipe is to be insulated with at least 2 inches (51 mm) of high-temperature mineral composition material from the vent end of the chamber to the photometer location. A photoelectric cell of which the output is directly proportional to the amount of light received is to be mounted over the light source and connected to a recording device for indicating changes in the attenuation of incident light by passing smoke, particulate and other effluent. The distance between the light source lens and the photocell lens shall be 36 inches ± 4 inches (914 mm ± 102 mm). The cylindrical light beam shall pass through 3-inch-diameter (76 mm) openings at the top and bottom of the 16-inch-diameter (406 mm) duct, with the resultant light beam centered on the photocell.

Linearity of the photometer system shall be verified periodically by interrupting the light beam with calibrated neutral density filters. The filters shall cover the full range of the recording instrument. Transmittance values measured by the photometer, using neutral density filters, shall be within ± 3 percent of the calibrated value for each filter.

An automatically controlled damper to regulate the draft pressure shall be installed in the vent pipe downstream of the smoke-indicating attachment. The damper shall be provided with a manual override.

Other manual or automatic draft regulation devices, or both, may be incorporated to maintain fan characterization and airflow control throughout test periods.

A No. 18 AWG (1.02 mm) thermocouple, with 3/8 inch ± 1/8 inch (9.5 mm ± 3.2 mm) of the junction exposed in the air, shall be inserted through the floor of the test chamber so that the tip is 1 inch ± 1/32 inch (25.4 mm ± 0.8 mm) below the top surface of the asbestos gasketing tape and 23 feet ± 1/2 inch (7010 mm ± 13 mm) from the center line of the burner ports at the center of its width.

A No. 18 AWG (1.02 mm) thermocouple embedded 1/8 inch (3.2 mm) below the floor surface of the test chamber is to be mounted in refractory or portland cement carefully dried to avoid cracking at distances of 13 feet ± 1/2 inch (3962 mm ± 13 mm) and 231/4 feet ± 1/2 inch (7087 mm ± 13 mm) from the center line of the burner ports.

The room in which the test chamber is located is to have provision for a free inflow of air during test to maintain the room at atmospheric pressure during the entire test run.

**SECTION 8.103 — TEST SPECIMENS**

The test specimen shall be at least 2 inches (51 mm) wider [nominally 201/4 inches ± 3/4 inch (514 mm ± 19 mm)] than the interior width of the tunnel and total 24 feet ± 1/2 inch (7315 mm ± 13 mm) in...
length. The specimen may consist of a continuous, unbroken length or of sections joined end-to-end. A 14-inch ± 1/8-inch (356 mm ± 3 mm) length of uncoated 16-gage (0.053-inch to 0.060-inch) steel sheet shall be placed on specimen mounting ledge in front of and under the specimen in the upstream end of the tunnel. Specimens shall truly represent the materials for which classification is desired. Properties adequate for identification of the materials or ingredients, or both, of which the test specimen is made are to be determined and recorded.

The test specimen shall be conditioned to a constant weight at a temperature of 73.4°F. ± 5°F. (23°C. ± 2.8°C.) and at a relative humidity of 50 ± 5 percent.

SECTION 8.104 — CALIBRATION OF TEST EQUIPMENT

A 1/4-inch (6.3 mm) asbestos-cement board shall be placed on the ledge of the furnace chamber. The removable top of the test chamber shall be placed in position.

With the 1/4-inch (6.3 mm) asbestos-cement board in position on top of the ledge of the furnace chamber, and with the removable top in place, the draft is to be established so as to produce a 0.15-inch (3.8 mm) water-column reading on the draft manometer, with the fire-end shutter open 3 inches ± 1/16 inch (76 mm ± 1.6 mm) by manually setting the damper as a characterization of fan performance. The fire-end shutter shall be closed and sealed without changing the damper position. The manometer reading shall increase to at least 0.375-inch (9.53 mm) water column, indicating that no excessive air leakage exists.

In addition, a supplemental leakage test is to be conducted periodically with the fire shutter and exhaust duct beyond the differential manometer tube sealed, by placing a smoke bomb in the chamber. The bomb shall be ignited and the chamber pressurized to 0.375 inch ± 0.15-inch (9.53 mm ± 3.18 mm) water column. All points of leakage observed in the form of escaping smoke particles shall be sealed.

A draft reading shall be established within the range 0.055-inch to 0.100-inch (1.40 to 2.54 mm) water column. The required draft gage reading shall be maintained by the automatic damper. Record the air velocity at seven points, 23 feet (7010 mm) from the center line of the burner ports, 6 inches ± 1/4 inch (168 mm ± 7 mm) below the plane of the specimen mounting ledge. Determine these seven points by dividing the width of the tunnel into seven equal sections and recording the velocity at the geometrical center of each section. During the measurement of velocity, remove the turbulence bricks and exposed 23-foot (7010 mm) thermocouple and place 24-inch-long (670 mm) straightening vanes between 16 feet and 18 feet (4876 mm and 5486 mm) from the burner. The straightening vanes shall divide the furnace cross section into nine uniform sections. Determine the velocity with furnace air temperature at 73.4°F. ± 5°F. (23°C. ± 2.8°C.) using a velocity transducer. The velocity, determined as the arithmetic average of the seven readings, shall be 240 feet ± 5 feet (7.32 m ± 1.5 m) per minute.

Maintain the air supply at a temperature of 73.4°F. ± 5°F. (23°C. ± 2.8°C.) and a relative humidity of 50 ± 5 percent.

The fire test chamber shall be supplied with natural (city) or methane (bottled) gas fuel of uniform quality with a heating value of nominally 1,000 Btu/ft³ (37.3 MJ/m³). The gas supply is to be initially adjusted at approximately 5,000 Btu/min. (5.3 MJ/min.) The gas pressure, the pressure differential across the orifice plate and the volume of gas used shall be recorded in each test. Unless otherwise corrected for, when bottled methane is employed, a length of coiled copper tubing is to be inserted into the gas line between the supply and metering connection to compensate for possible errors in the flow indicated due to reductions in gas temperature associated with the pressure drop and expansion across the regulator. With the draft and gas supply adjusted as indicated in this section, the test flame is to extend downstream to a distance of 4 1/2 feet (1372 mm) over the specimen surface, with negligible upstream coverage.

The test chamber shall be preheated with the 1/4-inch (6.3 mm) asbestos-cement board and the removable top in place and with the fuel supply adjusted to the required flow. The preheating shall
be continued until the temperature indicated by the floor thermocouple at 23\(\frac{3}{4}\) feet (7087 mm) reaches 150°F. ± 5°F. (66°C. ± 2.8°C.). During the preheat test, the temperatures indicated by the thermocouple at the vent end of the chamber shall be recorded at 15-second intervals and compared to the preheat temperature shown in the time-temperature curve, Figure 8-1-3. The preheating is for the purpose of establishing the conditions that will exist following the successive tests and to indicate the control of the heat input into the test chamber. If the appreciable variation from the temperatures shown in the representative preheat curve is observed, because of variation in the characteristics of the gas used, adjustments in the fuel supply may be made prior to proceeding with the red oak calibration tests.

The furnace shall be allowed to cool after each test. When the floor thermocouple at 13 feet (3962 mm) shows a temperature of 105°F. ± 5°F. (40.5°C. ± 2.8°C.), the next specimen shall be placed in position for test.

With the test equipment adjusted and conditioned as described in this section, a test or series of tests shall be made, using nominal 23\(\frac{3}{32}\)-inch (18.3 mm) Select grade red oak flooring as the sample, conditioned to 6 to 8 percent moisture content as determined by the 221°F. (105°C.) oven-dry method in accordance with approved nationally recognized standards. Observations shall be made at distance intervals of not more than 2 feet (610 mm) and time intervals of not more than 30 seconds and the time recorded when the flame reaches the end of the specimen, that is, 19\(\frac{1}{2}\) feet (5944 mm) from the end of the ignition fire. The end of the ignition fire shall be considered as being 4\(\frac{1}{2}\) feet (1372 mm) from the burners. The flame shall reach the end point in five and one-half minutes ± 15 seconds. The temperature measured by the thermocouple near the vent end shall be automatically recorded at least every 15 seconds. The photoelectric cell output shall be automatically recorded immediately prior to the test and at least every 15 seconds during the test.

The results of tests of Select grade red oak flooring in which the flame spreads 19\(\frac{1}{2}\) feet (5944 mm) from the end of the igniting flame in five and one-half minutes shall be considered as representing a classification of 100. Plot the flame spread distance, temperature, and change in photoelectric cell readings separately on suitable coordinate paper. Figures 8-1-4, 8-1-5 and 8-1-6 are representative curves for red oak flame spread distance, time-temperature development, and smoke density, respectively. Flame-spread distance shall be determined as the observed distance minus 4\(\frac{1}{2}\) feet (1372 mm).

Following the calibration tests for red oak, a similar test(s) is to be conducted on samples of 1\(\frac{1}{4}\)-inch (6.3 mm) asbestos-cement board. The results are to be considered as representing a classification of zero. The temperature readings shall be plotted separately on coordinate paper. Figure 8-1-7 is a representative curve for fuel contribution of asbestos-cement board.

SECTION 8.105 — MOUNTING METHODS

8.105.1 General.

8.105.1.1 Purpose. The methods specified in this section have been compiled as an aid in selecting a means for mounting and supporting various building materials in the fire test chamber for test method uniformity and convenience. They are not meant to imply restriction in the specific details of field installation.

8.105.1.2 Application. These methods shall apply to (i) materials that, in and of themselves, are not self-supporting when installed in the test chamber in accordance with Section 8.106, and (ii) materials that are self-supporting as indicated herein, but which become dislodged from their mounting position or otherwise separate or distort so that they fall to the floor of the test chamber during the test. Materials that are installed and perform as described in (ii) above shall be retested when mounted and supported in accordance with the applicable method specified in this section.

8.105.1.3 Alternates. For some building materials, none of the methods described may be applicable. In such cases, other means of mounting and support shall be devised to minimize the
effect of the mounting and support method on the performance of the material when tested in accordance with this standard.

8.105.4 **Format.** These mounting methods are grouped according to building materials to be tested, which are broadly described either by usage or by form of the material.

8.105.5 **Cement board backing.** Whenever inorganic reinforced cement board is specified as a backing in this section, the material shall be nominal $\frac{1}{4}$-inch (6.3 mm) thick, high density [110 ± 5 lb./ft.$^3$ (1792 ± 80 kg/m$^3$)] and uncoated.

8.105.6 **Use of metal rods.** When metal rods or bars are specified in this section as supports, they shall be:

- Steel rods, $\frac{1}{4}$ inch (6.3 mm) diameter
- Steel bars, $\frac{3}{16}$ inch by 2 inches (5 mm by 51 mm)

  The rods or bars shall span the width of the tunnel. Rods shall be placed approximately 2 inches (51 mm) from each end of each panel and at approximately 2-foot (610 mm) intervals starting with the fire end of each panel.

  Bars shall be used instead of rods only when they are required to support the sample. The bars shall be placed approximately 2 inches (51 mm) from each end of each panel and at approximately 2-foot (610 mm) intervals starting with the fire end of each panel.

8.105.7 **Use of netting.** Whenever netting is specified as a support in this section, the material shall be 20 gage, 2-inch (51 mm), hexagonal galvanized steel netting (chicken wire).

8.105.2 **Acoustical and Other Similar Panel Products Less Than 20 Inches (508 mm).**

8.105.2.1 For acoustical materials and other similar panel products whose maximum dimension is less than 20 inches (508 mm), metal splines or wood furring strips and metal fasteners shall be used.

8.105.2.2 Steel tee splines for mounting kerfed-acoustical tile shall be nominal $\frac{1}{2}$-inch (13 mm) web by $\frac{3}{4}$-inch (19 mm) flange, formed No. 24 gage [0.021 inch (0.53 mm) minimum thickness] sheet metal.

8.105.2.3 Wood furring frames for mounting acoustical materials and other similar panel products whose maximum dimension is less than 20 inches (508 mm) shall be nominal 1-inch by 2-inch (25 mm by 51 mm) wood furring joined with corrugated-metal fasteners. Use two frames as shown in Figure 8-1-9.

8.105.3 **Adhesives.** To determine the surface-burning characteristics of adhesives, they shall be mixed as specified in the manufacturer's instructions and shall be applied to inorganic reinforced cement board in the thickness or at the coverage rate recommended by the manufacturer. The adhesive application shall be cured prior to testing.

8.105.4 **Batt or Blanket-type Insulating Materials.** Batt or blanket materials that do not have sufficient rigidity or strength to support themselves shall be supported by metal rods inserted through the material and positioned such that the bottom of the rod is approximately $\frac{1}{4}$ inch (6.3 mm) from the surface to be exposed to the flame. Batt or blanket materials less than 1 inch (25.4 mm) thick shall not be mounted for testing in this manner.

8.105.5 **Coating Materials, Cementitious Mixtures and Sprayed Fibers.** Coating materials, cementitious mixtures and sprayed fibers shall be mixed and applied as specified in the manufacturer's instructions.

8.105.6 **Loose-fill Insulation.** Loose-fill insulation shall be placed on the floor of the tunnel at an approximate thickness of 2 inches (51 mm) by length of the tunnel, packed to the density specified by the manufacturer. Ceramic paper with a nominal density of 0.7 kg/m$^2$, shall be laid on the floor of the tunnel beneath the insulation, with appropriate cutouts being made to accommodate the burners and thermocouple.
The following modifications to the tunnel shall be made:

Inside windows shall be removed, leaving only the outside windows.

The burners shall be capable of vertical movement upwards and adjusted so that their center line is 2 inches ± 1/32 inch (50.8 mm ± 3.2 mm) above the nominal level of the top of the test sample. The elbows constituting the burner ports shall be rotated until they are pointed downwards at an angle of 45 degrees to the horizontal in the direction of the air flow (see Figure 8-1-12).

To reduce (air) eddies and possible ablation of low density materials in the burner vicinity, an air ramp (see Figure 8-1-13) shall be placed as shown with the downstream end of the ramp terminating beneath the center line of the burner tee and overlapping the specimen 1 inch (25.4 mm). The ramp shall be made of No. 304 stainless steel, minimum thickness 1/16 inch (1.6 mm), 26 inches (660 mm) long and sized to fit within 1/8 inch (3.2 mm) of the furnace width.

Flame Spread Index shall be determined as follows:

If the total area \( (A_T) \) is less than or equal to 97.5 feet•min., the Flame Spread Index shall be 0.564 times the total area \( (FSI = 0.564 A_T) \) (For SI: If \( A_T \leq 29.7 \text{ m} \cdot \text{min.}, FSI = 1.85 A_T \)).

If the total area \( (A_T) \) is greater than 97.5 feet•min., the Flame Spread Index shall be \( 5363/195 - \text{total area} \) \( (FSI = 5363/(195 - A_T)) \) (For SI: If \( A_T > 29.7 \text{ m} \cdot \text{min.}, FSI = 1640/(59.4 - A_T) \)).

Smoke developed is determined as stated in Section 8.104.

8.105.7 Plastics. Plastics shall be supported by metal rods or bars, or by netting supported with metal bars or rods, spanning the width of the tunnel in accordance with Section 8.105.1.6.

8.105.8 Thin Membranes. Single-layer membranes or thin laminates consisting of a limited number of similar or dissimilar layers shall be supported on netting placed on metal rods in accordance with Section 8.105.1.6.

8.105.9 Wall Coverings. Wall coverings of various types intended for application directly to a noncombustible wall surface shall be mounted to 1/4-inch (6.8 mm) inorganic-cement board with the adhesive specified by the manufacturer in a manner consistent with field practice.

If intended to be applied over gypsum wallboard, the wall coverings shall be tested on that substrate.

If intended for application over a combustible substrate, the wall coverings shall be tested on that substrate.

Wall coverings not intended to be adhered directly to a wall surface, but hung or otherwise supported by framing or a track system, shall be mounted for test in a manner that is representative of their installation. Where this is not practical, the sample shall be supported on netting placed on metal rods as provided.

8.105.10 Mounting Method for Heavy Textile Materials. When the surface-burning characteristics of the material itself are required, specimens shall be mounted on inorganic reinforced cement board with high-temperature bonding mortar or the equivalent.

The application shall be determined by a 1/32-inch (2.4 mm) notched trowel held at an 80-degree to 90-degree angle using a random pattern. The adhesive shall be applied only to the specimen back. The specimen shall then be placed on the smooth side of the inorganic reinforced-cement board and rolled using a 100-pound (45.4 kg) roller [nominal 5-inch (127 mm) diameter, three 5-inch-long (127 mm) sections placed end-to-end for a total length of 15 inches (381 mm)]. The prepared samples can be dead stacked overnight but should be transferred to separate storage racks until tested. Each sample shall be vacuumed prior to test.

SECTION 8.106 — TEST PROCEDURE

With the furnace draft operating, the test specimen shall be placed on the test chamber ledges which have been completely covered with nominal 1/8-inch-thick (3.2 mm) by 1 1/2-inch-wide (38 mm) woven asbestos tape. The removable top shall be placed in position over the specimen.

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The completely mounted specimen is to remain in position in the chamber with the furnace draft operating for 120 ± 15 seconds prior to application of the test flame.

The igniting flame shall be lighted and adjusted. The distance and time of maximum flame front travel is to be observed and recorded. The test shall be continued for a 10-minute period unless the sample is completely consumed in the fire area before that time, in which case the test is to be ended after no further progressive burning is evident and the photoelectric cell reading has returned to the base line.

The photoelectric cell output shall be recorded immediately prior to the test and at least every 15 seconds during test.

The gas pressure, the pressure differential across the orifice plate and the volume of gas used shall be recorded in each test.

When the test is ended, the gas supply shall be shut off. Smoldering and other conditions within the test duct are to be observed and the sample removed for further examination.

The temperature, flame-spread distance and change in photoelectric cell readings shall be plotted separately on the same coordinate paper as used for those graphs required in Section 8.104 for use in determining the flame-spread and smoke-developed indexes as outlined in Section 8.106. Flame front advancement shall be recorded at the time of occurrence or at least every 30 seconds if no advancement is noted. Flame-spread distance shall be determined as the observed distance minus 4\(\frac{1}{2}\) feet (1372 mm).

SECTION 8.107 — INTERPRETATION OF RESULTS

The flame-spread index (FSI) shall be determined as follows:

In plotting the flame-spread distance-time relationship, all progressive flaming as previously recorded shall be included at the time of occurrence. A straight line shall be used to connect successive points. The total area \(A_T\) under the flame-spread distance-time plot shall be determined by ignoring any flame front recession. For example, in Figure 8-1-8 the flame spreads 10 feet (3048 mm) in \(2\frac{1}{2}\) minutes and then recedes. The area is calculated as if the flame had spread to 10 feet (3048 mm) in \(2\frac{1}{2}\) minutes and then remained at 10 feet (3048 mm) for the remainder of the test or until the flame front again passed 10 feet. This is shown by the dashed line in Figure 8-1-8. The area \(A_T\) used for calculating the flame-spread index is the sum of areas \(A_1\) and \(A_2\) in Figure 8-1-8.

If this total area \(A_T\) is less than or equal to 97.5 feet•min., the flame-spread index shall be 0.515 times the total area (FSI = 0.515 \(A_T\)) (For SI: If \(A_T \leq 29.7 \text{ m•min.}, \text{FSI} = 1.85 A_T\)).

If this total area \(A_T\) is greater than 97.5 feet•min., the flame-spread index shall be 4,900, divided by the difference of 195 minus the total area \(A_T\). \(\text{FSI} = \frac{4,900}{(195 - A_T)}\) (For SI: If \(A_T > 29.7 \text{ m•min.}, \text{FSI} = \frac{1640}{(59.4 - A_T)}\)).

The test results for smoke shall be plotted, using the same coordinates as in Section 8.104. The area under the curve shall be divided by the area under the curve for red oak, and multiplied by 100, to establish a numerical index by which the performance of the material may be compared with that of asbestos-cement board and Select grade red oak flooring, which have been arbitrarily established as 0 and 100, respectively.

SECTION 8.108 — ANALYSIS OF PRODUCTS OF COMBUSTION

Samples for combustion product analysis, when analysis is requested, shall be taken downstream from the photometer, or shall consist of not more than 1 percent of the total flow. It should be noted that analysis of the products of combustion is not required in this method.

SECTION 8.109 — REPORT

The report shall include the following:
1. Description of the material being tested,
2. Test results as calculated in Section 8.106,
3. Details of the method used in placing the specimen in the test chamber,
4. Observations of the burning characteristics of the specimen during test exposure, such as delamination, sagging, shrinkage, fallout, etc., and
5. Graphical plots of flame-spread and smoke-developed data.
FIGURE 8-1.1—DETAILS OF TEST FURNACE
FIGURE 8-1-2—SECTION B-B
FIGURE 8-1-3—TIME-TEMPERATURE FOR PREHEAT TEMPERATURE
FIGURE 8-1-4—REPRESENTATIVE TIME-DISTANCE CURVE FOR FLAME SPREAD OF RED OAK
FIGURE 8-1-5—TIME-TEMPERATURE CURVE FOR FUEL CONTRIBUTION OF RED OAK

980°F. (527°C.) AT 5 MINUTES, 30 SECONDS
FIGURE 8-1-6—SMOKE DENSITY—RED OAK
FIGURE 8-1-7—TIME-TEMPERATURE CURVE FOR FUEL CONTRIBUTION ASBESTOS-CEMENT BOARD
FIGURE 8-1-6—EXAMPLE OF TIME-DISTANCE RELATIONSHIP WITH FLAME FRONT RECESSION
(Total Area, $A_T = A_1 + A_2$)
FIGURE 8-1-9—WOOD FRAME FOR ACOUSTICAL MATERIALS AND OTHER SIMILAR PANEL PRODUCTS LESS THAN 20 INCHES (508 mm)

Nominal wood furring strips
Corrugated fasteners all joints

Two Required

FIGURE 8-1-10—WOOD DECK FOR COATING MATERIAL

3" x 2" x 3/16" steel angles
(76 mm x 51 mm x 4.8 mm)

1 1/2" x 13 1/2" x 3/16" steel bars
(38 mm x 343 mm x 4.8 mm)

Three Required

FIGURE 8-1-11—STEEL FRAME FOR LOOSE FILL MATERIALS

3" (76 mm)

Three Required
SECTION 8-B

REMOVABLE TOP PANEL

1" MAX. (25.4 mm)

1/4" (6.4 mm) CEMENT BOARD

2" (51 mm) MINERAL COMPOSITION INSULATION
(MAXIMUM TEMPERATURE 1,200°F, (649°C)

ZIRCON OR OTHER HIGH TEMPERATURE STRUCTURAL MATERIAL

FIRE BRICK, 9" x 4 1/2" x 2 1/2"
(229 x 114 x 64 mm)

MAX. TEMP. = 2,600°F. (1427°C.

GASKETING TAPES

1" MAX. (25.4 mm)

12" ± 1/2"
(305 ± 13 mm)

4" ± 1/2"
(102 ± 13 mm)

3/4" ELBOWS
(19 mm)

TEST SAMPLE

OBSERVATION WINDOW

GAS PORTS

FIGURE 8-1-12—SECTION B-B
FURNACE WIDTH
+0″–1/8″
(+0–3.2 mm)

AIR RAMP
NO. 304—STAINLESS STEEL 1/16″ MINIMUM (1.6 mm)

26″ ± 1/4″
(660 ± 6.4 mm)

GAS BURNER

ADJUSTING SCREW

TOP VIEW

FIGURE 8-1-13—AIR RAMP
FIGURE 8-1-13—AIR RAMP—(Continued)
UNIFORM BUILDING CODE STANDARD 8-2
STANDARD TEST METHOD FOR EVALUATING ROOM FIRE GROWTH CONTRIBUTION OF TEXTILE WALL COVERING

Test Method of the International Conference of Building Officials
See Sections 801.2 and 805, Uniform Building Code

SECTION 8.201 — SCOPE
This standard describes a method for determining the contribution of textile wall covering to room fire growth during specified fire exposure conditions. This method is not intended to evaluate the fire endurance of assemblies, nor is it able to evaluate the effect of fires originating within the wall assembly. The method is not intended for the valuation of floor or ceiling finishes.

This method is to be used to evaluate the flammability characteristics of textile wall coverings when such materials constitute the exposed interior surfaces of buildings. This test method does not apply to fabric covered less than ceiling height, freestanding, prefabricated panel furniture systems or demountable, relocatable, full-height partitions used in open building interiors. Freestanding panel furniture systems include all freestanding panels that provide visual and/or acoustical separation and are intended to be used to divide space and may support components to form complete work stations. Demountable, relocatable, full-height partitions include demountable, relocatable, full-height partitions that fill the space between the finished floor and the finished ceiling.

This method is to be used to evaluate the flammability characteristics of textile wall coverings when required by this code.

SECTION 8.202 — SIGNIFICANCE AND USE
This fire test measures certain fire performance characteristics of textile wall covering materials in an enclosure under specified fire exposure conditions. It determines the extent to which the textile wall covering materials may contribute to fire growth in a room and the potential for fire spread beyond the room under the particular conditions simulated. The test indicates the maximum extent of fire growth in a room, the rate of heat release, and if they occur, the time to flashover and the time to flame extension beyond the doorway following flashover. It does not measure the fire growth in, or the contribution of, the room contents. Time to flashover is defined herein as either the time when the radiant flux onto the floor reaches 20 kW/m² or the temperature of the upper air reaches 600°C. A crumpled single sheet of newspaper shall be placed on the floor 3 feet (914 mm) out from the center of the rear wall. The spontaneous ignition of this newspaper provides the visual indication of flashover.

The potential for spread of fire to other objects in the room, remote from the ignition source, is evaluated by measurements of:
1. The total heat flux incident on the center of the floor.
2. A characteristic upper-level gas temperature in the room.
3. Instantaneous net peak rate of heat release.

The potential for the spread of fire to objects outside the room of origin is evaluated by the measurement of the total heat release of the fire.

Measurements of the rate of production of carbon monoxide and carbon dioxide are taken. Where carbon dioxide is “scrubbed” and therefore not measured, refer to Section 8.214 for alternate calculation method for rate of heat release.

The overall performance of the test specimen is to be visually documented by full-color photographic records. Videotaping of the complete fire test may be done as an alternative to the photo-
graphic record. Such records shall show when each area of the test specimen becomes involved in the fire.

SECTION 8.203 — SUMMARY OF METHOD

The test method has two types of protocols. One is a “screening test” protocol and the second is the “fully lined test” protocol. The “screening test” protocol utilizes a corner test exposure of relatively small specimens mounted on the walls of the test compartment. The “fully lined test” protocol involves the same test in a compartment having three fully lined walls.

This method uses a gas burner to produce a diffusion flame to expose the walls in the corner of an 8- by 12- by 8-foot-high (2348 mm by 3658 mm by 2438 mm) room. The burner produces a prescribed rate of heat output of 40 kW for five minutes followed by 150 kW for 10 minutes, for a total exposure period of 15 minutes. The contribution of the textile wall covering to fire growth is measured via constant monitoring of the incident heat flux on the center of the floor, the temperature of the gases in the upper part of the room, the rate of heat release and the time to flashover. The test is conducted with natural ventilation to the room provided through a single doorway 30 inches by 80 inches (762 mm by 2032 mm) in width and height. The combustion products are collected in a hood feeding into a plenum connected to an exhaust duct in which measurements are made of the gas velocity, temperature, and concentrations of selected gases.

SECTION 8.204 — IGNITION SOURCE

The ignition source for the test shall be a gas burner with a nominal 12- by 12-inch (305 mm by 305 mm) porous top surface of a refractory material. See Figure 8-2-1. A burner may be constructed with 1-inch-thick (25.4 mm) porous ceramic-fiberboard over a 6-inch (152 mm) plenum, or, alternatively, a minimum 4-inch (102 mm) layer of Ottawa sand can be used to provide the horizontal surface through which the gas is supplied.

The top surface of the burner through which the gas is applied shall be 12 inches (305 mm) above the floor, and the burner enclosure shall be located such that the edge of the diffusion surface is located 2 inches (51 mm) from both walls in the left corner of the room opposite from the door. See Figure 8-2-3.

The gas supply to the burner (see Figure 8-2-1) shall be of C.P. grade propane (99 percent purity). The burner shall be capable of producing a gross heat output of 40 ± 1 kW for five minutes followed by 150 ± 5 kW for 10 minutes. The flow rate shall be metered throughout the test. Flow rates may be calculated using propane’s gross heat of combustion as 2,480 Btu/foot³ (92.5 MJ/m³) at 68°F (20°C) and 14.70 psia (101.4 kPa). The burner design shall permit switching from 40 kW to 150 kW within 10 seconds. Burner controls should be provided for automatic shutoff of the gas supply if flameout occurs. Two arrangements for gas supply that have been used are shown in Figures 8-2-2A and 8-2-2B.

The burner shall be ignited by a pilot burner or a remotely controlled spark igniter.

SECTION 8.205 — COMPARTMENT GEOMETRY AND CONSTRUCTION

The interior dimensions of the floor of the fire room, when the specimens are in place, shall measure 8 feet ± 1 inch by 12 feet ± 1 inch (2438 mm ± 25 mm by 3658 mm ± 25 mm). The finished ceiling shall be 8 feet ± 0.5 inch (2438 mm ± 13 mm) above the floor. There shall be four walls at right angles defining the compartment.

There shall be a 30- ± 0.25- by 80- ± 0.25-inch (762 mm ± 6 mm by 2032 mm ± 6 mm) doorway in the center of one of the 8- by 8-foot (2438 mm by 2438 mm) walls, and no other wall, floor or ceiling openings that allow ventilation.
The inside surface of the wall containing the door shall be of calcium-silicate board of 46 pounds per cubic foot (737 kg/m$^3$) density and 0.5 inch (12.7 mm) in nominal thickness or 0.5-inch (12.7 mm) gypsum wallboard. The door frame shall be constructed to remain unchanged during the test period to a tolerance of ±1 percent in height and width.

The test compartment may be framed or a concrete block structure. If self-supporting panels are tested, a separate exterior frame or block compartment may not be required.

The floor, ceiling and walls of the test compartment shall be covered by calcium silicate board or by gypsum wallboard.

### SECTION 8.206 — SPECIMEN MOUNTING

Test specimens shall be mounted on a framing or support system comparable to that intended for their actual use, using backing materials, insulation or air gaps as appropriate to the intended application and representing a typical value of thermal resistance for the wall system. Where a manufacturer specifies use of an adhesive, specimens shall be mounted using the adhesive and application rate as recommended by the manufacturer and comparable to actual field installations. The adhesive utilized shall be the same as that intended for actual use.

Where a textile wall covering has a distinct directionality, the sample shall be mounted such that the machine direction is vertical unless the manufacturer indicates a different method of mounting will be used in actual installations.

For the screening test protocol, specimens shall be mounted on the left side and rear walls (as viewed from the room door) and as illustrated in Figure 8-2-3. Vertically mounted portions of test specimens shall extend 2 feet (610 mm) from the room corner on the left side and rear walls. Horizontally mounted specimens on the rear and left sidewalls shall extend 2 feet (610 mm) down from the ceiling and be installed for the full 8-foot (2438 mm) width of the rear wall and the full 12-foot (3658 mm) wall length of the left sidewall.

In the fully lined room protocol test, specimens shall be mounted to fully cover both 8- by 12-foot (2438 mm by 3658 mm) walls and the 8- by 8-foot (2438 mm by 2438 mm) wall, which does not have a door in it.

### SECTION 8.207 — FIRE ROOM ENVIRONMENT

**8.207.1 General.** The test building in which the fire room is located shall have vents for the discharge of the combustion products and have provisions for fresh air intake so that no oxygen-deficient air shall be introduced into the fire room during the test. Prior to the start of the test, the ambient air at the midheight entrance to the compartment shall have a velocity in any direction of less than 100 feet per minute (30.5 m/min.). The building shall be of adequate size so that there shall be no smoke accumulation in the building below the level of the top of the fire compartment.

**8.207.2 Ambient Conditions in Test Building.** The ambient temperature in the test building at locations around the fire compartment shall be above 40°F. (4.4°C.) and the relative humidity shall be less than 75 percent for the duration of the test.

**8.207.3 Ambient Conditions in Fire Room.** If test samples are installed within the test room two or more hours prior to test, the following ambient conditions shall be maintained:

1. The ambient temperature in the fire room measured by one of the thermocouples in Section 42.208 shall be from 65°F. to 75°F. (18.3°C. to 23.9°C.).
2. The ambient relative humidity in the fire room shall be within the range of 50 ± 5 percent.

**8.207.4 Specimen Conditioning.** Prior to testing, mounted specimens shall be conditioned for a minimum of seven days and until the sample reaches a rate of weight change of less than 0.1 percent per day at a temperature of 70°F. ± 5°F. (21.1°C. ± 2.8°C.) and at a relative humidity of 50 ± 5 percent.
SECTION 8.208 — INSTRUMENTATION

The following are minimum requirements for instrumentation for this test:

8.208.1 Total Heat Flux Gage.

8.208.1.1 Location. A gage shall be mounted a maximum of 2 inches (51 mm) above the floor surface, facing upward in the geometric center of the test room (see Figure 8-2-4).

8.208.1.2 Specification. The gage shall be of the Gardon type, with a flat black surface, and a 180 degree view angle. In operation, it shall be maintained at a constant temperature (within ± 5 percent °F. (± 2.8 percent °C.)) above the dew point by water supplied at a temperature from 120°F. to 150°F. (48.9°C. to 65.6°C.). This will normally require a flow rate of at least 0.1 gallon per minute (6.31 mL/s). The full-scale output range shall be 50 kW/m² for the gage.

8.208.2 Gas Temperature Thermocouples.

8.208.2.1 Specification. Bare chromel-alumel thermocouples 20 mil in diameter shall be used at each required location. The thermocouple wire, within 0.5 inch (13 mm) of the bead, should be run along expected isotherms to minimize conduction errors. The insulation between the chromel and alumel wires shall be stable to at least 2,000°F. (1093°C.) or the wires shall be separated. Metal-clad thermocouples with ceramic-powder filling shall be used.

8.208.2.2 Location in doorway. A thermocouple shall be located in the interior plane of the door opening on the door center line, 4 inches (102 mm) down from the top. (See Figure 8-2-5.)

8.208.2.3 Locations for room. Thermocouples shall be located 4 inches (102 mm) below the ceiling at the center of the ceiling, the center of each of the four ceiling quadrants and directly over the center of the ignition burner. The thermocouples shall be mounted on supports or penetrate through the ceiling with their junctions 4 inches (102 mm) away from a solid surface. (See Figure 8-2-5.) Any ceiling penetration shall be just large enough to permit passage of the thermocouples. Spackling compound or ceramic fiber insulation shall be used to backfill the holes around the thermocouple wires.

8.208.2.4 Location in canopy hood and duct system. One pair of thermocouples shall be placed 11 feet (3353 mm) downstream of the entrance to the horizontal duct. The pair of thermocouples shall straddle the center of the duct and be separated 2 inches (51 mm) from each other. (See Figure 8-2-6.)

8.208.3 Canopy Hood and Exhaust Duct.

8.208.3.1 Location and design. A hood shall be installed immediately adjacent to the door of the fire room. The bottom of the hood shall be level with the top surface of the room. The face dimensions of the hood shall be at least 8 feet by 8 feet (2438 mm by 2438 mm) and the depth shall be 3.5 feet (1067 mm). The hood shall feed into a plenum having a 3- by 3-foot (914 mm by 914 mm) cross section. The plenum shall have a minimum height of 3 feet (914 mm) and a maximum height of 6 feet (1829 mm). The exhaust duct connected to the plenum shall be 16 inches (406 mm) in diameter, horizontal, and shall have a circular aperture of 12 inches (305 mm) at its entrance. (See Figures 8-2-6 and 8-2-7.)

8.208.3.2 Draft. The hood shall have sufficient draft to collect all of the combustion products leaving the room. [This draft should be capable of moving up to 7,000 standard cubic feet per minute (3303 L/s) equivalent to 16,000 acfm at 750°F. (7550 L/s at 399°C.) during the test.] Provisions shall be made so that the draft can operate at either 1,000 or 7,000 standard cubic feet per minute (472 L/s or 3303 L/s). Mixing vanes may also be required in the duct if concentration gradients are found to exist.

8.208.3.3 Alternate exhaust system. An alternative exhaust system design may be used if it has been shown to produce equivalent results. (Equivalency may be shown in meeting the requirements of Section 8.209.)

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8.208.4 Duct Gas Velocity. A bidirectional probe or an equivalent measuring system shall be used to measure gas velocity in the duct. The probe shown in Figure 8-2-8 consists of a short, stainless steel cylinder 1.75 inches (44 mm) long and 0.875 inch (22.2 mm) inside diameter with a solid diaphragm in the center. The pressure taps on either side of the diaphragm support the probe. The axis of the probe shall be along the center line of the duct 11 feet (3353 mm) downstream from the entrance. The taps shall be connected to a pressure transducer that shall be able to resolve pressure differences of 0.001 inch H2O (0.25 Pa). Capacitance transducers have been found to be most stable for this application.

8.208.5 Oxygen-depletion Measurements.

8.208.5.1 Determination of rate of heat release. A stainless steel gas sampling tube shall be located 13 feet (3962 mm) downstream from the entrance to the duct at the geometric center of the duct 11/2 inches (±3 mm) to obtain a continuously flowing sample for determining the oxygen concentration of the exhaust gas as a function of time. A suitable filter and cold trap shall be placed in the line ahead of the analyzer to remove particulates and water. The oxygen analyzer shall be of the paramagnetic or polarographic type and shall be capable of measuring the oxygen concentration in the range from 21 percent down to 15 percent with a relative accuracy of ± 2 percent in this concentration range. The signal from the oxygen analyzer shall be within 5 percent of its final value in 30 seconds after introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube.

8.208.5.2 Duct carbon dioxide concentration: specification. The gas-sampling tube described in Section 8.208 may be used to provide a continuous sample for the measurement of the carbon dioxide concentration using an analyzer with a range of 0 to 20 percent, with a maximum relative error of 2 percent of full scale. The total system response time between the sampling inlet and the meter shall be no greater than 30 seconds.

8.208.5.3 Duct carbon monoxide concentration: specification. The gas-sampling tube defined in Section 8.208 shall provide a continuous sample for the measurement of the carbon monoxide concentration using an analyzer with a range from 0 to 10 percent with a maximum relative error of 2 percent of full scale. The signal from the analyzer shall be within 5 percent of its final value in 30 seconds after introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube.

8.208.6 Photographic Records. Photographic or video equipment shall be used to record the fire spread in the room and the fire projection from the door of the room. The location of the camera shall avoid interference with the air inflow. The interior wall surfaces of the test room, adjacent to the corner in which the burner is located, shall be clearly marked with a 12-inch (305 mm) grid. A clock shall appear in all photographic records, giving time to the nearest 1 second or 0.01 minimum from the start of the test. This clock shall be accurately synchronized with all other measurements, or other provisions shall be made to correlate the photo record with time. Color slides shall be taken at 30-second intervals from the duration of the test or a continuous video recording shall be made.

SECTION 8.209 — CALIBRATION AND DOCUMENTATION OF IGNITION SOURCE AND TEST EQUIPMENT

A calibration test shall have been performed prior to and within 30 days of any fire test. The calibration test, to last for 15 minutes, shall use the standard ignition source with inert wall and ceiling materials [calcium silicate board of 46 pounds per cubic foot (737 kg/m³) density, 0.50 inch (12.7 mm) in thickness]. The following data shall be reported:

1. The output as a function of time, after the burner is activated, of all instruments normally used for the standard fire test.

2. The maximum extension of the burner flame, as recorded by still photographs taken at 30-second intervals or continuous video recording.
3. The temperature and velocity profiles across the duct cross section at the location of the bidirectional probe. These profiles shall be used to determine the factor, \( k \), in Formula (12) of Section 8.213.

4. The total rate of heat production as determined both by the oxygen consumption calculation and by independent measurement of the volumetric flow rate and weight loss of propane supply shall agree to within 5 percent. A net heat of combustion is 2,339 Btu per cubic foot (92.5 MJ/m\(^3\)) for propane at 68°F (20°C) and 14.70 psia (101.4 kPa) value shall be used in this calculation.

SECTION 8.210 — PROCEDURE

The screening test protocol and the fully lined test protocol, except for specimen mounting, follow the same test procedure. Where indicated by Section 8.211, the fully lined test protocol shall be followed.

Establish an initial volumetric flow rate of 1,000 cubic feet per minute (472 L/s) through the duct and increase the volume flow rate to 7,000 cubic feet per minute (3303 L/s) when the oxygen content falls below 14 percent.

Turn on all sampling and recording devices, and establish steady-state baseline readings for at least three minutes.

Ignite the gas burner and simultaneously start the clock and increase gas flow rate to provide a rate of heat release of 40 kW ± 1 kW by the burner. Continue the exposure at the 40 kW ± 1 kW level for five minutes. Within 10 seconds following the five-minute exposure, increase the gas flow to provide a rate of heat release by the burner of 150 kW ± 5 kW exposure for 10 minutes.

Take 35mm color photographs at 30-second intervals or provide a continuous video recording to document the growth of the fire.

Provide a continuous voice or written record of the fire, which will give times of all significant events, such as time of ignition, flames out the doorway, flashover, etc.

The ignition burner shall be shut off at 15 minutes after start of the test and the test terminated at that time, unless safety considerations dictate an earlier termination.

Document damage after the test, using words, pictures and drawings.

SECTION 8.211 — ACCEPTANCE CRITERIA

Textile wall coverings shall be considered as demonstrating satisfactory performance if, during the screening test protocol, the following conditions are met:

Flame shall not spread to the ceiling during the 40 kW exposure.

During the 150 kW exposure, the following criteria shall be met:

1. Flame shall not spread to the outer extremity of the sample on the 8- by 12-foot (2438 mm by 3658 mm) wall.

2. The specimen shall not burn to the outer extremity of the 2-foot-wide (610 mm) samples mounted vertically in the corner of the room.

3. Burning droplets shall not be formed and drop to the floor which are judged to be capable of igniting the textile wall covering or which persist in burning for 30 seconds or more.

4. Flashover shall not occur. Flashover may be judged to occur when heat flux at floor level exceeds 20 kW/m\(^2\), upper-level air temperatures within the room exceed 1,100°F (593°C) or flames project out the room door opening.

5. The maximum instantaneous net peak rate of heat release shall not exceed 300 kW. Textile wall coverings in the screening test protocol developing a maximum, instantaneous net peak rate of
heat release of 300 kW may or may not cause flashover in a fully lined room. A fully lined room test protocol shall be used to judge acceptability of such products. The maximum instantaneous net peak rate of heat release shall be derived by taking the measured maximum rate of heat release and subtracting the burner output.

Textile wall coverings which fail to meet the criteria of Section 8.211 may be judged to perform satisfactorily when tested following the fully lined test protocol and when meeting the following criteria:

A. Flame shall not spread to the ceiling during the 40 kW exposure.

During the 150 kW exposure, the following criteria shall be met:

(i) Flame shall not spread to the outer extremities of the samples on the 8- by 12-foot (2438 mm by 3658 mm) walls.

(ii) Flashover shall not occur. Flashover shall be judged to have occurred when heat flux at floor level exceeds 20 kW/m², upper-level air temperatures exceed 1,100°F (593°C.) or flames project out the room door opening.

SECTION 8.212 — REPORT

The report shall include the following:

8.212.1 Materials:

1. Material description. The name, thickness, density and size of the material to be listed, along with other identifying characteristics or labels.

2. Materials mounting and conditioning.

3. Layout of specimens and attachments in test room (include appropriate drawings).

4. Relative humidity and temperature of the room and the test building prior to and during the test.


8.212.3 Time History of the Total Heat Flux to Floor. The total incident heat flux at the center of the floor for the heat flux gage as a function of time starting three minutes prior to the test.

8.212.4 Time History of the Gas Temperature. The temperature of gases in the room, the doorway, and in the exhaust duct for each thermocouple as a function of time starting three minutes prior to the test.

8.212.5 Time History of the Total Rate of Heat Production of the Fire. The total of heat production shall be calculated from the measured oxygen and carbon monoxide concentrations (refer to Section 8.214) or measured oxygen, carbon monoxide and carbon dioxide concentrations (refer to Section 8.213) and the temperature and volumetric flow rate of the gas in the duct. The calculations shall be based on the method shown in either Section 8.213 or Section 8.214.

8.212.6 Time History of the Fire Growth. A transcription of the visual, photographic, audio and written records of the fire test. The records shall indicate the time of ignition of the wall finish, the approximate location of the flame front most distant from the ignition source, at intervals not exceeding 15 seconds during the fire test, the time of flashover, and the time at which flames extend outside the doorway. In addition, still photographs taken at intervals not exceeding 30 seconds or continuous video recordings shall be supplied. Drawings and photographs or video recordings showing the extent of the damage of the materials after the test shall also be supplied.

8.212.7 Discussion of Performance. Complete discussion of sample performances related to acceptance criteria within Section 8.211.
SECTION 8.213 — CALCULATION OF THE TOTAL RATE OF HEAT AND CARBON MONOXIDE OR CARBON DIOXIDE PRODUCTION

The total rate of heat production is as follows:

\[ Q = E \phi X^o_{O_2} V_A \quad (1) \]

WHERE:

- \( E \) = heat release per volume of oxygen consumed, 467 Btu/ft.\(^3\) or 17.4 MJ/m\(^3\).
- \( V_A \) = volume flow rate of air into the system corrected to 20°C., including that which enters the room and that which passes directly into the exhaust duct.
- \( X^o_{O_2} \) = ambient molar concentration of oxygen (0.21).
- \( \phi \) = fraction of the oxygen consumed.

The oxygen depletion is as follows:

\[ \phi = (M^o_{O_2} - M_{O_2})/M^o_{O_2} \quad (2) \]

WHERE:

- \( M^o_{O_2} \) = the molar flow rate of oxygen into the system.
- \( M_{O_2} \) = the molar flow rate of oxygen in the exhaust duct.

The concentrations of oxygen and carbon dioxide in the analyzers are given as follows:

\[ X_{O_2} = M_{O_2} / (M^o_{N_2} + M_{O_2} + M_{CO_2}) \quad (3) \]
\[ X_{CO_2} = M_{CO_2} / (M^o_{N_2} + M_{O_2} + M_{CO_2}) \quad (4) \]

WHERE:

- \( M^o_{N_2} \) = the molar flow rate of nitrogen into the system.
- \( M_{CO_2} \) = the molar flow rate of carbon dioxide in the exhaust duct. It is assumed that all of the water is trapped out and that the only gases passing through the analyzers are nitrogen, oxygen, and carbon dioxide. Combining Formulas (3) and (4) as follows:

\[ M_{CO_2} = (X_{CO_2} / X_{O_2}) M_{O_2} \]

and noting that

\[ X^o_{O_2} = M^o_{O_2} / (M^o_{N_2} + M^o_{O_2}) \]

Formula (3) can be solved for \( M_{O_2} \) as follows:

\[ M_{O_2} = \left[ (M^o_{O_2} (X_{O_2} / X^o_{O_2}) - X_{O_2}) / (1 - X_{O_2} - X_{CO_2}) \right] \]

which, when substituted into Formula (2), yields:

\[ \phi = [X^o_{O_2} - X_{O_2} / (1 - X_{CO_2})] / (X^o_{O_2} [1 - X_{O_2} / (1 - X_{CO_2})]) \]

The volume flow rate in the exhaust duct is as follows:

\[ V_S = (1 - \phi) V_A + \alpha \phi V_A \quad (7) \]
where \( V_S \) refers to standard conditions [68°F (20°C.)] and \( \alpha \) is the expansion factor, due to chemical reaction, of the air that is depleted of its oxygen.

\[
\alpha = X^oN_2 + bX^oO_2 = 0.79 + 0.21b \tag{8}
\]

where \( b \) is the ratio of the moles of combustion products formed to the moles of oxygen consumed. The value of \( \alpha \) ranges from 1.000 for carbon to 1.175 for cellulose with the plastics having values in between. In order to reduce the error incurred when unknown products are burning, \( \alpha \) is taken to have an intermediate value of 1.084, which is exact for propane, the burner gas. From Formula (7), the volume flow rate of air entering the system is as follows:

\[
V_A = \frac{V_S}{[1 + (\alpha - 1)\phi]} \tag{9}
\]

Setting \( \alpha = 1.084, E = 467 \text{ Btu/ft.}^3 \) (17.4 \text{ MJ/m}^3) and \( X^oO_2 = 0.21 \), Formula (1) becomes

\[
Q = \left[ E\phi X^oN_2 V_S / [1 + (\alpha - 1)\phi] \right] = \left[ 98.1\phi V_S / (1 + 0.084\phi) \right] \text{ Btu/min}. \tag{10}
\]

if \( V_S \) is measured as cfm referred to 68°F (20°C.), Setting \( E = 17.4 \text{ MJ/m}^3 \) \( Q = \left[ 3.65\phi V_S / (1 + 0.084\phi) \right] \text{MW} \tag{11} \)

where \( V_S \) is measured as cubic meters per second. The oxygen depletion, \( \phi \), is obtained from Formula (6) and \( V_6 \) is determined from the flow measurement in the exhaust duct.

When the velocity is measured with a bidirectional probe and the Reynolds number correction is taken into account, the volumetric flow rate in \text{m}^3/\text{sec} in the duct under standard conditions is as follows:

\[
V_S = 0.926kA \left( \frac{2\Delta p T_0}{\rho_o T} \right)^{1/2} = 20.1kA \sqrt{\Delta p/T} \tag{12}
\]

WHERE:

- \( 0.926 = \) a suitable calibration factor for air velocities in excess of 3 ft./sec. (0.914 m/sec.) in a 16-inch (406 mm) duct.
- \( A \) = cross-sectional area of the duct at the location of the probe, m².
- \( k \) = ratio of the average duct gas mass flow per unit area, as determined by measuring the velocity and temperature profiles across the stack, and the velocity and temperature at the center line where the bidirectional probe is located during the test.
- \( T \) = the duct gas temperature in K.
- \( \Delta p \) = the differential pressure measured with the probe in Pa.
- \( \rho_o \) = the density of air in kg/m³ and at the reference temperature \( T_0 \), K, and

The volumetric flow rate can be expressed in cubic feet per minute (scfm) at 60°F (15.6°C.) using common engineering units as follows:

\[
V_S = 8.38 \times 10^4 kA \left( \frac{\Delta p}{(t + 459)} \right)^{1/2} \text{ standard ft.}^3/\text{min}. \tag{13}
\]

For SI: \( \times 28.32 \) for L/min.

WHERE:

- \( A \) = given in \text{ft.}²
- \( t \) = the duct gas temperature in °F.
\[ \Delta p = \text{given in inches of water.} \]

The volume flow rate of CO in \( \text{m}^3/\text{sec} \) through the duct may be calculated as follows:

\[ V_{CO} = [0.79 V_S X_{CO}/(1 + 0.084 \phi) (1 - X_{O_2} - X_{CO} - X_{CO})] \]  

**WHERE:**

- \( X_{CO} \) = is the concentration of carbon monoxide measured in the analyzer. This can be calculated as follows:

\[ \frac{V_{CO}}{V_A} = \frac{M_{CO}}{M_{Air}} = \frac{M_{CO} M_{O_2}}{M_{O_2} M_{O_2}^e M_A} \]

\[ = \frac{X_{CO} M_{O_2}}{X_{O_2} M_{O_2}^e X_{O_2}} \]

where \( M_{CO} \) and \( M_A \) are the molar flow rates of carbon dioxide in the duct and of the air into the system including that flowing into the room and that entering the exhaust duct directly. The ratio of the CO and O\(_2\) concentration in the duct are the same as in the analyzer so that

\[ \frac{M_{CO}}{M_{O_2}} = \frac{X_{CO}}{X_{O_2}} \]

When CO is present in the sampling line, Formula (5) becomes

\[ M_{O_2} = M_{O_2}^e (1 - X_{O_2} - X_{CO} - X_{CO}) \]

Formula (14) is obtained by combining Formulas (15), (16) and (17), letting

\[ 1 - X_{O_2} = 0.79, \text{ and letting } V_A = \frac{S}{1 - 0.084 \phi} \]

**SECTION 8.214 — ALTERNATE CALCULATION OF THE TOTAL RATE OF HEAT RELEASE WHEN CARBON MONOXIDE IS MEASURED AND CARBON DIOXIDE IS REMOVED FROM THE GAS SAMPLING TRAIN**

When CO\(_2\) is not measured, but is removed from the sample line, and CO is measured, \( \phi \) and \( Q \) are calculated as follows:

\[ \phi = \frac{X^e_{O_2} - (X_{O_2}/(1 - X_{CO}))}{X^e_{O_2} (X_{O_2}/(1 - X_{CO}))} \]

\[ Q = \{ \phi - [(E'' - E')/E'] (1 - \phi)/2 (X_{CO}/X_{O_2}) \} E' X^e_{O_2} V_A (\text{MW}) \]

**WHERE:**

- \( E'' = 23.4 \text{ MJ/m}^3 \).
- \( E' = 17.4 \text{ MJ/m}^3 \).
- \( V_A = \text{m}^3/\text{sec} \).
referred to a 68°F. (20°C.) base. Thus $Q$ becomes

$$Q = \{\phi - 0.345[1 - \phi][1 + \phi/2][X_{\text{CO}}/X_{\text{O}_2}]\}17.4X_{\text{O}_2}V_A(MW)$$

When Formulas (18) through (20) are used to calculate the rate of heat release, the carbon dioxide must be removed from the sample streams flowing through the oxygen and carbon monoxide analyzers. The removal of carbon dioxide can be accomplished by passing the sample stream through a filter of either ascarite or an aqueous solution of sodium hydroxide.
FIGURE 8-2-1—GAS BURNER

FILLED WITH WHITE OTTAWA SILICA SAND

NOM. 3/4" PIPE (19 mm)

GAS

12" (305 mm)

6" (152 mm)

3" (76 mm)

6" (152 mm)

1 1/8" (28.6 mm)

6" (152 mm)

8-2

1994 UNIFORM BUILDING CODE

3-158
FIGURE 8-2-2A—TYPICAL GAS FLOW REGULATION SYSTEM

FIGURE 8-2-2B—TYPICAL GAS FLOW REGULATION SYSTEM
NOTE: HATCHED AREAS REPRESENT TEST MATERIALS. THE TEST MATERIAL IS APPLIED SUCH THAT THE MACHINE DIRECTION IS VERTICAL. THE BURNER IS LOCATED 2 INCHES (51 mm) FROM BOTH THE REAR WALL AND THE LEFT SIDEWALL.

FIGURE 8-2-3
FIGURE 8-2-4—ROOM RADIOMETER LOCATION
FIGURE 8-2-5—ROOM THERMOCOUPLE LOCATIONS
FIGURE 8-2-6—CANOPY HOOD AND EXHAUST DUCT

* Height of plenum may be increased up to 6 ft. (1829 mm) to adjust to building constraints.
** Support for hood must not interfere with air inflow to burn room.
*** Capable of exhausting 7000 sc fm (3303 L/s) during test
FIGURE 8-2-7—PLAN VIEW OF CANOPY HEAD

FIGURE 8-2-8—BIDIRECTIONAL PROBE
UNIFORM BUILDING CODE STANDARD 9-1
INSTALLATION OF SPRINKLER SYSTEMS

See Sections 307.11.3; 404.3.1; 405.1.1; 405.3.4; 804.1; 902; 904.1.2; 904.1.3; 904.2.5.3; 904.2.7; 904.2.8; 2603.7.1; 2603.8.1, Item 4; Appendix 327.2

Uniform Building Code

This standard, with certain exceptions, is based on the National Fire Protection Association Standard for the Installation of Sprinkler Systems, NFPA 13-1991.


Part I

SECTION 9.101 — AMENDMENTS

The National Fire Protection Association standard adopted by this standard applies to the selection, installation, acceptance inspection and acceptance testing of sprinkler systems, except as follows:

1. Sec. 1-1 is amended by changing the note to read as follows:
   Consult other recognized and accepted standards for additional requirements relating to water supplies.

2. Sec. 1-4 is amended by changing the definition of “authority having jurisdiction” to read as follows:
   Authority Having Jurisdiction is the building official.
   The definitions of “approved” and “listed” shall be as set forth in Volume 1 of this code.
   Sec. 1-4.1 is amended by deleting the definitions of the terms “limited combustible material,” “noncombustible material,” “should” and “standard;” by deleting the note following the definition of “sprinkler system;” and by adding definitions for “acceptance,” “building official” and “thermal barrier” to read as follows:
   Acceptance is acceptance by the building official.
   Building Official is the officer or other designated authority charged with the administration and enforcement of this standard, or the officer’s or other designated authority’s duly authorized representative.
   Thermal Barrier is a material that will limit the average temperature rise of the unexposed surface to not more than 250°F. (121°C.) after 15 minutes of fire exposure complying with nationally recognized standards.

3. Sec. 1-4.7 is amended to read as follows:
   1-4.7. For the purpose of determining the level of protection to be provided by required sprinkler system installations, Table 1.4.7 shall be used.
   For hazard classifications other than those indicated, see appropriate nationally recognized standards for design criteria.
   When fire sprinkler systems are required in buildings of undetermined use, they shall be designed and installed to have a sprinkler density of not less than that required for an Ordinary Hazard Group 2 use with a minimum design area of 3,000 square feet (279 m²).
   Use is considered undetermined if not specified at time permit is issued.
   Where a subsequent occupancy requires a system with greater capability, it shall be the responsibility of the occupant to upgrade the system to the required density for the new occupancy.
Other Uniform Codes or standards contain sprinkler system design criteria for fire control or suppression of specific hazards.

<table>
<thead>
<tr>
<th>TABLE 1.4.7—HAZARD CLASSIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GROUP A OCCUPANCIES</strong></td>
</tr>
<tr>
<td>Group A Occupancies used as meeting rooms, library reading rooms, restaurant seating areas, clubs, theaters, museums, health clubs, educational classrooms and churches. Group B Occupancies used as offices, data processing areas, colleges and universities. Group C Occupancies other than shops and laboratories. Group D Occupancy living and sleeping areas. Group E, Division 1 Occupancies. Typically these uses are such that the quantity and combustibility of contents is such that relatively low-rate-of-heat-release fires would be expected.</td>
</tr>
<tr>
<td><strong>GROUP B OCCUPANCIES</strong></td>
</tr>
<tr>
<td>Groups B, F and S Occupancies used for light manufacturing, commercial kitchens, laundries, automobile parking garages, bakeseries, canneries, electronic plants, beverage manufacturing and glass products manufacturing plants not producing dust or fibers. Typically these uses are such that the quantity of combustibles is relatively low, the combustibility of contents is moderate, storage does not exceed 8 feet (2438 mm) in height, and moderate-rate-of-heat-release fires would be expected.</td>
</tr>
<tr>
<td><strong>GROUP M OCCUPANCIES</strong></td>
</tr>
<tr>
<td>Groups B, F and S Occupancies used for chemical plant laboratories, mercantile, machine shops, printing plants, library stack areas, metal working, wood product assembly, textile manufacturing, confectionery products, cold storage warehouses, cereal mills, service stations and repair garages. Typically these uses are such that the quantity of combustibles is moderate. The combustibility of contents is moderate, storage does not exceed 12 feet (3658 mm) in height and moderate-rate-of-heat-release fires would be expected.</td>
</tr>
<tr>
<td><strong>GROUP H OCCUPANCIES</strong></td>
</tr>
<tr>
<td>Group H Occupancies used for printing (using inks with flash points below 100°F. [38°C.]), combustible hydraulic fluid-use areas such as die casting and metal extruding, upholstering with plastic foam, rubber reclaiming, compounding, drying, milling, vulcanizing, plywood and particle board manufacturing, sawmills, textile picking, opening, blending, garnetting, carding and combing of cotton, synthetics, wool shoddy or burlap. Typically these uses are such that a significant fire hazard exists.</td>
</tr>
<tr>
<td>Group H Occupancies used as asphalt saturating, flammable liquids spraying, flow coating, open oil quenching, varnish and paint dipping, solvent cleaning, and manufactured home or modular building manufacturing (where the finished building enclosure is present and has combustible interiors). These uses are such that a severe fire hazard exists.</td>
</tr>
</tbody>
</table>

1See also Section 5-3.2
2For high-piled storage, see U.F.C. Article 81.
3For additional or more stringent criteria, see U.F.C. Article 79 or 80.

4. Sec. 2-1.1 is revised to read as follows:

2-1.1 All materials and devices shall be listed and approved.

5. Sec. 2-3.5 is revised to read as follows:

2-3.5. Other types of pipe or tube, such as plastic, may be used if is investigated and found to be listed for this service.

6. Sec. 2-8.1 is revised to read as follows:

2-8.1. The fire department connection(s) shall be internal swivel fittings having national standard hose thread or as approved by the chief.

7. Sec. 2-9.1 is revised by changing the last line as follows: “on the premises within two minutes after such flow begins.”
8. Sec. 2-9.5.1 is revised to read as follows:

Electrically operated alarm attachments forming part of an auxiliary, proprietary, remote station or local signalling system shall be installed in accordance with Uniform Fire Code Standard No. 10-2.

9. Sec. 3-9.1 is revised by deleting the last sentence.

10. Sec. 4-2-1 is revised by changing the last item to read as follows:

Storage—High piled storage (as defined in Uniform Fire Code)—40,000 square feet (3716 m²).

(Except to remain unchanged.)

11. Table 4-2.2 is revised by substituting “Uniform Fire Code Standards 81-1 and 81-2” for “NFPA 231 and 231C” in Footnote 6, Item 1, and by deleting “NFPA” in Footnote 6, Item 2.

12. Sec. 4-3.6.1 is revised by substituting “U.B.C. Standard 9-3” for “NFPA 13R, Standard for the Installation of Sprinkler Systems in Residential Occupancies up to and including Four Stories in Height,” and by deleting references to NFPA 13D.

13. Sec. 4-4.1.4.2 is revised by adding Exception 3 to read as follows:

Exception No.3: Where sprinklers are installed under composite wood joists less than 16 inches (406 mm) in depth, sprinkler deflectors shall be a minimum of 1 inch (25 mm) and a maximum of 6 inches (152 mm) below the bottom of the composite wood joist and the joist channels shall be fire-stopped the full depth of the joist with a material equivalent to the web construction so that individual channel areas do not exceed 300 square feet (27.9 m²). Where the depth of the composite wood joist is 16 inches (406 mm) or greater, protection shall be provided by using one or more of the following methods:

(a) Provide a sprinkler in each joist channel. The distance between sprinklers within the joist channel shall not exceed 15 feet (4572 mm).

(b) Protect the composite wood joist with 5/8-inch (16 mm) Type X gypsum wallboard attached directly to the bottom of the composite wood joist. Joist channels shall be fire-stopped the full depth of the joist with a material equivalent to the web construction so that the volume of individual channels do not exceed 160 cubic feet (4.53 m³).

(c) Completely fill the channel with noncombustible insulation. The insulation shall be secured to prevent the insulation from falling. Joist channels shall be fire-stopped the full depth of the joist with a material equivalent to the web construction so that the volume of individual channels does not exceed 160 cubic feet (4.53 m³).

14. Sec. 4-4.1.7.17 is revised to read as follows:

Rack Storage. For sprinklers in rack storage, see Uniform Fire Code Standard 81-2.

15. Sec. 4-5.2.1.2 is revised to read as follows:

When sprinkler piping is installed in storage racks as defined in U.F.C. Standard 81-2, piping shall be substantially supported from the storage rack structure or building in accordance with all applicable provisions of Sections 4-5.2 and 4-5.4.3.

16. Sec. 4-6.1.1.1 is revised to read as follows:

Local water-flow alarms shall be provided on each sprinkler system having more than five sprinklers and shall be located in an area approved by the chief.

17. Sec. 5-2.3.1.1 is revised by substituting “nationally recognized” for “NFPA” in the first line of Exception 1.

18. Sec. 5-2.3.1.3 (e) is revised by substituting the phrase “Uniform Building Code” for “NFPA 14, Standard for the Installation of Standpipe and Hose Systems” in the fourth line of the text and where located in the two exceptions.
19. Sec. 5-3.4.1 is revised by substituting “nationally recognized” for “NFPA” in the second line of the text.
20. Sec. 6-1.1.1.1 (l) is revised to read as follows:
   6-1.1.1.1 (l). Manufacturing data sheets for sprinkler head which contain at least the following information:
   - Make
   - Type
   - K-factor
   - Nominal office size
   - Temperature rating
   - Minimum operating pressures and discharge rates for proposed area of coverage.
21. Sec. 7-2.1 is revised by deleting “See NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances.”
22. Sec. 7-2.2.1 is revised by substituting “nationally recognized standards” for “NFPA 20, Standard for the Installation of Centrifugal Pumps.”
23. Sec. 7-2.3.1.1 is revised by substituting “nationally recognized standards” for “NFPA 22, Standard for Water Tanks for Private Fire Protection.”
24. Sec. 7-2.4 is revised by substituting “nationally recognized standards” for “NFPA 22, Standard for Water Tanks for Private Fire Protection.”
25. Sec. 8-2.2.5 is revised by substituting “nationally recognized standards” for “NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances” in the first sentence.
26. Sec. 8-2.2.5 is revised by substituting “nationally recognized standards” for “NFPA 24, Standard for the Installation of Private Fire Service Mains and Their Appurtenances” in the first sentence and by deleting “by NFPA 24 and” from the second sentence.
27. Sec. 8-4.1 is revised to read as follows:
   8-4.1. The installer of the system shall provide the owner with written instructions and information relating to the care and maintenance of the sprinkler system, with special attention given to the sprinkler system devices.
   Subsections (a) and (b) are deleted.
28. Sec. 9-1.1 is revised to read as follows:
   9-1.1. A sprinkler system installed under this standard shall be maintained in accordance with the U.F.C. Article 10.
29. Sec. 9-3.1 is revised by deleting “(See NFPA 24, standard for the installation of private Fire Service Mains and Their Appurtenances.”)
30. Chapter 10 is deleted.

Part II

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UNIFORM BUILDING CODE STANDARD 9-2
STANDPIPE SYSTEMS

See Sections 902, 904.1.2 and 904.5.1, Uniform Building Code

This standard, with certain exceptions, is based on the National Fire Protection Association Standard for the Installation of Standpipe and Hose Systems, NFPA 14-1993.

Part I of this standard contains exceptions to NFPA 14-1993. Part II of this standard contains NFPA 14-1993 reproduced in its entirety with permission of the publisher.

Vertically in the margin of Part II indicates there is a revision to the provisions within Part I.

Unless specifically adopted elsewhere, supplemental standards referenced in this primary standard shall only be considered to be guidance material subject to the approval of the building official.

Part I

SECTION 9.201 — AMENDMENTS

The Standard for Installation of Standpipe and Hose Systems, NFPA 14-1993, applies to the installation of standpipe systems except as follows:

1. Sec. 1-4 is revised by changing the definition of “authority having jurisdiction” as follows:

   AUTHORITY HAVING JURISDICTION is the building official.

   The definitions of “approved” and “listed” shall be as set forth in Volume I of this code.

   The definition of “shall” is deleted.

2. Sec. 2-4.2.5 is revised by substituting “(See NFPA 13)” with “(See U.B.C. Standard 9-1)” in the exception.

3. Sec. 4-1.2.5 is revised by substituting “NFPA 13, Standard for the Installation of Sprinkler Systems” with “U.B.C. Standard 9-1.”

4. Sec. 5-9.1.3.1 is revised by substituting “NFPA 13, Standard for the Installation of Sprinkler Systems” with “U.B.C. Standard 9-1” in the exception.

5. Sec. 8-7 is revised by substituting “NFPA 72, Standard for the Installation, Maintenance and Use of Protective Signaling Systems” with “U.F.C. Standard 14-1.”

6. Sec. 8-8 is revised by deleting Subsection (b).

7. Chapter 10 is deleted.

Part II

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UNIFORM BUILDING CODE STANDARD 9-3
INSTALLATION OF SPRINKLER SYSTEMS IN
GROUP R OCCUPANCIES FOUR STORIES OR LESS

See Sections 804.1, 805, 902, 904.1.2, 2603.7.1 and 2603.8.1,
Uniform Building Code

Part I

SECTION 9.301 — ADOPTION OF NFPA STANDARD

Except for the limitations, deletions, modifications and amendments set forth in Section 9.302 of this standard, the installation of sprinkler systems in Group R Occupancies required by this code shall be in accordance with the Standard for the Installation of Sprinkler Systems in Residential Occupancies, NFPA 13R-1989, published by the National Fire Protection Association, copyright © 1989, Batterymarch Park, Quincy, Massachusetts 02269, as if set out at length herein, or U.B.C. Standard 9-1.


SECTION 9.302 — AMENDMENTS

The National Fire Protection Association standard adopted by Section 9.101 applies to the selection, installation, acceptance inspection and acceptance testing of sprinkler systems in residential occupancies four stories or less, except as follows:

1. Sec. 1-3 is amended as follows:

The definition of “authority having jurisdiction” is revised as follows:

The “authority having jurisdiction” is the building official.

The definitions of “approved” and “listed” shall be as set forth in Volume 1 of this code.

The definitions of “should” and “standard” are deleted.

The definition of “residential occupancies” is revised as follows:

RESIDENTIAL OCCUPANCIES are Group R Occupancies.

The definitions of “acceptance” and “building official” are added as follows:

ACCEPTANCE is acceptance by the building official.

BUILDING OFFICIAL is the officer or other designated authority charged with the administration and enforcement of this standard, or the officer’s or other designated authority’s duly authorized representative.

2. Sec. 1-6.2.1 is revised by changing the reference to “NFPA 13” to “U.B.C. Standard 9-1.”

3. Sec. 2-1.3.2 is revised by changing the reference to “NFPA 13” to “U.B.C. Standard 9-1.”

4. Sec. 2-3.2 is revised by changing the reference to “NFPA 20 and 22” to “nationally recognized standards” and changing the reference to “NFPA 13” to “U.B.C. Standard 9-1.”

5. Sec. 2-3.3.2 is revised by changing the reference to “NFPA 13” to “U.B.C. Standard 9-1.”

6. Sec. 2-4.4 is revised by changing the reference to “NFPA 13” to “U.B.C. Standard 9-1.”

7. Sec. 2-5.2 is revised by changing the references to “NFPA 13” to “U.B.C. Standard 9-1.”

8. Sec. 2-5.3 is revised by changing the reference to “NFPA 13” to “U.B.C. Standard 9-1.”

9. Sec. 2-6 is revised by changing the reference to “NFPA 220” to “the Building Code.”
10. **Secs. 2-7.1 and 2-7.2 are added as follows:**

2-7.1. A sprinkler system installed under this standard shall be maintained in accordance with the Fire Code.

2-7.2. The installer of the system shall provide the owner with written instructions and information relating to the care and maintenance of the sprinkler system, with special attention given to the sprinkler system devices.

11. **Chapter 3 is deleted in its entirety.**

**Part II**

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¹The current edition is NFPA 13R-1994.
UNIFORM BUILDING CODE STANDARD 10-1
POWER-OPERATED EXIT DOORS
Test Standard of the International Conference of Building Officials
See Sections 1001.1 and 1004.8, Uniform Building Code

SECTION 10.101 — SCOPE

10.101.1 General. These requirements and methods of test apply to power-operated swinging doors and combination sliding and swinging doors intended for installation in locations where conforming exits are required by Chapter 10.

10.101.2 Operators and Activators. Power-operated doors may be provided with air, hydraulic or electric operators actuated from a floor, activating carpet, photoelectric device or other approved signaling device.

10.101.3 Fire Door Assemblies. Power-operated doors intended for installation in openings where fire door assemblies are required shall, in addition to the requirements of this standard, be tested in accordance with Fire Tests of Door Assemblies, U.B.C. Standard 7-2.

SECTION 10.102 — GENERAL

10.102.1 Panic Hardware. Power-operated doors intended for installation in openings where panic hardware is required shall be tested with panic hardware on the doors.

10.102.2 Opening Degree. When manually operated in the direction of egress, leaves of swinging doors or swing-out sections of sliding doors shall swing open to not less than 90 degrees from the closed position.

10.102.3 Locking Mechanisms. Locking mechanisms on doors intended for locations which do not require panic hardware shall be of a type readily identified as locked, and the doors shall be posted with durable, permanent signs reading THESE DOORS MUST REMAIN UNLOCKED DURING BUSINESS HOURS. Signs shall be 1-inch-high (25.4 mm) block letters on a contrasting background. Signs shall be located on the header framing.

10.102.4 Swinging and Sliding Doors. Each swing-out leaf of swinging or sliding doors with swinging sections shall be provided with durable signs in not less than 1-inch (25.4 mm) block letters on a contrasting background reading, IN EMERGENCY PUSH TO OPEN, or other approved wording. The sign shall be located at the closing edge of the door not less than 36 inches (914 mm) nor more than 60 inches (1524 mm) above the floor. The sign shall read horizontally and may be in two lines.

10.102.5 Electrical Wiring and Devices. Electrical wiring, electrical devices and controls shall be of a type tested and approved by the building official.

10.102.6 Testing. Doors with power operators shall be examined and tested by an approved testing agency.

10.102.7 Test Report. The test report shall contain engineering data and drawings, size and weight of door tested, wiring diagrams of electrical control systems, schematic drawings of mechanical controls and operating manuals. The report shall describe the mechanical operation of the power operator in sequence as the door opens and closes under normal and emergency conditions. The report shall set forth the tests performed in accordance with the provisions of this standard and the results thereof. Additionally, the report shall contain an analysis comparing each feature of the design against the performance test procedures contained herein.
10.102.8 Simulated Installation and Test Equipment. Doors with power operators shall be installed in a simulated wall and door framing assembly in accordance with the manufacturer's instructions. The test specimen shall not be less than 3 feet wide (914 mm) by 7 feet high (2134 mm). A motor-driven or suitable mechanism shall be used to actuate the activating carpet. The rate of operation or number of cycles shall be three to five per minute. On sliding doors with a swing-out section, additional operating endurance tests shall be conducted. A motor-driven mechanism or other approved means shall be used to push the swinging door section open and pull the swinging section closed at a rate of three to five cycles per minute, so that the latching mechanism and disconnect switches operate as in service. During the test the door specimen shall have only the lubrication which is provided by the manufacturer at the factory, or as may be recommended in the manufacturer's installation instructions.

10.102.9 Endurance Tests. The power operator shall function as intended to open and close the door for 100,000 cycles of operation without failure or excessive wear of parts. The release mechanisms and disconnect switches of the swinging section in sliding doors shall function as intended for 250 cycles of operation without failure or excessive wear of parts. The opening and closing forces, and the speed of opening and closing, shall be recorded at the start of the endurance tests and shall again be recorded at the end of the endurance tests. Opening and closing forces at the beginning and at the end of the endurance test shall not exceed the maximum forces prescribed in these test procedures.

SECTION 10.103 — SWINGING DOORS

10.103.1 Opening Size. Each door opening, when the door is in the 90-degree open position, shall provide a clear opening width of not less than 32 inches (813 mm), with no single leaf less than 24 inches (610 mm) in width.

10.103.2 Doors in Pairs. Doors in pairs shall be equipped with a separate operator for each leaf unless tests with a tandem operator with one leaf jammed in a closed and in a partially open position indicates that the second leaf continues to operate or is free to swing into the open position without exceeding the maximum permitted manual opening pressures. On doors with mechanical controls, one mechanism shall be subjected to fault conditions; during the fault condition, the second leaf shall be operable manually without exceeding the maximum permitted opening pressure.

10.103.3 Closing Mechanism. Normal closing of doors shall be by spring action, pressure-operated mechanism or electrically driven mechanism. The closing force measured at the closing stile shall not exceed 40 pounds (178 N) at any point in the closing arc. The time of final 10 degrees of closing shall not be less than one and one-half seconds.

10.103.4 Operation. Each possible fault condition that affects the power supply shall be introduced into the door and power operator assembly. Under each fault condition, single doors and each leaf of doors in pairs shall open to the 90-degree position with an applied pressure at the normal location of the push plate not exceeding 40 pounds (178 N).

10.103.5 In-swinging Doors. Power-operated in-swinging doors are not recognized for determining exit width opening required to swing in the direction of egress.

10.103.6 Activating Carpets and Safety Mats. Activating carpets and safety mats shall comply with the following provisions:

1. When carpets are used as the activating device, they shall have a width not less than 10 inches (254 mm) less than the clear width of the door opening with the center line of the carpet in the center line of the door opening. The width shall be measured between the exposed edges of the carpet tread surface excluding molded edge bevels or edge trim.

2. The length of activating carpets shall not be less than 42 inches (1067 mm). The length of activating carpets for doors exceeding 42 inches (1067 mm) in width shall not be less than 56 inches.
(1422 mm). The length shall be measured from the center line of the door pivot to the exposed edge of the carpet tread surface excluding molded edge bevels or edge trim.

3. Doors serving one-way traffic only shall be provided with a safety mat having a length not less than the width of the widest leaf. A safety mat is one that will prevent the door from opening if there is pressure on the safety mat before pressure is applied to the activating mat, and one that will prevent the door from closing following normal door actuation until pressure on the safety mat is removed.

4. Doors serving both egress and ingress shall have a series of joined carpets on the swing side of the door arranged as follows:
   4.1 One safety carpet or mat nearest to the door at least as long as the width of the door leaf;
   4.2 One or more activating carpets to provide a total carpet length on the swing side of not less than two and one-half times the width of the widest door leaf.

SECTION 10.104 — SLIDING DOORS

10.104.1 General. Sliding doors shall comply with the following provisions:
   1. Sliding leaves of sliding doors shall be provided with swinging sections arranged to swing in the direction of egress when pressure is applied at the location of normal push plates or on the crossbar of panic hardware on doors where panic hardware is required.
   2. Operation of the swinging section shall disconnect the sliding door power operator.
   3. Permanent stops shall be provided to prevent double swing.
   4. Location of the breakaway tension adjustment, opening and closing speed adjustment, opening and closing snub speed adjustments, opening and closing power pressure adjustments, and similar controls shall be concealed and not readily accessible where they may be subject to tampering.
   5. Doors shall be suspended from an overhead track. Operators and control levers or mechanisms shall be guarded.

10.104.2 Closing Mechanism. The closing force of sliding doors at 24 inches (610 mm) of opening shall not exceed 30 pounds (133 N) with a closing speed not in excess of 1.5 feet (457 mm) per second.

10.104.3 Opening Width. The minimum clear width of the door opening with the swinging section in position shall not be less than 32 inches (813 mm) with no single leaf less than 24 inches (610 mm) in width.

10.104.4 Opening Forces. The swinging section in sliding doors shall swing open into the full open position when an opening force not exceeding 40 pounds (178 N) is applied at the normal push plate location or on the crossbar of panic hardware.

10.104.5 Fault Condition Introduced. Under each possible fault condition that affects the power supply and with the sliding leaf or leaves retracted one half the leaf width into its or their pocket, each swinging section shall open to the 90-degree position with an applied pressure at the normal location of the push plate not exceeding 40 pounds (178 N).

10.104.6 Sliding Doors without Swing-out Section. Power-operated sliding doors which are not provided with a swing-out section may be evaluated for conformance to the requirements and endurance tests provided in this standard. Power-operated sliding doors which are not provided with a swing-out section shall not be listed for use in locations where required exits are specified by this code.

10.104.7 Activating Carpets and Safety Mats. Activating carpets and safety mats shall conform to Section 10.103.5.
SECTION 10.105 — MARKING

The name of the manufacturer, or trademark by which the manufacturer can be readily identified, shall be legibly marked on the operating equipment where it can be seen after installation. The type, model number or letter designation identifying the product as a listed device shall be provided on a label attached in a location as indicated in its listing.
UNIFORM BUILDING CODE STANDARD 10-2
STAIRWAY IDENTIFICATION

Specification Standard of the International Conference of Building Officials
See Sections 1001.1 and 1006.16, Uniform Building Code

SECTION 10.201 — SCOPE
Signs to provide information to the occupants and fire department personnel to ensure that they do not become confused during emergencies shall be installed in accordance with this standard.

SECTION 10.202 — GENERAL
Standardized signs shall be installed in stairways when the building is four or more stories in height. The signs shall identify each stair landing and indicate the upper and lower termination of the stairway.

SECTION 10.203 — SIGN DETAILS
10.203.1 Size. Signs shall be a minimum 12 inches (305 mm) by 12 inches (305 mm).

10.203.2 Stairway Location. The stairway location, such as STAIR NO. 1 or WEST STAIR, shall be placed at the top of the sign in 1-inch-high (25.4 mm) block lettering with 1/4-inch (6.4 mm) strokes.

10.203.3 Upper Terminus. The stairway’s upper terminus, such as ROOF ACCESS or NO ROOF ACCESS, shall be placed under the stairway identification in 1-inch-high (25.4 mm) block lettering with 1/4-inch (6.4 mm) strokes.

10.203.4 Floor Level Number. The floor level number shall be placed in the middle of the sign in 5-inch-high (127 mm) lettering with 3/4-inch (19 mm) strokes. The mezzanine levels shall have the letter “M” preceding the floor number. Basement levels shall have the letter “B” preceding the floor number.

10.203.5 Lower Terminus. The lower and upper terminus of the stairway shall be placed at the bottom of the sign in 1-inch-high (25.4 mm) block lettering with 1/4-inch (6.4 mm) strokes.
Examples:

- 1-inch (25.4 mm) size with \( \frac{1}{4} \)-inch (6.4 mm) stroke
- 5-inch (127 mm) size with \( \frac{3}{4} \)-inch (19 mm) stroke
- 1-inch (25.4 mm) size with \( \frac{1}{4} \)-inch (6.4 mm) stroke

WEST STAIR
NO ROOF ACCESS
M 1
B2 THROUGH 24

12 inches (305 mm)

STAIR 3
ROOF ACCESS
6
1 THROUGH 12

12 inches (305 mm)
SECTION 10.301 — SCOPE
This standard for exit ladder devices is applicable where such devices are permitted by the building
official for installation on existing apartment houses and hotels in conformance with Appendix
Section 3412.1 of this code.

SECTION 10.302 — INSTRUCTIONS
Installation shall be in accordance with the manufacturer’s instructions. Instructions shall be illus­
trated and shall include directions and information adequate for attaining proper and safe installa­
tion of the product. Where exit ladder devices are intended for mounting on different support
surfaces, specific installation instructions shall be provided for each surface.

SECTION 10.303 — GENERAL DESIGN
All load-bearing surfaces and supporting hardware shall be of non-combustible materials. Exit
ladder devices shall have a minimum width of 12 inches (305 mm) when in the position intended for
use. The design load shall not be less than 400 pounds (1780 N) for 16-foot (4877 mm) length and
600 pounds (2669 N) for 25-foot (7620 mm) length.

SECTION 10.304 — PERFORMANCE
10.304.1 Exit ladder devices shall be capable of withstanding an applied load of four times the de­
sign load when installed in the manner intended for use. Test loads shall be applied for a period of
one hour.

10.304.2 Exit ladder devices of the retractable type shall, in addition to the static load requirements
of Section 10.304.1, be capable of withstanding the following tests:
1. Rung strength.
2. Rung-to-side-rail shear strength.
3. Release mechanism.
4. Low temperature.

SECTION 10.305 — RUNG-STRENGTH TEST
Rungs of retractable exit ladder devices shall be capable of withstanding a load of 1,000 pounds
(4448 N) when applied to a 3 1/2-inch-wide (89 mm) block resting at the center of the rung. The test
load shall be applied for a period of one hour. The ladder shall remain operational following this
test.

SECTION 10.306 — RUNG-TO-SIDE-RAIL SHEAR TEST
Rungs of retractable exit ladder devices shall be capable of withstanding a load of 1,000 pounds
(4448 N) when applied to a 3 1/2-inch-wide (89 mm) block resting on the center rung as near the side
3-512
rail as possible. The test load shall be applied for a period of one hour. Upon removal of the test load
the fasteners attaching the rung to the side rail shall show no evidence of failure. The ladder shall
remain operational following this test.

SECTION 10.307 — RELEASE MECHANISM TEST

The release mechanism of retractable exit ladder devices shall operate with an average applied
force of not more than 5 pounds (22.2 N) for hand-operated releasing mechanisms and an average
applied force of not more than 25 pounds (111 N) for foot-pedal types of releasing mechanisms. For
these tests, a force gauge shall be applied to the release mechanism, and the average of three
consecutive readings shall be computed.

SECTION 10.308 — LOW TEMPERATURE OPERATION TEST

Representative samples of the exit ladder device shall be subjected to a temperature of −40°C, in an
environmental chamber for a period of 24 hours. The release mechanism shall be operated immedi­
ately upon removal from the chamber. The ladder device shall function as intended without any
restriction of operation.
UNIFORM BUILDING CODE STANDARD 10-4
PANIC HARDWARE

Based on Standard 305, July 30, 1979, of the
Underwriters Laboratories Inc.

See Sections 1001.1 and 1004.4, Uniform Building Code

SECTION 10.401 — SCOPE
10.401.1 General. These requirements cover releasing devices actuated by a crossbar for outward-opening doors designed to facilitate the safe egress of persons from buildings in the event of panic or other emergency.

10.401.2 Installation. A copy of the operating and installation instructions or equivalent information is to be furnished with the samples submitted for investigation for use as a guide in the examination and test of the mechanism. For this purpose a printed edition is not required.

SECTION 10.402 — CONSTRUCTION
10.402.1 Assembly. The mechanism shall be of a type which can be readily maintained in proper operating condition.

The mechanism shall be designed so as to release the door latch or latches when pressure is applied to the release bar in the direction of exit travel.

The ends of the release bar shall be curved, guarded or otherwise designed to prevent them from catching on the clothing of persons during exit.

The release mechanism shall not depend on springs to open the door latch or latches.

A locking or dogging device provided as part of the mechanism shall not prevent release of the door latch or latches when pressure is applied to the release bar in the direction of exit travel.

A dead-locking bolt shall not be employed unless it is released by the action of the release bar.

The projection of the release bar when in the depressed position shall not unduly restrict the exit opening.

10.402.2 Materials. The materials employed shall have adequate mechanical strength to perform their intended function. A metal or alloy shall have a solidus point not less than 1,000°F. (538°C.).

The materials employed shall minimize the likelihood of the release mechanism becoming inoperative due to corrosion.

SECTION 10.403 — PERFORMANCE
10.403.1 Endurance Test. The release mechanism and latches shall function as intended for 100,000 cycles of operation without failure or excessive wear of the parts.

The assembly is to be installed on a simulated door and frame assembly in accordance with the manufacturer’s instructions. A motor-driven mechanism is to actuate the release bar so as to release the latches and push the door open, as in service. The rate of operation is to be approximately 30 cycles of operation per minute. For this test, the assembly is to have the lubrication which is provided at the factory or recommended by the manufacturer.

10.403.2 Emergency Operation Test. The release mechanism shall be so designed that a horizontal force of 15 pounds (67 N) or less will actuate the release bar and latches. When the latched door is subjected to outward pressure as described below, a force of 50 pounds (222 N) or less shall actuate the release bar.

3-514
The sample is to be subjected to the 15-pound (67 N) test before and after the endurance test and subjected to the 50-pound (222 N) test after the endurance test.

A horizontal force of 250 pounds (1112 N) is to be applied against the latching edge adjacent to the latch in the direction in which the door opens. A spring scale or similar means is to be used to measure the horizontal force which is applied against the center of the release bar.

For double doors, a horizontal force of 250 pounds (1112 N) is to be applied against the midpoint of the outer stile of each door.

The release bar is not to be deformed by the test, and a spacing of at least 1 inch (25.4 mm) is to be provided between the release bar and the door face when the horizontal force is applied against the center of the release bar.

SECTION 10.404 — MARKING

The manufacturer’s or vendor’s name and a distinctive type of model designation shall be plainly marked on the release-bar assembly.

If a manufacturer produces panic hardware assemblies at more than one factory, each such assembly shall have a distinctive marking or identifying symbol to identify it as the product of a particular factory.
UNIFORM BUILDING CODE STANDARD 14-1
KRAFT WATERPROOF BUILDING PAPER

Based on Federal Specification UU-B-790a
(February 5, 1968)

See Sections 601.3, 711.1, 1401.2 and 1402.1, Uniform Building Code

SECTION 14.101 — SCOPE
This standard covers building papers composed predominantly of sulfate pulp fibers intended for use as a weather-resistive barrier.

SECTION 14.102 — CLASSIFICATION
The building papers shall be of Type I and not less than the following grades:
Grade A—High water-vapor resistance.
Grade B—Moderate water-vapor resistance.
Grade C—Water resistant.
Grade D—Water-vapor permeable.
Style 1a—Uncreped, not reinforced.
Style 1b—Uncreped, not reinforced, red rosin sized.
Style 2—Uncreped, not reinforced, saturated.
Style 3—Creped one direction, not reinforced.
Style 4—Uncreped, reinforced.

SECTION 14.103 — GENERAL REQUIREMENTS
14.103.1 Description. The paper shall be either a single-ply or a multi-ply lamination.
14.103.2 Paper. The paper shall consist of 100 percent sulfate pulp fibers, free of ground wood pulp, except as permitted in Section 14.104.8.
14.103.3 Construction. Lapped papers shall be securely cemented together throughout the seam area and shall have a minimum lap of 4 inches (102 mm). Laminated paper shall contain no area of more than \( \frac{1}{2} \) inch (13 mm), measured from the longitudinal edge of the combined sheet, which is devoid of the laminating agent. The paper shall not stick together to such an extent as to cause tearing when unrolled.
14.103.4 Treatment. The paper shall be treated by the addition of asphalt, asphalt waxes, wax blends, wet-strength resins, rosins, fire-retarding salts or any combining agent, to impart the necessary characteristics to the paper.
14.103.5 Reinforcing. When reinforcing is provided, the paper shall be reinforced by imbedding cords or strands of vegetable or inorganic fibers in the combining agent of the lamination.

SECTION 14.104 — SPECIFIC REQUIREMENTS
14.104.1 General. Except for Style 2, the paper shall not crack when bent over a \( \frac{1}{16} \)-inch (1.6 mm) mandrel at the temperature of 32°F (0°C.). If reinforced, the cords or strands shall average not less than 10 per foot (305 mm) in each direction.

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14.104.2 Grade A, High Water-Vapor Resistant. Grade A paper shall have the dry tensile strength, water-resistance and water-vapor transmission properties shown in Table 14-1-A.

14.104.3 Grade B, Moderate Water-Vapor Resistant. Grade B paper shall have the dry tensile strength, water-resistance and water-vapor transmission properties shown in Table 14-1-A.

14.104.4 Grade C, Water Resistant. Grade C paper shall have the dry tensile strength and water-resistance properties shown in Table 14-1-A.

14.104.5 Grade D, Water-Vapor Permeable. Grade D paper shall have the dry tensile strength, water-resistance and water-vapor transmission properties shown in Table 14-1-A.

14.104.6 Style 1a, Uncreped, Unreinforced. Style 1a paper shall be uncreped and shall not be reinforced.

14.104.7 Style 1b, Uncreped, Unreinforced, Red Rosin Sized. Style 1b paper shall be uncreped, not reinforced, and shall be coated with red rosin sizing.

14.104.8 Style 2, Uncreped, Unreinforced, Saturated. Style 2 paper shall be uncreped, not reinforced, and shall be saturated or infused with asphalt on both sides. Ground wood pulp may be included in the paper.

14.104.9 Style 3, Creped One Direction, Unreinforced. Style 3 paper shall be creped in one direction, not reinforced, and shall have a minimum elongation (stretch) of 15 percent.

14.104.10 Style 4, Uncreped, Reinforced. Style 4 paper shall be uncreped and reinforced.

SECTION 14.105 — TEST SPECIMENS

14.105.1 General. Test specimens shall be of the size designated by the applicable test or as otherwise provided herein.

The specimens shall be cut from the interior of the sample roll so that no specimen edge is nearer than 3 inches (76 mm) to the original sample edge. A minimum of 10 specimens, five in each direction of the paper, shall be cut from each sample for fire-resistance tests. Five specimens, each 5 inches square (127 mm by 127 mm), shall be cut from each sample for water-repellency tests. One specimen, 6 inches by 1 inch (152 mm by 25 mm) in the machine direction of the paper, shall be cut from each sample for the pliability test.

14.105.2 Grade Requirement. Grade requirement tests shall be made. Nonconformance to grade requirements of Table 14-1-A shall constitute failure of this test.

<table>
<thead>
<tr>
<th>PHYSICAL PROPERTY REQUIREMENT</th>
<th>GRADE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Dry tensile strength: minimum, pounds per inch width, both directions</td>
<td>20 (3500 N/m)</td>
</tr>
<tr>
<td>Water resistance: permeation of water through papers, hours minimum</td>
<td>24</td>
</tr>
<tr>
<td>Water-vapor transmission: grams per sq. meter per 24 hours</td>
<td>4</td>
</tr>
<tr>
<td>Maximum</td>
<td>Minimum</td>
</tr>
</tbody>
</table>

Approved test methods shall be used.
UNIFORM BUILDING CODE STANDARD 14-2

VINYL SIDING

Based on Standard Specification D 3679-91 for Rigid Polyvinyl Chloride (PVC) of the American Society for Testing and Materials
See Sections 1401.2 and 1404, Uniform Building Code

SECTION 14.201 — SCOPE

This standard establishes requirements and test methods for the materials, dimensions, warp, impact strength, weatherability, expansion and appearance of extruded single-wall siding manufactured from rigid PVC compound.

Unless specifically adopted elsewhere, supplemental standards referenced in this primary standard shall only be considered as guidance subject to the approval of the building official.

SECTION 14.202 — CONDITIONING

Specimens shall be preconditioned and tested in accordance with Procedure A of the ASTM D 618-61 (Reapproved 1990) for Method of Conditioning Plastics and Electrical Insulating Materials for Testing.

SECTION 14.203 — PHYSICAL REQUIREMENTS

The siding shall be made principally of polyvinyl chloride compound prepared from polyvinyl chloride homopolymer resin. The compound shall conform to the requirements of Table 14-2-A. The siding made from the resin shall conform to the requirements of Table 14-2-B.

14.203.1 Warp. A full length of siding shall not have a warp greater than 1/8 inch (3.2 mm).

14.203.2 Surface Distortion. The siding shall be free of bulges, waves and ripples.

SECTION 14.204 — WEATHERABILITY

14.204.1 General. The purpose of this test is to determine whether the siding will successfully retain its appearance after exposure to weather conditions for an extended period of time.

14.204.2 Procedure. Extruded specimens 6 inches (153 mm) long shall be exposed to the following climates:

2. Hot, humid climate (example: Miami, Florida).
3. Temperature, northern, industrial climate (example: Cincinnati, Ohio).

Specimen exposures shall be in accordance with ASTM D 1435-85. Samples shall face south either at a 45-degree angle of elevation for a minimum of one year or at an angle of elevation representative of the manufacturer's normal installation requirements for the siding for at least two years.

14.204.3 Conditions of Acceptance. Following exposure, the siding shall maintain a uniform color and be free of any visual surface or structural changes such as peeling, chipping, cracking, flaking and pitting.

SECTION 14.205 — MARKING

Each carton shall be labeled “Conforms to U.B.C. Standard 14-2.”
### TABLE NO. 14-2-A—MINIMUM PROPERTIES FOR PVC COMPOUNDS USED FOR SIDING

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact strength: (ft. lb./in. of notch)</td>
<td>1.5 (0.08 N•m/mm of notch)</td>
</tr>
<tr>
<td>Tensile strength (psi)</td>
<td>5,510 (37.99 MPa)</td>
</tr>
<tr>
<td>Modulus of elasticity (psi)</td>
<td>290,000 (1999 MPa)</td>
</tr>
<tr>
<td>Deflection temperature under load, (°F., at 264 psi)</td>
<td>158 (70°C., at 1.82 MPa)</td>
</tr>
</tbody>
</table>

### TABLE NO. 14-2-B—MINIMUM PROPERTIES FOR PVC SIDING

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (in.)</td>
<td>0.035 (0.89 mm)</td>
</tr>
<tr>
<td>Impact Resist. (in./lb./mil)</td>
<td></td>
</tr>
<tr>
<td>Embossed Siding</td>
<td>1.74 (391 mm/N/mm)</td>
</tr>
<tr>
<td>Unembossed</td>
<td>2.0 (450 mm/N/mm)</td>
</tr>
<tr>
<td>Coefficient of Lineal Expansion (max.) (in./in./°F.)</td>
<td>4.5 × 10⁻⁵ (2.5 × 10⁻⁵ m/m/°C.)</td>
</tr>
</tbody>
</table>
UNIFORM BUILDING CODE STANDARD 15-1
ROOFING AGGREGATES

Material Standard of the International Conference of Building Officials
See Section 1501.2 and Table 15-E, Uniform Building Code

SECTION 15.101 — SCOPE
This standard covers the quality, grading and amounts to be applied of mineral roofing aggregate.

SECTION 15.102 — CHARACTERISTICS
The mineral aggregate at the time of application shall be hard, durable, opaque, chemically inert, free of clay, loam, sand or foreign substances, and surface dry to 0.5 percent by weight moisture content.

SECTION 15.103 — GRADING
The mineral aggregate shall conform to the sieve analysis requirements prescribed in Table 15-1-A.

**TABLE 15-1-A**

<table>
<thead>
<tr>
<th>SIEVE SIZE</th>
<th>FOR USE WITH EMBEDMENT COAT OF 60 POUNDS PER ROOFING SQUARE (3.0 kg/m²) (percentage)</th>
<th>FOR USE WITH EMBEDMENT COAT OF 50 POUNDS PER ROOFING SQUARE (2.5 kg/m²) (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{5}{8}$ (16 mm)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>$\frac{1}{2}$ (12.5 mm)</td>
<td>90-100</td>
<td>90-100</td>
</tr>
<tr>
<td>$\frac{3}{8}$ (9.5 mm)</td>
<td>25-60</td>
<td>30-70</td>
</tr>
<tr>
<td>$\frac{1}{4}$ (6.3 mm)</td>
<td>0-10</td>
<td>0-10</td>
</tr>
<tr>
<td>No. 4 (4.75 mm)</td>
<td>0-2</td>
<td>0-10</td>
</tr>
<tr>
<td>No. 8 (2.36 mm)</td>
<td>0-4</td>
<td>0-1</td>
</tr>
<tr>
<td>No. 10 (2 mm)</td>
<td>0-1</td>
<td>0-0.5</td>
</tr>
<tr>
<td>No. 20 (850 mm)</td>
<td>0-0.5</td>
<td>0-0.5</td>
</tr>
</tbody>
</table>

SECTION 15.104 — WATER ABSORPTION
Aggregate shall not absorb more than 5 percent of the dry weight of the aggregate when tested using any nationally recognized standard.

SECTION 15.105 — TRANSLUCENCY
Aggregate shall have a translucency intensity of not more than “slight” when visually inspected.

SECTION 15.106 — HARDNESS
Aggregate shall have a hardness factor of not more than 20 percent.

SECTION 15.107 — APPLICATION
If the unit weight (loose) of the aggregate is 60 pounds per cubic foot (960 kg/m³), or more, the amount applied per roofing square shall be as specified in this code.

If the unit weight (loose) is less than 60 pounds per cubic foot (960 kg/m³), the amount applied shall be as follows:

3–520
1. For an embedment coat of 60 pounds of asphalt per roofing square (3.0 kg/m²), not less than 5 cubic feet of aggregate per roofing square (0.015 m³/m²) shall be applied.

2. For an embedment coat of 50 pounds of asphalt per roofing square (2.5 kg/m²), not less than 4 cubic feet of aggregate per roofing square (0.012 m³/m²) shall be applied.
UNIFORM BUILDING CODE STANDARD 15-2
TEST STANDARD FOR DETERMINING THE FIRE RETARDANCY
OF ROOF-COVERING MATERIALS

Based on Standard Specification 790 October 5, 1983,
of the Underwriters Laboratories Inc.

See Sections 601.3; 1501.2; 1502; 2602.5.2; 2603.1.6; 2603.7.1, Item 2; Table 15-A
Uniform Building Code

SECTION 15.201 — GENERAL

15.201.1 Scope. These requirements cover the performance of roof-covering materials exposed
to fire conditions, and are intended to indicate the characteristics of roof coverings when exposed to
fire originating from sources outside a building on which the coverings may be installed. They are
applicable to roof coverings intended for installation on either combustible or noncombustible
decks when the roof coverings are applied as intended.

Class A roof coverings are effective against severe fire test exposures. Under such exposures,
roof coverings of this class are not readily flammable, afford a fairly high degree of fire protection to
the roof deck, do not slip from position, and are not expected to produce flying brands.

Class B roof coverings are effective against moderate fire test exposures. Under such exposures,
roof coverings of this class are not readily flammable, afford a moderate degree of fire protection to
the roof deck, do not slip from position, and are not expected to produce flying brands.

Class C roof coverings are effective against light fire test exposures. Under such exposures, roof
coverings of this class are not readily flammable, afford a measurable degree of fire protection to
the roof deck, do not slip from position and are not expected to produce flying brands.

Tests conducted in accordance with these requirements are intended to demonstrate the
performance of roof coverings during the types and periods of exposure involved, but are not intended to
determine the acceptability of roof coverings for use after exposure to fire.

Roof-covering materials are also required to comply with the requirements for construction, ma-
terial specifications and performance as applicable to specific types, designs, sizes and arrange-
ments. All such applicable additional requirements are not considered to be within the scope of
these requirements for fire tests.

The terms “combustible” and “noncombustible” as used in the standard apply to decks as follows:
1. Combustible is a deck formed of wood (sheathing boards or plywood).
2. Noncombustible is a deck formed of metal, concrete or poured gypsum.

15.201.2 Test Apparatus. As illustrated in Figure 15-2-1, the apparatus used for the tests de-
scribed in Section 15.202 is to consist of the following:
1. A test deck to which the roof-covering materials to be tested are applied, mounted on a frame-
work. The pitch of the framework is to be adjustable.
2. A construction of noncombustible boards, mounted on the front of the framework to simulate
eaves and cornices.
3. A gas burner (for intermittent-flame, spread-of-flame and flying-brand tests) consisting of a
44-inch (1120 mm) length of nominal 2-inch (51 mm) [2.38-inch (60.3 mm) outside diameter] pipe
having a 1/2-inch-wide (12.7 mm), 36-inch-long (910 mm) slot in the side toward the test deck. The
burner is to be supplied with gas at both ends through nominal 1-inch (25 mm) [1.32-inch (33.4 mm)
outside diameter] pipe to provide uniform gas pressure at the burner assembly.
4. A blower and air duct for providing the required wind conditions. The air introduced by the blower is to be taken from outside the test room.

5. Adjustable fins mounted inside the air duct to straighten the airstream and reduce turbulence.

6. A baffle mounted on the back edge of the test deck to prevent backfiring under the deck.

7. Noncombustible boards extending from the sides and bottom of the air duct to the simulated-eaves-and-cornice construction mentioned in Item 2 (not used during burning-brand test).

The tests are to be conducted in a room vented to the outer air to relieve the air pressure created by the blower. During these tests, all doors and windows in the room are to be closed, and the room otherwise controlled as necessary to prevent outside wind and weather conditions from affecting the test results. Tests are not to be conducted if the room temperature is less than 50°F. (10°C.) or more than 90°F. (32°C.)

Figure 15-2-2 illustrates the essential elements of the rain test apparatus.

15.201.3 Preparation of Samples.

15.201.3.1 Deck construction. Except for treated wood shingles or shakes for the intermittent-flame and the burning-brand tests, the test deck is to be 3\(\frac{1}{3}\) feet (1016 mm) wide by 4\(\frac{1}{3}\) feet (1320 mm) long and is to be made of kiln-dried No. 1 white pine or ponderosa pine lumber with not less than 8 percent or more than 12 percent moisture content. The lumber is to be free from large or loose knots, sapwood, rot or pitch pockets, and is to contain no edge knots. Individual deck boards are to be of nominal 1- by 8-inch (25 mm by 203 mm) lumber (dressed on four sides). If used for the Class C burning-brand test, the width of the deck board is to be such that the brands will be located directly over the spaces between the boards. The deck boards are to be laid across the shorter dimension of the test deck, spaced \(\frac{1}{14}\) inch (6.4 mm) apart, and securely nailed to two nominal 2- by 4-inch (51 mm by 102 mm) wood battens located under and flush with the outer edges of the deck. Decks so constructed are to be even and uniform.

For the intermittent-flame, burning-brand and flying-brand tests on treated wood shingles and shakes, the test decks are to be constructed of nominal 1- by 4-inch (25 mm by 102 mm) lumber (dressed on four sides), spaced \(\frac{1}{12}\) inch (13 mm) apart and securely nailed to two nominal 2- by 4-inch (51 mm by 102 mm) wood battens. The lumber is to be of the quality specified in the above paragraph.

At the manufacturer's option, the roof covering may be investigated when applied to plywood decks of the minimum thickness recommended by the manufacturer. The plywood (A-C grade, Group 1, exterior) is to have face and back veneers of Douglas fir. A plywood deck is to have \(\frac{1}{16}\)-inch (3.2 mm) vertical and horizontal joints, and all vertical joints are to be centered on nominal 2- by 4-inch (51 mm by 102 mm) wood battens. If the manufacturer specifies that the battens are also to be used for horizontal joints, the classification shall be so restricted.

A plywood deck to be used for the intermittent-flame test is to have a horizontal joint 8 inches (229 mm) from and parallel to the 3\(\frac{1}{3}\)-foot-long (1020 mm) leading edge. In addition, a vertical joint that is centered on the deck and extends from the leading edge of the deck to the horizontal joint is to be provided. As the lower 11\(\frac{1}{2}\) inches (38 mm) of this joint is not protected by the nominal 2- by 4-inch (51 mm by 102 mm) batten, due to the mounting arrangement of the carriage, the underside of this joint from the end of the 2 by 4 (51 mm by 102 mm) to the leading edge of the deck is to be covered by a piece of sheet steel 2 inches (51 mm) wide.

A plywood deck to be used for a Class A or Class B burning-brand test is to be provided with a horizontal joint that is 22\(\frac{1}{2}\) inches (572 mm) from and parallel to the leading edge of the deck. A deck to be used for a Class A test is to have a vertical joint centered on the deck and extending above the horizontal joint. A deck to be used for a Class B test is to be provided with two vertical joints, extending above the horizontal joint, and each located 10 inches (254 mm) from and parallel to the side edges of the deck. A plywood deck to be used for a Class C burning-brand test is to have five horizontal joints with at least \(\frac{1}{16}\)-inch (3.2 mm) spacing between joints in the plywood.
Unless the material to be tested is intended for use on noncombustible decks only, the test deck for the spread-of-flame test, on material other than wood shingles and shakes, is to be constructed in accordance with either the intermittent-flame test or the manufacturer’s option above, except that (1) the vertical and horizontal joints need not be provided and (2) the length of the deck is to be 13 feet (3962 mm) for Class C tests; 9 feet (2743 mm) for Class B tests; and 8 feet (2438 mm) for Class A tests. For tests on materials intended for use on noncombustible decks only, a noncombustible deck of the applicable length may be used. The test deck for wood shingles and shakes is to be constructed of nominal 1- by 4-inch (25 mm by 102 mm) lumber (dressed on four sides) spaced 1 1/2 inches (38 mm) apart, and securely nailed to two nominal 2- by 4-inch (51 mm by 102 mm) wood battens, except that the length of the deck is to be as specified above.

15.201.3.2 Roof-covering application. Representative samples of a roof-covering material are to be applied to test decks constructed in accordance with the applicable requirements described above. The assemblies are to be conditioned in accordance with Subsection 3 below. The roof-covering material to be tested is to be applied, in accordance with the manufacturer’s instructions, to the applicable number of test decks as specified in Table 15-2-A. The material is to extend to, and be flush with, the edges of the deck, except for a 1-inch (25 mm) overhang at the leading edge.

15.201.3.3 Conditioning. The completed test assemblies are to be stored indoors at temperatures not lower than 60°F (16°C.) or higher than 90°F (32°C.) for the period of time necessary to cure the material, but not more than 60 days. Should storage conditions vary from those specified, the decks are to be stored until moisture determinations indicate that the deck lumber has no less than 8 percent or more than 12 percent moisture content. Test decks are to be stored so that each will be surrounded by freely circulating air.

SECTION 15.202 — PERFORMANCE

15.202.1 General. The intermittent-flame test, the spread-of-flame test and the burning-brand test are applicable to all roof coverings. The flying-brand test, the rain test and the weathering test are conducted only on treated wood shingles and shakes.

**EXCEPTION:** When the roof covering is limited to installation on noncombustible decks, the penetration tests, that is, the intermittent-flame test and the burning-brand test, need not be conducted.

For these tests, mortar (cementitious mixture, lime and water) is to be troweled into the joint formed by the leading edge of the roof-covering material and the framework of the carriage, to prevent air or the test flame from traveling under the material being tested.

During the tests, the test decks are to be subjected to an air current that flows uniformly over the top surface of the roof-covering material, as determined by a pretest calibration of the equipment using a bare 3 1/2- by 3 1/4-foot (1016 mm by 991 mm) plywood deck. At points midway up the slope of the bare deck, with the deck positioned at an incline of 5 inches to the horizontal foot (127 mm per 0.3 m), the velocity of the air current is to be 12 ± 1/2 miles per hour (19 ± 0.8 km/h), as measured at the center and edges of the deck, with each measurement being 3 11/16 inches (94 mm) above the surface of the deck.

For these tests, the test decks are to be at an incline of 5 inches per horizontal foot (127 mm per 0.3 m); except that built-up roof coverings are to be tested at the maximum incline recommended by the manufacturer, but not more than 5 inches per horizontal foot (127 mm per 0.3 m).

15.202.2 Intermittent-flame Test. A test deck is to be mounted on the framework at the required incline, and subjected to the specified air current. The test deck is then to be subjected to a luminous gas flame approximately triangular in shape, approximately 3 feet (914 mm) wide at the leading edge of the deck, and gradually narrowing to a width of approximately 6 inches (151 mm) at the top of the deck. Licks of flame may extend approximately an additional 1 to 2 feet (300 mm to 600 mm). The gas supply is to be regulated so that the flame, if not augmented by combustion of the roof covering, develops a temperature of 1,400°F ± 50°F. (760°C. ± 28°C.) for a Class A or Class B test, and
1,300°F ± 50°F (704°C ± 28°C) for a Class C test. The temperature is to be determined by a No. 14 B. & S. gage (0.064 inches) (1.63 mm) chromel-alumel wire thermocouple located 1 inch (25.4 mm) toward the source of flame from the lower edge of the first board of a bare deck formed of noncombustible material.

The flame is to be intermittently applied at intervals as specified in Table 15-2-B.

Following the last application of flame, air current is to be maintained until all evidence of flame, glow and smoke has disappeared from the exposed surface of the material being tested or until unacceptable results occur, but in no case is the air current to be maintained for more than one hour for a Class A or Class B test or one-half hour for a Class C test.

During the intermittent-flame test, including the on and off periods of flame application and the subsequent period of maintained airflow, the test deck is to be observed for the appearance of sustained flaming on the underside, production of flaming or glowing brands, displacement of portions of the test sample, and exposure or falling away of portions of the roof deck.

15.202.3 Spread-of-flame Test. A test deck is to be mounted and luminous gas flame applied, as described in Section 15.202.2, second paragraph, for the intermittent-flame tests.

For a Class A or Class B test, the gas flame is to be applied continuously for 10 minutes or until the spread of flame (flaming of the material being tested) permanently recedes from a point of maximum spread, whichever is the shorter duration. For a Class C test, the gas flame is to be applied for four minutes and then removed.

During and after the application of the test flame, the test sample is to be observed for the distance to which flaming of the material has spread, production of flaming or glowing brands, and displacement of portions of the test sample. The observation is to continue until the flame has permanently receded from a point of maximum spread.

15.202.4 Burning-brand Test.

15.202.4.1 General. A test deck is to be mounted as described in Section 15.202.2, second paragraph, for the intermittent-flame test, except that the framework is to be 60 inches (1524 mm) from the air duct outlet (see Figure 15-2-1), and the gas piping and burner are to be removed so as not to obstruct the airflow.

15.202.4.2 Size and construction of brands. The brands to be used in these tests are to be as shown in Figure 15-2-3 and are to be constructed as follows. Prior to the test, the brands are to be conditioned in an oven at 105°F to 120°F (40°C to 49°C) for at least 24 hours.

The Class A brand is to consist of a grid, 12 inches (305 mm) square and approximately 2 1/4 inches (57 mm) thick, made of kiln-dried Douglas fir lumber that is free from knots and pitch pockets. The brand is to be made of 36 strips of lumber each 3/4 inch by 3/4 inch (19.1 mm by 19.1 mm) square by 12 inches (305 mm) long, placed in three layers of 12 strips each, with strips spaced 1/4 inch (6.4 mm) apart. These strips are to be placed at right angles to those in adjoining layers and are to be nailed, using 1 1/2-inch (38.1 mm) long No. 16 gage nails, or stapled using No. 16 gage steel wire staples having a 7/32-inch (5.6 mm) crown and 1 1/4-inch (31.8 mm) legs, at each end of each strip on one face, and in a diagonal pattern as shown in Figure 15-2-3 on the other face. The dry weight of the finished brand is to be 2,000 grams ± 50 grams at the time of the test.

The Class B brand is to consist of a grid, 6 inches (153 mm) square and approximately 2 1/4 inches (57 mm) thick, made of kiln-dried Douglas fir lumber that is free from knots and pitch pockets. The brand is to be made of 18 strips of lumber 3/4 inch by 3/4 inch (19.1 mm by 19.1 mm) square and 6 inches (153 mm) long, placed in three layers of six strips each, with strips spaced 1/4 inch (6.4 mm) apart. The strips are to be placed at right angles to those in adjoining layers and are to be nailed, using 1 1/2-inch-long (38.1 mm) No. 16 gage nails, or stapled using No. 16 gage steel wire staples having a 7/32-inch (5.6 mm) crown and 1 1/4-inch (31.8 mm) legs, at each end of each strip on one face, and in a diagonal pattern as shown in Figure 15-2-3 on the other face. The dry weight of the finished brand is to be 500 grams ± 50 grams at the time of the test.
The Class C brand is to consist of a piece of kiln-dried nonresinous white pine lumber that is free from knots and pitch pockets. The brand is to measure 1 1/2 inches by 10 inches by 2 5/32 inch (38.1 mm by 38.1 mm by 19.8 mm) and a saw kerf 1/8 inch (3.2 mm) wide is to be cut across the center of both the top and bottom faces to a depth of one half the thickness of the brand, and at right angles to each other. The dry weight of the finished brand is to be 9 1/4 grams ± 1 1/4 grams at the time of the test.

15.202.4.3 Ignition of brands. Before application to the test deck, the brands are to be ignited so as to burn freely in still air as described below. The flame of the gas burner used to ignite the brands is to essentially envelop the brands during the process of ignition. The temperature of the igniting flame is to be 1,630°F ± 50°F (888°C ± 10°C) measured 2 5/16 inches (58.7 mm) above the top of the burner. The burner is to be shielded from drafts.

Class A brands are to be exposed to the flame for five minutes, during which time they are to be rotated to present each surface to the flame as follows:
- Each 12- by 12-inch (305 mm by 305 mm) face for 30 seconds.
- Each 2 1/4- by 12-inch (57.2 mm by 305 mm) face for 45 seconds.
- Each 12- by 12-inch (305 mm by 305 mm) face again for 30 seconds.

Class B brands are to be exposed to the flame for four minutes, during which time they are to be rotated to present each surface to the flame as follows:
- Each 6- by 6-inch (152 mm by 152 mm) face for 30 seconds.
- Each 2 1/4- by 6-inch (57.2 mm by 152 mm) face for 30 seconds.
- Each 6- by 6-inch (152 mm by 152 mm) face again for 30 seconds.

Class C brands are to be exposed to the flame for two minutes, during which time they are to be rotated to present each of the 1 1/2- by 1 1/2-inch (38.1 mm by 38.1 mm) faces to the flame for one minute.

15.202.4.4 Test conditions.

15.202.4.4.1 Class A. A brand is to be placed on the surface of each test deck at the location considered most vulnerable (point of minimum coverage over deck joint) with respect to ignition of the deck, but in no case closer than 4 inches (102 mm) from either side or 12 inches (305 mm) from the top or bottom edge of the deck. The brand is to be placed so that the strips in both the upper and lower layers are parallel to the direction of airflow. The brand is to be secured to the deck by a No. 18 B.&S. gage (0.040 inches) (1.02 mm) soft iron wire.

If the roof covering is applied to a pine board deck, the brand ordinarily will be in the most vulnerable location when the upper edge of the brand is located 3 inches (76 mm) above a horizontal joint in the test deck. If the roof covering is applied to a plywood deck, the brand ordinarily will be in the most vulnerable location when the brand is placed so that it is centered laterally with respect to the vertical joint in the test deck, and the upper edge of the brand is located 3 inches (76 mm) above the horizontal joint.

15.202.4.4.2 Class B. A brand is to be placed on the surface of the test deck at each of the two locations considered most vulnerable (point of minimum coverage over deck joint) with respect to ignition of the deck. Each brand is to be positioned with its upper edge 1 1/2 inches (38.1 mm) above the selected joint in the deck boards, but in no case closer than 6 inches (152 mm) from each side or 12 inches (305 mm) from the top or bottom edge of the deck. The brands are to be placed so that the strips in both the upper and lower layers are parallel to the direction of airflow. They are to be secured to the deck by a No. 18 B.&S. gage (0.040 inches) (1.02 mm) soft iron wire. The second brand is not to be applied until all burning resulting from the first brand has ceased.

If the roof covering is applied to a pine board deck, the brands ordinarily will be in the most vulnerable location when the upper edge of each brand is located 3 inches (76 mm) above a horizontal
joint in the test deck. If the roof covering is applied to a plywood deck, the brands ordinarily will be in the most vulnerable location when they are placed so that they are centered laterally with respect to a vertical joint in the test deck, and the upper edge of each brand is located 1\(\frac{1}{2}\) inches (38.1 mm) above the horizontal joint.

**15.202.4.4.3 Class C asphalt shingles.** Loose or unfastened portions of the shingles that can be bent up to 90 degrees without injury to the fastenings are to be cut away. Twenty ignited brands are then to be placed at one- or two-minute intervals in the areas of minimum coverage \(\frac{1}{2}\) inch (12.7 mm) away from any cut edge of shingles in the course above that course on which the brand is placed. No brand is to be placed closer than 4 inches (102 mm) to the point where the previous brand was located.

Brands are to be located not closer than 2 inches (50.8 mm) to the joints between adjacent shingles on the same course. All brands are to be placed so that the center of each brand is directly over the space between the deck boards. The saw kerf on the deck side of the brand is to be parallel to the direction of the airflow. The wire is to be placed in the other saw kerf.

If the roof covering is applied to plywood decks, the brands are to be placed centrally over the joints in the plywood deck.

**15.202.4.4.4 Class C sheet roofing or built-up covering assemblies.** Twenty ignited brands are to be placed at one- or two-minute intervals in the areas of minimum coverage. No brand is to be placed closer than 4 inches (102 mm) to the joint where a previous brand was located. All brands are to be placed so that the center of each brand is directly over the space between the deck boards. See “asphalt shingles” for securing of brands in place and relative positioning of brand saw kerfs.

**15.202.4.4.5 Class C treated wood shingles and shakes.** Twenty ignited brands are to be placed on each treated wood shingle deck at one- or two-minute intervals. For treated wood shakes, 20 ignited brands are to be distributed at one- or two-minute intervals on each pair of decks. Each brand is to be centered over the \(\frac{1}{4}\)-inch (6.4 mm) joint between shakes or shingles so that the top edge of the brand is approximately \(\frac{1}{2}\) inch (12.7 mm) below the butt of the shake or shingle in the course above. No brand is to be placed closer than 4 inches (102 mm) to the point where a previous brand was located. See “asphalt shingles” for securing of brands in place and relative positioning of brand saw kerfs.

**15.202.4.4.6 Duration of tests.** Each individual test, whether Class A, Class B or Class C, is to be continued until the brand is consumed and until all evidence of flame, glow and smoke has disappeared from both the exposed surface of the material being tested and the underside of the test deck, or until unacceptable results occur, but not for more than 1\(\frac{1}{2}\) hours for a Class A or Class B test. The results of tests in which the brands do not show progressive and substantially complete consumption after application to the test deck are to be disregarded.

**15.202.4.4.7 Observations.** During the tests, observations are to be made for the appearance of sustained flaming on the underside of the test deck, production of flaming or glowing brands of roof-covering material, displacement of the test sample and the exposure or falling away of portions of the roof deck.

**15.202.5 Flying-brand Test.** This test applies to Class B and Class C treated wood shingles and shakes. If a Class A rating is desired, appropriate tests of increased severity are to be conducted.

A test deck is to be mounted and a luminous gas flame applied as described in Section 15.202.2, second paragraph, for the intermittent-flame test.

The gas flame is to be applied continuously for (1) 10 minutes for a Class B test and (2) four minutes for a Class C test. The air current is to be maintained until all evidence of flame, glow and smoke has disappeared from the exposed surface of the material being tested to determine if flying
brands will be developed. For treated wood shakes, the velocity of the air current is to be increased to 18 miles per hour (29 km/h) after the gas flame is extinguished.

15.202.6 Rain Test. The test decks are to be mounted in a framework at a slope of 4 units vertical to 12 units horizontal (33.3%). Spray nozzles that deliver an average of 0.7 inch (18 mm) of water per hour at a temperature of 35°F. to 60°F. (2°C. to 15°C.) are to be mounted approximately 7 feet (2134 mm) above the test decks. The test decks are to be exposed to 12 one-week conditioning cycles. Each cycle is to consist of 96 hours of water exposure followed by 72 hours of drying time at 140°F. (60°C.). The final drying cycle is to be controlled so that the moisture content of the deck lumber is between 8 and 12 percent. The conditioned decks are then to be tested in accordance with Table 15-2-A.

An alternative test cycle may be utilized at the manufacturer's option whereby two sets of six decks are to be alternately exposed to seven days (168 hours) of water exposures, followed by two days' (48 hours) draining and five days' (120 hours) curing at 140°F. (60°C.). This cycle is to be repeated seven times, except that the seventh water exposure is to be reduced to six days (144 hours).

15.202.7 Weathering Test. The test decks are to be mounted outdoors at an incline of 5 units vertical to 12 units horizontal (41.7%), facing south. After each of one, two, three, five and 10 years of exposure, three test decks are to be brought indoors and conditioned until the deck lumber attains a moisture content between 8 and 12 percent. From each set of decks, one deck is to be subjected to the intermittent-flame test, one to the burning-brand test and one to the flying-brand test.

SECTION 15.203 — CONDITIONS OF ACCEPTANCE FOR CLASSIFICATION

At no time during the intermittent-flame, spread-of-flame or burning-brand tests shall:

1. Any portion of the roof-covering material be blown or fall off the test deck in the form of flaming or glowing brands, or
2. The roof deck be exposed by breaking, sliding, cracking or warping of the roof covering, or
3. Portions of the roof deck fall away in the form of glowing particles.

For the purpose of the requirements, any piece of roof covering that continues to glow or flame upon landing on the test room floor is considered to be a glowing or flaming brand, respectively.

At no time during the Class A, Class B or Class C intermittent-flame or burning-brand tests shall there be sustained flaming of the underside of the deck.

**EXCEPTION:** If flaming does occur, another series of tests may be conducted and the results accepted provided no additional sustained flaming occurs.

For the spread-of-flame test, the flaming of the material shall not have spread beyond 6 feet (1829 mm) for Class A, 8 feet (2438 mm) for Class B and 13 feet (3962 mm) (the top of the deck) for Class C. There shall have been no significant lateral spread of flame from the path directly exposed to the test flame.

For the flying-brand test on treated wood shingles and shakes, flying, flaming or glowing brands shall not be produced.
### TABLE 15-2-A—REQUIRED TESTS AND TEST ASSEMBLIES

<table>
<thead>
<tr>
<th>MATERIAL TO BE TESTED</th>
<th>REQUIRED NUMBER OF TEST ASSEMBLIES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intermittent-flame Test</td>
</tr>
<tr>
<td>Other than wood shakes or shingles, for installation on:</td>
<td></td>
</tr>
<tr>
<td>A. Combustible decks:</td>
<td></td>
</tr>
<tr>
<td>1. Class A</td>
<td>2</td>
</tr>
<tr>
<td>2. Class B or C</td>
<td>2</td>
</tr>
<tr>
<td>B. Noncombustible decks only</td>
<td>NA</td>
</tr>
<tr>
<td>Wood shakes and shingles</td>
<td></td>
</tr>
<tr>
<td>A. Class A</td>
<td>3 (2) [5]</td>
</tr>
<tr>
<td>B. Class B or C</td>
<td>3 (2) [5]</td>
</tr>
</tbody>
</table>

**Notes:**
- NA—Test is not required.
- The number in parentheses is the number of samples from the rain test.
- The number in brackets is the number of samples from the weathering test.

### TABLE 15-2-B—FLAME APPLICATION

<table>
<thead>
<tr>
<th>CLASS</th>
<th>FLAME ON (minutes)</th>
<th>FLAME OFF (minutes)</th>
<th>NUMBER OF TEST CYCLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>
FIGURE 15-2-1—FIRE TEST APPARATUS
Free outlet to be provided to relieve air pressure created by blower. Doors and windows in the room that houses the apparatus to be kept closed at all times during tests to prevent turbulence which would otherwise distort flame and prevent adequate control thereof.

FIGURE 15-2-1—FIRE TEST APPARATUS—(Continued)
FIGURE 15-2-2—RAIN-TEST APPARATUS
UNIFORM BUILDING CODE STANDARD 15-3
WOOD SHAKES

Part I—Wood Shakes (Nonpreservative Treated)

Based on Grading and Packing Rules for Red Cedar Shakes of the
Cedar Shake and Shingle Bureau, 1975

See Sections 1501.2, 1502, 1507.2 and 1507.12, Uniform Building Code

SECTION 15.301 — SCOPE

Wood shakes regulated under this part shall be of an approved durable wood and shall be manufactured and graded No. 1 shakes or No. 1 or 2 taper-sawn shakes in accordance with this standard, and their use shall be governed by the provisions of Chapter 15 of this code.

SECTION 15.302 — DEFINITIONS

15.302.1 General. For the purposes of this part, certain words and phrases are defined as follows:

- **BUTT** is the thicker end of the shake.
- **CHECK** is any separation of the wood.
- **COURSE** is a horizontal layer forming one of a series of layers on a roof or wall or in the packed bundle.
- **CRIMPS** is a breaking down or collapse of wood cells during drying, characterized by a caved-in or corrugated appearance.
- **DECAY (ROT)** is the decomposition of wood substance caused by action of wood-destroying fungi, resulting in softening, loss of strength and weight and change of texture and color.
- **EXPOSURE** is the portion which, when applied, is exposed to the weather.
- **EXPOSURE LINE** is an imaginary line drawn across the shake at the same distance above the butt that is equal to the weather exposure.
- **FEATHER TIP** or shim is a condition of manufacture found on the thin ends of some shakes where the saw came out of the piece prematurely, producing a thin, flimsy, feather-like tip that is uneven or has corners sawn off.
- **GRAIN** is the direction, size, arrangement, appearance or quality of the fibers in wood. To have a specific meaning, the term must be qualified:
  - **Cross Grain** is a condition that should not be confused with the terms “flat grain” or “edge grain,” and that might better be termed “cross fiber,” since it is a deviation of the wood fibers from the true parallel of the face of the shake. It is a defect when it runs from one face of the shake to the other within a longitudinal distance of 3 inches (76 mm) or less in that portion measured 6 inches (153 mm) from the butt. There is to be no excessive cross grain in the remainder of the shake.
  - **Diagonal Grain** is a condition where the grain of the wood does not run parallel to the edges of the shake. It is considered a defect when the grain diverges or slants 2 inches (51 mm) or more in width in 12 inches (305 mm) of length.
  - **Edge Grain or Vertical Grain** is wood cut in a plane approximately at right angles to the annual rings. A condition in which the rings form an angle of 45 degrees or more with the face of the piece.
  - **Flat Grain** is wood cut in a plane approximately tangential to the annual rings and means a condition in which the rings form an angle of less than 45 degrees with the face of the piece.
Torn Grain (Torn Fiber) is a fuzzy or whiskered appearance in the face of the shake. Usually caused by a dull saw or grain deviations.

HEARTWOOD (HEART) is the inner layer of a woody stem wholly composed of nonliving cells and usually differentiated from the outer enveloping layer (sapwood) by its darker color.

KNOT is that portion of a branch or limb which has been surrounded by subsequent growth of wood of the tree.

LINEAL INCH is the total width of any given number of shakes when laid edge to edge.

PLY is the minimum number of thicknesses, when applied, of shakes or at any point on the covered surface. This term is relative to exposure.

SAPWOOD is wood containing some living cells and forming the initial wood layer beneath the bark of the log. Sapwood may be lighter in color than heartwood.

SHIM. See “feather tip.”

SQUARE PACK is a unit providing sufficient shakes for the coverage of a given area when the shakes are laid at the required exposure to the weather. (See Tables 15-3-A and 15-3-B.)

TIP is the thinner end of the shake.

WAVES are the washboard-like irregularities on the face of a shake.

WORMHOLE is a hole or passage burrowed by a worm or insect.

15.302.2 Shake Types. Shake types shall be one of the following types:

1. Handsplit-and-resawn have split faces and sawn backs, and are produced by running split wood blanks or boards of proper thickness diagonally through a handsaw to produce two tapered shakes from each blank.

2. Shake hip and ridge are two shakes that have one edge, each sawn on a bevel and fastened together to produce the cap for the hip or ridge of the roof.

3. Straight-split are manufactured by splitting from only one end of a block of wood, producing shakes which are the same thickness throughout.

4. Taper-sawn are tapered pieces sawn both sides.

5. Taper-split are split both sides. A natural taper, from butt to tip, is achieved by reversing the block, end for end, with each split.

SECTION 15.303 — QUALITY STANDARDS

15.303.1 No. 1 Grade Shake. Shakes shall be 100 percent clear, graded from the split face in the case of handsplit-and-resawn shakes and from the best face in the case of taper-split, taper-sawn and straight-split shakes.

Shakes shall be 100 percent heartwood, free of bark and sapwood, except that up to 1/8 inch (3.2 mm) of sapwood is permitted on one edge.

Taper-split shakes and straight-split shakes shall be 100 percent edge-grain; taper-sawn shakes may include up to 10 percent of flat-grain in the lineal inches (mm) of any bundle. Handsplit-and-resawn shakes may include up to 20 percent of flat-grain in the lineal inches (mm) of any bundle.

Curvature in the sawed face of handsplit-and-resawn shakes shall not exceed 1 inch (25 mm) from a level plane in the length of the shake. Excessive grain sweep on the face shall not be permitted. Knots, wormholes, decay, checks, crimps, waves and torn fiber are not permitted.

15.303.2 No. 2 Grade Taper-sawn Shakes. No. 2 grade taper-sawn shakes shall be of sound and serviceable material, graded from the best face. Flat grain is allowed in the No. 2; sapwood is restricted to 1 inch (25 mm) in width in the first 10 inches (254 mm) above the butt. Defects such as
knots, wormholes, decay, crimps, cross grain, waves or torn fiber are not allowed in the first \(7\frac{1}{2}\) inches, 9 inches and 12 inches (191 mm, 229 mm and 305 mm) from the butt in the 15-inch, 18-inch and 24-inch (380 mm, 455 mm and 610 mm) lengths, respectively, of the No. 2 grade taper-sawn shakes. In the same product, grain characteristics, other than cross grain, are not considered defects; defects may be up to \(1\frac{1}{2}\) (38 mm) inches in diameter, but aggregate defects must not exceed one half the width of the shakes.

SECTION 15.304 — SIZE

15.304.1 Length.

15.304.1.1 No. 1 grade shake. Nominal shake lengths shall be 15 inches, 18 inches or 24 inches (380 mm, 455 mm and 610 mm), with a minus tolerance of \(1\frac{1}{2}\) inch (13 mm) and a plus tolerance of 2 inches (51 mm). A variation, including shims or feather tips, of 1 inch (25 mm) from these nominal lengths of 18-inch (455 mm) shakes shall be permitted in 5 percent of the lineal inches of shakes in any bundle. A variation of 2 inches (51 mm) shall be permitted in 24-inch (610 mm) shakes. See Table 15-3-A. The 15-inch (380 mm) starter-finish course grade shall permit a tolerance of 1 inch (25 mm) over and under the nominal 15-inch (380 mm) length.

15.304.1.2 No. 2 grade shake. Minimum lengths of 15-inch, 18-inch and 24-inch (380 mm, 455 mm and 610 mm) shakes shall be 14, 16 and 22 inches (356, 406 and 559 mm), respectively.

15.304.2 Thickness.

15.304.2.1 No. 1 grade shakes. Shake thickness shall be determined by measurement of the butt within \(1\frac{1}{2}\) inch (13 mm) from each edge. If corrugations or valleys exceed \(1\frac{1}{2}\) inch (13 mm) in depth, a minus tolerance of \(1\frac{1}{8}\) inch (3.2 mm) is permitted in the minimum specified thickness. The thickness at the exposure line shall be a minimum of one half the butt thickness, except that \(3\frac{1}{8}\)-inch (9.5 mm) shakes shall have a minimum thickness of \(1\frac{1}{4}\) inch (6.4 mm) at the exposure line.

15.304.2.2 No. 1 and No. 2 grade taper-sawn shakes. No. 1 and No. 2 grade taper-sawn shakes shall have one of two thicknesses at the butt, \(5\frac{1}{8}\) inch (16 mm) or \(3\frac{1}{4}\) inch (19 mm) with a minus tolerance of \(1\frac{1}{16}\) inch (1.6 mm) in 10 percent of a bundle.

15.304.3 Width.

15.304.3.1 No. 1 grade shake. Shakes shall be of random widths, none narrower than 4 inches (102 mm). Handsplit-and-resawn shakes shall have a maximum width of 14 inches (356 mm).

15.304.3.2 No. 2 grade taper-sawn shake. No. 2 grade taper-sawn shakes shall have a minimum width of 3 inches (76 mm); shakes less than 4 inches (102 mm) in width shall not constitute more than 10 percent of the running inches of each bundle. Edges shall be parallel within \(1\frac{1}{2}\) inch (13 mm).

15.304.4 Edges. Edges of shakes shall be parallel within 1 inch (24 mm). Edges of taper-sawn shakes shall be parallel within \(3\frac{1}{8}\) inch (16 mm).

SECTION 15.305 — PACKING

15.305.1 General. Shakes shall be packed in straight courses in regular frames 18 to 20 inches (457 to 508 mm) wide. See Tables 15-3-A and 15-3-B.

15.305.2 Identification. Each bundle of wood shakes graded under this standard shall bear the label of an approved inspection bureau or agency. The label shall be white base stock with predominantly blue ink and shall clearly indicate No. 1 grade.

SECTION 15.306 — INSPECTION

Shakes shall be adjudged off grade if the total lineal inches of on-grade shakes is less than 268 inches (6807 mm) per bundle.
SECTION 15.307 — REINSPECTION

In case of reinspection, 10 or more bundles selected at random shall constitute a fair sampling of the shipment. The criteria for inspection of shakes specified in Section 15.306 shall also apply for reinspection.

Part II—Grading Rules for Shake Hip and Ridge Based on the Standards of the Cedar Shake and Shingle Bureau

SECTION 15.308 — DEFINITION

Shake, hip and ridge units are manufactured from No. 1 grade handsplit and resawn shakes, or No. 1 or No. 2 taper-sawn shakes that have one edge sawn on a bevel and fastened together to produce the cap for the hip or ridge of the roof.

SECTION 15.309 — QUALITY STANDARDS

No. 1 hip and ridge units shall be produced from material that meets the standard for No. 1 shakes; No. 2 units shall be produced from material that meets the standard for No. 2 taper-sawn shakes. Lower grade material is not permitted.

SECTION 15.310 — SIZE

At the time of manufacture, the shake hip and ridge assembly width shall be 9 inches (229 mm), measured on the underneath side of the assembly at the butt end. A minus tolerance of \( \frac{1}{8} \) inch (3.2 mm) is allowed. Butt misalignment of assemblies in excess of \( \frac{1}{4} \) inch (6.4 mm) is not permitted. The narrow component shall have a minimum width of 4 1/2 inches (115 mm) at the butt end. For taper-sawn ridge, top corners at the outer edge of the units shall not be more than a 90-degree angle.

SECTION 15.311 — PACKING

Individual shake hip and ridge units are made up of one wide and one narrow component. They shall be packed 20 units per bundle with an equal number of right-hand and left-hand units (for alternating laps). Units shall be manufactured to a 4 units vertical to 12 units horizontal (33.3%) pitch or steeper. Units shall be joined with not less than two fasteners applied between 1 inch and 8 inches (25 mm and 203 mm) from the butt. Either staples or nails are acceptable. Fasteners shall be corrosion resistant, spaced approximately 4 inches (102 mm) apart.

SECTION 15.312 — INSPECTION

Each off-grade unit counts as 5 percent of the grade; more than two off-grade units per bundle shall preclude a passing grade.

Part III—Wood Shakes Preservatively Treated

SECTION 15.313 — SCOPE

Wood shakes regulated by this part shall be manufactured, preservative treated and graded in accordance with this standard, and their use shall be governed by the provisions of Chapter 15 of this code.
SECTION 15.314 — DEFINITIONS

For the purpose of this section, certain words and phrases are defined as follows:

- **COVERED AREA** refers specifically to that portion of the face which will be covered in place.
- **EXPOSED FACE** refers specifically to that 10-inch (252 mm) or 7 1/2-inch (190 mm) section which will be exposed to the elements.
- **FACE** refers to the entire best side of the shake, which would be expected to be installed facing up.
- **REVERSE** refers to the entire reverse side which would be expected to be installed facing down.
- **TAPER-SAWN SHAKES** are sawn both sides with edges sawn and are 18 inches or 24 inches (455 mm or 610 mm) in length.
- **TIP ZONE** refers to the final 4 inches (102 mm) or 3 inches (76 mm) [of a 24-inch (610 mm) or 18-inch (455 mm) shake, respectively] adjacent to the tip.

SECTION 15.315 — QUALITY STANDARDS

15.315.1 Manufacture.

15.315.1.1 Length. The length of shakes shall be 24 inches (610 mm) and 18 inches (455 mm), allowing for a minus tolerance of 1/2 inch (13 mm) and a plus tolerance of 2 inches (51 mm).

A variation of a minus 1 inch (25 mm), including shims and feathertips, would be permitted in 5 percent of lineal inches (mm) of shakes per bundle, provided that the shake thickness on both edges at the 22-inch (560 mm) and 16-inch (406 mm) lengths is at least 1/8 inch (3.2 mm).

Angled end trim at butt shall not exceed approximately 1/2 inch (13 mm) per 4 inches (102 mm) of width.

15.315.1.2 Thickness. The green butt thickness of shakes shall be 13/16 inch (21 mm), with a minus tolerance of 1/8 inch (3.2 mm) allowed in 10 percent of lineal inches (mm) of shakes per bundle. The maximum thickness shall not exceed 1 1/16 inches (27 mm).

Tip thickness shall be 1/8 inch to 1/4 inch (3.2 mm to 6.4 mm).

Thickness variation across the width limited by the above-stated maximums and minimums.

“Dish out” of thickness along length is allowed if it does not reduce the thickness more than 1/4 inch (6.4 mm) on the exposed face and is not less than one half the standard thickness in the covered area.

15.315.1.3 Width. Minimum green width shall be 4 inches (102 mm); maximum shall be 8 inches (203 mm). When checking dry material, a maximum shrinkage allowance of 1/4 inch (6.4 mm) under the 4-inch (102 mm) minimum will be considered.

Shakes shall be parallel within 1/16 inch (1.6 mm).

15.315.1.4 Treatment. Southern pine taper-sawn shakes shall be preservative treated in accordance with approved nationally recognized standards.

15.315.2 Grade Defects Limited throughout Each Shake.

15.315.2.1 Compression wood. Compression wood is prohibited if in readily identifiable and damaging form. Damaging form includes, but is not limited to, bands of compression wood exceeding 1/2 inch (13 mm) in width, or bands running along an edge, or solid blocks of compression wood.

15.315.2.2 Density. Medium to dense grain is required measured across the entire butt. Not less than four complete annual rings per inch are permitted at any location.
15.315.2.3 Heart or ring shakes. Heart or ring shakes are prohibited.
15.315.2.4 Slope of grain. Diagonal or spiral grain shall not exceed 1 inch (25 mm) in 10 inches (254 mm). Abnormal grain distortions on face are not permitted.
15.315.2.5 Stain. Medium blue stain is permitted.
15.315.2.6 Unsound wood. Unsound wood is prohibited on either face.
15.315.2.7 Warp. Facial curvature (bow), twist, or both, shall not exceed $\frac{1}{4}$ inch (6.4 mm) from a level plane.

15.315.3 Grade Defects Limited by Location.
15.315.3.1 General. The shake shall be graded from the best face.
15.315.3.2 Holes. Well-scattered ambrosia beetle pin holes up to $\frac{1}{16}$ inch (1.6 mm) in diameter are allowed if not through the thickness and if limited to six per 10 inches (254 mm) of length on the face. All other types of knot, insect or mechanical holes are prohibited, except an occasional $\frac{1}{2}$-inch (13 mm) hole or encased pith knot is allowed along an edge of the covered area if not extending more than $\frac{1}{2}$ inch (13 mm) into the shake width.
15.315.3.3 Knots. Knots shall be measured by average facial dimensions. Pith knots are prohibited on the face. They are allowed on reverse side only if the pith hole is not through the thickness. Generally, no knots are permitted on the exposed face. However, 5 percent of the lineal inches (mm) of shakes per bundle may have up to a $1\frac{1}{2}$-inch (38 mm) cumulative area of sound or firm and tight knots. Sound or firm and tight knots are limited to a 2-inch (51 mm) cumulative size located in the top one half of the shake at the tapered end. Individual knots of any quality are limited to a maximum size of $1\frac{1}{2}$ inches (38 mm) on the reverse face. A No. 2 shake may contain up to a $1\frac{1}{2}$-inch (38 mm) cumulative area of sound or firm and tight knots in the exposed $7\frac{1}{2}$- or $5\frac{1}{2}$-inch (190 mm or 140 mm) face.
15.315.3.4 Grain. Generally, vertical grain is required. On the exposed face, flat grain is allowed only along an edge of the face. Center of flat grain not permitted within $1\frac{1}{2}$ inches (38 mm) of center of shake. For No. 2 grade shakes, there are no restrictions on amount or location of flat grain in shake.
15.315.3.5 Pitch pockets. Pitch pockets are prohibited on the exposed face. They are allowed if not through in the covered area and on the reverse side, with the exception that through pitch pockets are allowed in the tip zone.
15.315.3.6 Pith. Pith is not allowed if contained within the thickness of a shake, or if along the surface of the exposed face. A superficial (split) pith is allowed in the covered area or on the reverse side.
15.315.3.7 Wane. Pencil wane is only allowed on the face. Wane on the reverse side is allowed, not to exceed one half the thickness by one sixth the width if located within one half the shake length from the butt; otherwise, wane in occasional pieces may be through the thickness if not reducing the face width by more than $\frac{1}{2}$ inch (13 mm).
15.315.3.8 Reverse Face. Other than the limitations described, the reverse face shall be free of defects which might prevent normal use.

SECTION 15.316 — INSPECTION
Shakes shall be adjudged off grade if the total lineal inches (mm) of defective shakes exceeds 5 percent of the total lineal inches (mm) per bundle. See Table 15-3-A.
SECTION 15.317 — REINSPECTION

In case of reinspection, 10 or more bundles selected at random shall constitute a fair sampling of the shipment. The 5 percent tolerance for defective materials per bundle specified in Section 15.316 shall also apply for reinspection.

Part IV—Southern Yellow Pine, Black Gum/Sweetgum Taper-sawn Shake Hip and Ridge Units

SECTION 15.318 — SCOPE

Southern yellow pine, black gum/sweetgum taper-sawn shake hip and ridge units regulated by this part shall be manufactured, treated and graded in accordance with this standard and their use shall be governed by the provisions of Chapter 15 of this code.

SECTION 15.319 — QUALITY STANDARDS

Shake hip and ridge units shall be manufactured from only No. 1 grade taper-sawn shakes.

Units shall be fabricated at point of attachment with alternating laps, and shall be correspondingly packed 12/12 inches (12/30 mm) per bundle.

Inner surface of units at the butt shall measure not less than 9 inches (229 mm), with the width of the narrower pieces not less than 4 1/2 inches (115 mm).

Units shall be joined with not less than two fasteners applied within 8 inches (203 mm) of the butt. Fasteners shall be a minimum of approximately 3 inches (76 mm) apart and shall be corrosion resistant. Either staples or nails are acceptable. Fasteners shall hold the assembly together until applied properly on the roof.
**TABLE 15-3-A—HANDSPLIT SHAKES SUMMARY OF SIZES, PACKING REGULATIONS AND COVERAGE**

<table>
<thead>
<tr>
<th>LENGTH AND THICKNESS</th>
<th>20-INCH (508 mm)</th>
<th>18-INCH (457 mm)</th>
<th>APPROXIMATE COVERAGE (in square feet) OF ONE SQUARE BASED ON FOLLOWING WEATHER EXPOSURES: 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Courses</td>
<td>No. of Courses</td>
<td>xy (in mm) x 0.0929 for m²</td>
</tr>
<tr>
<td></td>
<td>per Bdl. (9.29 m²)</td>
<td>per Bdl. (9.29 m²)</td>
<td>5 1/2&quot; (140 mm)</td>
</tr>
<tr>
<td>25.4 ft²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18&quot; x 1/2&quot; handsplit and resawn</td>
<td>10/10</td>
<td>4</td>
<td>9/9</td>
</tr>
<tr>
<td>18&quot; x 3/4&quot; handsplit and resawn</td>
<td>8/8</td>
<td>5</td>
<td>9/9</td>
</tr>
<tr>
<td>24&quot; x 3/8&quot; handsplit</td>
<td>10/10</td>
<td>4</td>
<td>9/9</td>
</tr>
<tr>
<td>24&quot; x 1 1/2&quot; handsplit and resawn</td>
<td>10/10</td>
<td>4</td>
<td>9/9</td>
</tr>
<tr>
<td>24&quot; x 3/4&quot; handsplit and resawn</td>
<td>8/8</td>
<td>5</td>
<td>9/9</td>
</tr>
<tr>
<td>24&quot; x 1 1/2&quot; taper split</td>
<td>10/10</td>
<td>4</td>
<td>9/9</td>
</tr>
<tr>
<td>18&quot; x 3/8&quot; true edge straight split</td>
<td>14 Straight</td>
<td>4</td>
<td>—</td>
</tr>
<tr>
<td>18&quot; x 3/8&quot; straight split</td>
<td>19 Straight</td>
<td>5</td>
<td>—</td>
</tr>
<tr>
<td>24&quot; x 3/8&quot; straight split</td>
<td>16 Straight</td>
<td>5</td>
<td>—</td>
</tr>
<tr>
<td>15&quot; starter finish course</td>
<td>8/8</td>
<td>5</td>
<td>9/9</td>
</tr>
<tr>
<td>10/10</td>
<td>4</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>18&quot; x 5/8&quot; taper sawn</td>
<td>—</td>
<td>—</td>
<td>9/9</td>
</tr>
<tr>
<td>24&quot; x 5/8&quot; taper sawn</td>
<td>—</td>
<td>—</td>
<td>9/9</td>
</tr>
</tbody>
</table>

1For maximum weather exposure on wall construction, see Table 23-L; on roof construction, see Table 15-3-B of the Uniform Building Code.

**TABLE 15-3-B—MAXIMUM WEATHER EXPOSURE**

<table>
<thead>
<tr>
<th>GRADE LENGTH</th>
<th>3 INCHES TO LESS THAN 4 INCHES IN 12 INCHES (25% to less than 33%)</th>
<th>4 INCHES IN 12 INCHES AND STEEPER (33% and steeper)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wood Shakes 1</td>
<td>7 1/2</td>
</tr>
<tr>
<td>No. 1 18-inch</td>
<td>10</td>
<td>7 1/2</td>
</tr>
<tr>
<td>No. 1 24-inch</td>
<td>10</td>
<td>7 1/2</td>
</tr>
<tr>
<td>No. 2 18-inch taper-sawn shakes</td>
<td>5 1/2</td>
<td>7 1/2</td>
</tr>
<tr>
<td>No. 2 24-inch taper-sawn shakes</td>
<td>7 1/2</td>
<td></td>
</tr>
</tbody>
</table>

1Exposure of 24-inch by 3/8-inch (610 by 10 mm) handsplit resawn shakes shall not exceed 5 inches (127 mm) regardless of the roof slope.
UNIFORM BUILDING CODE STANDARD 15-4
WOOD SHINGLES

Part I—Based on the Standards of the Red Cedar Shingle and Handsplit Shake Bureau and Material Product Standards of the International Conference of Building Officials

See Sections 1501.2, 1502, 1507.2 and 1507.13, Uniform Building Code

SECTION 15.401 — SCOPE
This standard provides a minimum specification for sawn wood shingles of No. 1 grade, No. 2 grade and No. 3 grade. It covers length, width, thickness, grain characteristics and color for these requirements, plus definitions and specifications.

SECTION 15.402 — DEFINITIONS
For the purposes of this standard, the following terms shall be construed as herein specified.

**BUTT** is the thicker end of the shingle.

**CHECK** is any separation of the wood.

**COURSE** is a horizontal layer forming one of a series of layers on a roof or wall or in the packed bundle.

**CRIMPS** are a breaking down or collapse of wood cells during drying, characterized by a caved-in or corrugated appearance.

**DECAY (ROT)** is the decomposition of wood substance caused by action of wood-destroying fungi, resulting in softening, loss of strength and weight and change of texture and color.

**EXPOSURE** is the portion which, when applied, is exposed to the weather.

**GRAIN** is the direction, size, arrangement, appearance or quality of the fibers in wood. To have a specific meaning, the term must be qualified:

- **Cross Grain** is a condition that should not be confused with the terms “flat” or “edge” grain, and that might better be termed “cross fiber,” since it is a deviation of the wood fibers from the true parallel of the face of the shingle. It is a defect when it runs from one face of the shingle to the other within a longitudinal distance of 3 inches (76 mm) or less in that portion measured 6 inches (153 mm) from the butt. Excessive cross grain must not be present in the remainder of the shingle.

- **Diagonal Grain** is a condition where the grain of the wood does not run parallel to the edges of the shingle. It is considered a defect when the grain diverges or slants 2 inches (51 mm) or more in width in 12 inches (305 mm) of length.

- **Edge Grain or Vertical Grain** is wood cut in a plane approximately at right angles to the annual rings. A condition in which the rings form an angle of 45 degrees or more with the face of the piece.

- **Flat Grain** is a condition in shingles or lumber where the growth rings are flat or horizontal, as opposed to edge-grained or quartered material where the growth rings are on edge, or vertical to the surface. Wood cut in a plane approximately tangential to the annual rings and means a condition in which the rings form an angle of less than 45 degrees with the face of the piece.

- **FEATHER TIPS** (or shim) is a condition of manufacture found on the thin ends of some shingles where the saw came out of the piece prematurely, producing a thin, flimsy, featherlike tip what is uneven or has corners sawn off.
HEARTWOOD (HEART) is the inner layer of a woody stem wholly composed of nonliving cells and usually differentiated from the outer enveloping layer (sapwood) by its darker color.

HIP AND RIDGE SHINGLE are two shingles that have one edge of each sawn on a bevel and fastened together to produce the cap for the hip or ridge of the roof. Hip and ridge units are manufactured from No. 1 grade shingles.

KNOT is that portion of a branch or limb which has been surrounded by subsequent growth of wood of the tree.

LINEAL INCHES are the total width of any given number of shingles when laid edge to edge.

PLY is the minimum number of thicknesses, when applied, of shingles at any point on the covered surface. This term is related to exposure.

SAPWOOD is wood containing some living cells and forming the initial wood layer beneath the bark of the log. Sapwood may be lighter in color than heartwood.

SHIM. See "feather tips."

SQUARE PACK is a unit providing sufficient shingles for the coverage of a given area when the shingles are laid at the specified exposure to the weather in Tables 15-C and 23-L of this code.

TIP is the thinner end of the shingle.

TORN FIBER (TORN GRAIN) is a fuzzy or whiskered appearance on the face of the shingle usually caused by a dull saw or grain deviations.

WAVES are the washboard-like irregularities on the face of a shingle.

WORMHOLE is a hole or passage burrowed by a worm or insect.

SECTION 15.403 — GRADING AND LABELING

15.403.1 General. Each bundle of No. 1 grade, No. 2 grade and No. 3 grade wood shingles graded under this standard shall bear the label of an approved inspection bureau or agency. For No. 1 grade, the label shall be of white base stock printed with predominantly blue ink and shall clearly indicate the No. 1 grade. For No. 2 grade, the label shall be of white base stock printed with predominantly red ink and shall clearly indicate the No. 2 grade. For No. 3 grade, the label shall be of white base stock printed with predominantly black ink and shall clearly indicate the No. 3 grade. All grades shall be well manufactured and neatly packed; they shall comply with or exceed the specifications herein established for quality. All shingles shall be graded from their best face. Wormholes, decay and crimps are not allowed on either face of No. 1 shingles and below the clear line to the butts on either face of No. 2 and No. 3 grade shingles.

15.403.2 Characteristics.

15.403.2.1 General. Shingles characteristics shall be in accordance with the provisions of this section:

15.403.2.2 No. 1 grade. No. 1 grade shall be vertical grain or edge grain, be clear of defects on the graded face and be 100 percent heartwood. Knots, knotholes, wormholes, decay and crimps are not allowed on either face. Flat grain, cross grain and sapwood constitute natural characteristics that are not admissible. Defects in manufacturing, including shims, feather tips, diagonal grain, and cross grain are likewise not admissible. Manufacturing defects such as checks, waves or torn fiber are permitted on the ungraded face.

15.403.2.3 No. 2 grade. In No. 2 grade, sapwood is restricted to 1 inch (25 mm) in width in the first 10 inches (254 mm) above the butt. Grain characteristics, other than cross grain, are not considered defects. Defects such as knots, knotholes, wormholes, decay and crimps are not allowed on either face in the first 10 inches, 11 inches and 16 inches (254 mm, 279 mm and 406 mm) from the butt in the 16-inch, 18-inch and 24-inch (406 mm, 457 mm and 610 mm) lengths, respectively. Manufac-
15.403.2.4 No. 3 Grade. In No. 3 grade, sapwood is permitted. Other grain deviations are not considered defects. Other defects, as listed above for No. 2 grade, are not allowed in the first 6 inches (153 mm) from the butt for 16-inch (405 mm) and 18-inch (455 mm) lengths and 10 inches (254 mm) for 24-inch (610 mm) lengths. Defects may be up to 3 inches (76 mm) in diameter, but aggregate defects shall not exceed two-thirds the width of the shingle.

SECTION 15.404 — LENGTH, WIDTH, THICKNESS

15.404.1 Length.

15.404.1.1 No. 1 Grade. For No. 1 grade the minimum length shall be 16 inches (405 mm). Shingles are usually manufactured in 16-inch, 18-inch and 24-inch (405 mm, 455 mm and 610 mm) lengths. A tolerance of 1 inch (25 mm) over the nominal length is allowed. A minus tolerance of $\frac{1}{4}$ inch (6.4 mm) below the nominal length is allowed. A minus tolerance of 1 inch (25 mm) below the nominal length is permitted in not more than 10 percent of the running inches (mm) in the bundle.

15.404.1.2 No. 2 Grade. For No. 2 grade the minimum lengths, including shims or feather tips for 16-inch, 18-inch and 24-inch (405 mm, 455 mm and 610 mm) shingles, shall be 15 inches (381 mm), 16 inches (406 mm) and 20 inches (508 mm), respectively.

15.404.1.3 No. 3 Grade. For No. 3 grade the minimum lengths, including shims or feather tips for 16-inch, 18-inch and 24-inch (405 mm, 455 mm and 610 mm) shingles, shall be 14 inches (356 mm), 16 inches (406 mm) and 18 inches (455 mm), respectively.

15.404.2 Width. Maximum width shall be 14 inches (356 mm).

15.404.2.1 No. 1 Grade. Minimum width up to but not including 24-inch lengths (610 mm), shall be 3 inches (76 mm). Minimum width for shingles 24 inches (610 mm) and longer shall be 4 inches (102 mm). In 16-inch and 18-inch (405 mm and 455 mm) shingles those less than 4 inches (102 mm) in width shall not constitute more than 10 percent of the running inches per bundle. Shingles shall be uniform in width; that is, with parallel sides. Edges shall be parallel within a tolerance of $\frac{1}{4}$ inch (6.4 mm).

15.404.2.2 No. 2 Grade. Minimum width shall be 3 inches (76 mm). Not more than 20 percent of the running inches (mm) in each bundle shall be less than 4 inches (102 mm) wide. Edges shall be parallel within a tolerance of $\frac{1}{4}$ inch (6.4 mm) in the 16-inch and 18-inch (405 and 455 mm) lengths and $\frac{3}{8}$ inch (9.5 mm) in the 24-inch (610 mm) length.

15.404.2.3 No. 3 Grade. Minimum width shall be 3 inches (76 mm) except it may be $2\frac{1}{2}$ inches (64 mm) for the 16-inch (405 mm) length. Not more than 30 percent of the running inches in each bundle shall be less than 4 inches (102 mm) wide. Edges shall be parallel within a tolerance of $\frac{3}{8}$ inch (9.5 mm).

15.404.3 Thickness. Shingles are measured for thickness at the butt ends and designated according to the number of pieces necessary to constitute a specific unit of thickness. At the time of manufacture, 16-inch (405 mm) shingles shall be 5/2 [the thickness of five butts will be 2 inches (51 mm)], 18 inches (455 mm) shall be 5/2/4 [five butts measure 2 1/4 inches (57.4 mm)] and 24 inches (610 mm) shall be 4/2 [four butts measure 2 inches (51 mm)]. Shingles shall be uniform in thickness, but a minus tolerance of 3 percent is allowable to compensate for the difference in shrinkage due to seasoning or kiln drying. This tolerance is based on the total thickness of the bundle.

SECTION 15.405 — INSPECTION

Shingles shall be adjudged off grade if the total lineal inches (mm) of defective shingles exceed 4 percent of the total lineal inches (mm) per bundle.
SECTION 15.406 — REINSPECTION
In case of reinspection, 10 or more bundles selected at random shall constitute a fair sampling of the shipment. The 4 percent tolerance for defective shingles specified in Section 15.405 shall also apply for reinspection.

Part II—Grading Rules for Shingle Hip and Ridge Units Based on the Standards of the Cedar Shake and Shingle Bureau

SECTION 15.407 — DEFINITION
Shingle hip and ridge units are manufactured from No. 1 or No. 2 grade shingles that have one edge sawn on a bevel and fastened together to produce the cap for the hip or ridge of the roof.

SECTION 15.408 — QUALITY STANDARDS
No. 1 hip and ridge units shall be produced from material that meets the standard for No. 1 shingles; No. 2 hip and ridge units shall be produced from material that meets the standard for No. 2 shingles. Lower-grade material is not permitted.

SECTION 15.409 — SIZE
At the time of manufacture, the shingle hip and ridge assembly width shall be 7 inches (178 mm), measured over the top of the assembly at the butt end. A minus tolerance of 1/8 inch (3.2 mm) is allowed. Butt misalignment of assemblies in excess of 1/8 inch (3.2 mm) is not permitted. On the outer edge of the units, top corners shall not be more than a 90-degree angle. The narrow component shall have a minimum width of 3 5/16 (84 mm) inches at the butt end.

SECTION 15.410 — PACKING
Individual shingle and ridge units are made up of one wide and one narrow component. Sixteen-inch (405 mm) shingles shall be packed 40 units per bundle; 18-inch (455 mm) shingles shall be packed 36 units per bundle, with an equal number of right-hand and left-hand units (for alternating laps). Units shall be manufactured to a 4 units vertical to 12 units horizontal (33.3%) pitch or steeper. Units shall be joined with not less than two fasteners applied between 1/2 inch and 5 1/2 inches (13 mm and 140 mm) from the butt. Either staples or nails are acceptable. Fasteners shall be corrosion resistant, spaced approximately 3 inches (76 mm) apart.

SECTION 15.411 — INSPECTION
Each off-grade unit shall count for 21/2 percent of the grade; more than four off-grade units per bundle shall preclude a passing grade.
UNIFORM BUILDING CODE STANDARD 15-5
ROOF TILE

Recommended Standard of the International Conference of Building Officials
See Sections 1501.2, 1502 and 1507.7, Uniform Building Code

SECTION 15.501 — SCOPE
This standard applies to all clay, concrete and other cement-based tiles. Supplementary tests justifying adequacy under loads prescribed in Chapter 16 shall be provided.

SECTION 15.502 — BASIC INFORMATION
The following basic information shall be submitted:
1. Manufacturing data as applicable such as mix design, density, protective coatings, mixing, forming, extruding, firing, curing, coloring and glazing.
2. Dimensioned scale drawings and details noting thicknesses, lugs, lips, contours, water diverters, size and location of all fasteners.

SECTION 15.503 — REPORT OF TESTS
A qualified representative of the independent testing agency shall witness the production, fabrication and installation of test specimens.

The test report must be in sufficient detail to identify specimen properties that could affect performance as a roof covering. The testing agency must verify and report dimensions, weight, density, moisture content and other relevant physical properties of the major components.

SECTION 15.504 — REQUIRED TESTS
Tiles shall be tested for strength and water absorption as set forth in this standard.

SECTION 15.505 — SAMPLES
A total of 10 representative samples shall be selected by the independent laboratory from the production line. The laboratory shall document production procedures as specified in Section 15.503. Cement-based products shall be conditioned at a temperature of 73°F ± 5°F (23°C ± 2.8°C) and 50 percent relative humidity for a period of 28 days. At the end of the conditioning period, the size and weight for each specimen shall be recorded.

SECTION 15.506 — TEST PROCEDURES
15.506.1 Strength Test.
15.506.1.1 Sample. Five samples conditioned as specified in Section 15.505 shall be subjected to the strength test.
15.506.1.2 Procedure.
15.506.1.2.1 Barrel-shaped ("Spanish") tile. The supports for the sample shall be two knife edges of the rocker type with edges at least as long as the width of the sample. The loading knife edge may be either the fixed or the rocker type and shall be at least as long as the width of the sample.
Place the sample on the knife edges with the open side or turned-down edges down, so that the sample is supported by the knife edges at a span of 12 inches (305 mm) centered on the length of the sample. Apply the load at center of the span and sample width through the loading knife edge. Apply loads at rates not to exceed 10 pounds (4.45 N) per second until failure and record the breaking load to the nearest 5 pounds (2.2 N).

15.506.1.2.2 Other tile. The test span shall be the maximum unsupported span specified for field installation. The sample shall be tested as shown in Figure 15-5-1 with the load applied at a uniform rate not exceeding 10 pounds (4.45 N) per second until failure, which shall be recorded to the nearest pound (5 N). The test shall be repeated on the other specimens and the average breaking load determined.

15.506.1.3 Conditions of acceptance.

15.506.1.3.1 Barrel-shaped tile. Barrel-shaped tiles are tiles having a minimum rise-to-width ratio of 1:4. The average breaking load shall not be less than 400 pounds (1780 N) with no single load less than 350 pounds (1560 N).

15.506.1.3.2 Other tiles. The average breaking load shall not be less than 300 pounds (1335 N) for five consecutively tested samples or 250 pounds (1110 N) for any individual sample.

15.506.2 Water Absorption Test.

15.506.2.1 Sample. A minimum of five samples from the tile fractured in the strength test shall be tested for water absorption. The sum of the dry weight for five samples at room temperature shall not be less than 12 pounds (5.4 kg). A total of five or more samples of the ridge and other accessory tile not subjected to the strength test shall also be tested. The aggregate dry weight at room temperature of these samples shall not be less than 5 pounds (2.2 N).

15.506.2.2 Procedure. Loose particles shall be removed by scrubbing with a fiber brush and clean water. Samples shall be dried in a well-ventilated oven for 24 hours at a temperature of 221°F (105°C.) varying not more than 3.6°F (2.0°C.). After drying, the samples may be cooled at room temperature for 15 minutes after identifying and weighing to the nearest 0.01 gram. The samples shall then be immersed in filtered or distilled water for 48 hours at a temperature of 68°F (20°C.), varying not more than 9°F (5°C.). One sample shall be removed, surfaces wiped dry and weighed immediately. The process shall be repeated for each sample.

15.506.2.3 Condition of acceptance. No sample shall absorb more than 15 percent water of its dry weight.
Notes:
$L = $maximum unsupported span specified for field installation.

The load shall be applied with a 2- by 4-inch (51 mm by 102 mm) (nominal size) wood piece laid flat and continuous from edge to edge of the tile. Where the effective width of tile exceeds 16 inches (406 mm), the loads specified in Section 15.506.1.2 shall be increased in proportion to the tile width.

FIGURE 15-5-1
SECTION 15.601 — SCOPE

15.601.1 General. This standard covers the following membranes used for roof coverings.

15.601.2 Modified Bitumen Membranes. Composite sheets consisting of bitumen modifiers and reinforcements. The material shall be of the following types of classes:

Type I—APP modified bitumen reinforced membrane composed primarily of asphalt blended with atactic polypropylene.

Type II—SBS modified bitumen reinforced membrane composed primarily of asphalt blended with styrene-butadiene-styrene.

Type III—Self-adhesive modified bitumen membrane composed primarily of asphalt blended with styrene-butadiene-styrene.

15.601.3 Thermoplastic Membranes. Sheets composed of polymers and other proprietary ingredients whose chemical composition allows the sheet to be welded together by either heat or solvent throughout its service life.

15.601.4 Thermoset Membranes. Sheets composed of polymers and other proprietary ingredients whose chemical composition vulcanizes or cross-links during its service life.

SECTION 15.602 — PHYSICAL PROPERTIES

The materials shall conform to the physical properties prescribed in Tables 15-6-A, 15-6-B, 15-6-C, 15-6-D and 15-6-E.

TABLE 15-6-A—PROPERTIES OF THERMOSET REINFORCED MEMBRANES USED FOR ROOF COVERINGS

<table>
<thead>
<tr>
<th>MATERIALS' PROPERTIES</th>
<th>TEST METHODS¹</th>
<th>UNITS</th>
<th>PHYSICAL PROPERTIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>ASTM D 751-79</td>
<td>inches (× 25.4 for mm)</td>
<td>≥ 0.030</td>
</tr>
<tr>
<td>Breaking strength²</td>
<td>ASTM D 751-79</td>
<td>lb./inch (× 0.175 for N/mm)</td>
<td>≥ 90</td>
</tr>
<tr>
<td>Elongation at fabric break³</td>
<td>ASTM D 751-79</td>
<td>Percentage</td>
<td>≥ 15</td>
</tr>
<tr>
<td>Tear resistance</td>
<td>ASTM D 751-79</td>
<td>lb. (× 4.45 for N)</td>
<td>≥ 25</td>
</tr>
<tr>
<td>Water absorption</td>
<td>ASTM D 471-79</td>
<td>166 hours at 73°F.</td>
<td></td>
</tr>
<tr>
<td>Dimensional stability</td>
<td>ASTM D 1204-84</td>
<td>24 hours at 130°F.</td>
<td></td>
</tr>
<tr>
<td>Low temperature flexibility</td>
<td>ASTM D 2137-83</td>
<td>°F. (−32 + 1.8 for °C.)</td>
<td>≤ −30</td>
</tr>
<tr>
<td>Factory seam strength</td>
<td>ASTM D 751-79</td>
<td>lb./inch (× 0.175 for N/mm)</td>
<td>≥ 50²</td>
</tr>
</tbody>
</table>

¹The test to be used shall be a method approved by the building official.

²Results of tensile strength after heat aging at 212°F (100°C.) for 166 hours will remain at ≥ 90 pounds (400 N). Accelerated weathering in xenon, carbon arc or QUV with water spray for 2,000 hours at 176°F (80°C.) will not reduce the breaking strength to less than 90 pounds (400 N).
3Elongation at break shall not be reduced by heat aging or accelerated weathering by more than 20 percent.
4Or membrane rupture.

<table>
<thead>
<tr>
<th>TABLE 15-6-B—PROPERTIES OF THERMOSET NONREINFORCED MEMBRANES USED FOR ROOF COVERINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATERIALS' PROPERTIES</td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>Thickness</td>
</tr>
<tr>
<td>Tensile strength²</td>
</tr>
<tr>
<td>Elongation³</td>
</tr>
<tr>
<td>Tear resistance</td>
</tr>
<tr>
<td>Water absorption</td>
</tr>
<tr>
<td>Dimensional stability</td>
</tr>
<tr>
<td>Low temperature flexibility</td>
</tr>
<tr>
<td>Factory seam strength</td>
</tr>
</tbody>
</table>

¹The test to be used shall be a method approved by the building official.
²Results of tensile strength after heat aging at 212°F. (100°C.) for 166 hours will remain at ≥ 1,000 psi (6890 kPa). Accelerated weathering in xenon, carbon arc or QUV with water spray for 2,000 hours at 176°F. (80°C.) will not reduce the tensile strength to less than 1,000 pounds (6890 kPa).
³Elongation at break shall not be reduced by heat aging or accelerated weathering by more than 20 percent.
⁴Or membrane rupture.

<table>
<thead>
<tr>
<th>TABLE 15-6-C—PROPERTIES OF THERMOPLASTIC REINFORCED MEMBRANES USED FOR ROOF COVERINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATERIALS' PROPERTIES</td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>Thickness</td>
</tr>
<tr>
<td>Breaking strength²</td>
</tr>
<tr>
<td>Elongation at fabric break³</td>
</tr>
<tr>
<td>Tear resistance</td>
</tr>
<tr>
<td>Water absorption</td>
</tr>
<tr>
<td>Dimensional stability</td>
</tr>
<tr>
<td>Low temperature flexibility</td>
</tr>
<tr>
<td>Factory seam strength</td>
</tr>
</tbody>
</table>

¹The test to be used shall be a method approved by the building official.
²Results of tensile strength after heat aging at 158°F. (70°C.) for 30 days will remain at ≥ 90 pounds (400 N). Accelerated weathering in xenon, carbon arc or QUV with water spray for 2,000 hours at 145°F. (63°C.) will not reduce the breaking strength to less than 90 pounds (400 N).
³Elongation at break shall not be reduced by heat aging or accelerated weathering by more than 20 percent.
⁴Or membrane rupture.
TABLE 15-6-D—PROPERTIES OF THERMOPLASTIC NONREINFORCED MEMBRANES USED FOR ROOF COVERINGS

<table>
<thead>
<tr>
<th>MATERIALS’ PROPERTIES</th>
<th>TEST METHODS</th>
<th>UNITS</th>
<th>PHYSICAL PROPERTIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>ASTM D 638-84</td>
<td>inches (× 25.4 for mm)</td>
<td>≥ 0.045</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>ASTM D 638-84</td>
<td>psi (× 6.89 for kPa)</td>
<td>≥ 1,500</td>
</tr>
<tr>
<td>Elongation</td>
<td>ASTM D 638-84</td>
<td>Percentage</td>
<td>≥ 250</td>
</tr>
<tr>
<td>Water absorption</td>
<td>ASTM D 570-81 166 hours at 158°F.</td>
<td>Weight change percentage</td>
<td>≤ 3.0</td>
</tr>
<tr>
<td>Dimensional stability</td>
<td>ASTM D 1204-84 6 hours at 176°F.</td>
<td>Percentage</td>
<td>≤ 2.0</td>
</tr>
<tr>
<td>Low temperature flexibility</td>
<td>ASTM D 2136-84</td>
<td>°F. (−32 + 1.8°C.)</td>
<td>≤ −30</td>
</tr>
<tr>
<td>Factory seam strength</td>
<td>ASTM D 638-84</td>
<td>psi (× 6.89 for kPa)</td>
<td>≥ 1,300</td>
</tr>
</tbody>
</table>

1The test to be used shall be a method approved by the building official.

2Results of tensile strength after heat aging at 194°F. (90°C.) for 168 hours will remain at ≥ 1,000 psi (6890 kPa). Accelerated weathering in xenon, carbon arc or QUV with water spray for 2,000 hours at 145°F. (63°C.) will not reduce the tensile strength to less than 1,000 psi (6890 kPa).

3Elongation at break shall not be reduced by heat aging or accelerated weathering to less than 200 percent.

4Or membrane rupture.

TABLE 15-6-E—PROPERTIES OF MODIFIED BITUMEN MEMBRANES USED FOR ROOF COVERINGS

<table>
<thead>
<tr>
<th>MATERIALS’ PROPERTIES</th>
<th>UNITS</th>
<th>PHYSICAL PROPERTIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>mils (× 0.0254 for mm)</td>
<td>≥ 120</td>
</tr>
<tr>
<td>Weight</td>
<td>lb./100 ft.² (× 0.05 for kg/m²)</td>
<td>≥ 60</td>
</tr>
<tr>
<td>Tensile strength at 0°F.</td>
<td>lb./in. (× 0.175 for N/mm)</td>
<td>≥ 100</td>
</tr>
<tr>
<td>Elongation at 0°F.</td>
<td>Percentage</td>
<td>≥ 4</td>
</tr>
<tr>
<td>Strain energy at 0°F.</td>
<td>lb. in./in. (× 4.45 for N mm/mm)</td>
<td>≥ 2</td>
</tr>
<tr>
<td>Water absorption</td>
<td>Percentage</td>
<td>≤ 5</td>
</tr>
<tr>
<td>Low temperature flexibility</td>
<td>°F. (−32 + 1.8°C.)</td>
<td>≤ 32</td>
</tr>
<tr>
<td>Dimensional stability</td>
<td>Percentage</td>
<td>≤ 1</td>
</tr>
<tr>
<td>Compound stability</td>
<td>°F. (−32 + 1.8°C.)</td>
<td>≥ 250</td>
</tr>
</tbody>
</table>

1Tests shall be approved methods of evaluating the properties of roofing materials.

2Stated property is before and after heat conditioning at 158°F. (70°C.) for 2,000 hours. Accelerated weathering in xenon, carbon arc or QUV with water spray for 2,000 hours at 145°F. (63°C.) will not reduce the tensile strength by more than 5 percent or the elongation by more than 10 percent.

3Strain energy is the area under the load elongation curve obtained from the machine chart or computer system converted to units of pounds per inch per inch (N per mm per mm). This is required if one of the minimum values for tensile strength or elongation is not met. Ultimate elongation for this calculation shall be the elongation to the point the load is 5 percent of the tensile strength of the membrane after the maximum load has been reached.
UNIFORM BUILDING CODE STANDARD 15-7
AUTOMATIC SMOKE AND HEAT VENTS

Standard of the International Conference of Building Officials
See Sections 906.1, 906.4 and 1501.2, Uniform Building Code

SECTION 15.701 — SCOPE
15.701.1 General. This standard applies to thermally activated, automatic smoke and heat vents designed for installation on the roof of buildings as required by Section 906 of the Building Code.

15.701.2 Instructions. A copy of the installation and operating instructions shall be supplied with each unit. The instructions shall prescribe construction representative of that used in the examination and testing of the product.

SECTION 15.702 — CONSTRUCTION AND MATERIALS
The critical operating components of vents, such as heat sensors, hinges, latches, linkages and other mechanical parts, shall be constructed of corrosion-resistant materials.

Plastics shall be approved plastics as defined in the Building Code.

Vent design for minimum roof live load shall be of adequate strength and durability to withstand the design loads as prescribed in the Building Code.

SECTION 15.703 — METHOD OF ACTIVATION
Releasing devices for vents shall be activated by heat. The heat-activated device shall be one of the following:

1. A fixed-temperature device having a melting temperature rating at least 30°F (17°C.) above the maximum expected ambient temperatures at the intended location.
2. A rate-of-rise device.
3. Approved, heat-sensitive glazing designed to shrink and drop out of the vent opening.

SECTION 15.704 — TEST PROCEDURES
15.704.1 General. Recognized and accepted testing procedures and testing equipment shall be used.

15.704.2 Samples. Samples submitted for acceptance tests shall be production units whose materials, design and specifications are representative of the models for which acceptance is sought. Written specifications shall be submitted for each model. Tests for multiple-sized models shall utilize the largest size unit for evaluations.

15.704.3 Heat Sensors. Heat-sensing devices shall be capable of activation in accordance with the requirements of the simulated fire test.

15.704.4 Load Performance. Vents shall be tested to open freely and fully against a live load of 10 pounds per square foot (495 N/m²). Vents intended for installation in areas subject to snow loads shall be tested to open freely and fully against snow loads as determined by the building official.

15.704.5 Simulated Fire Test.
15.704.5.1 Requirements. Vents shall be tested to open fully to operational position in five minutes when subjected to a precalibrated time-temperature gradient that heats the air within the
vent cavity to 500°F (260°C.) within the five-minute period. Where vents are operated by fixed-temperature fusible devices, the device shall be located in the expected flow pattern of hot gases and not shielded from fire temperatures. The actual load on the device shall not exceed its greatest load capacity.

15.704.5.2 Calibration. Correction of the test calibration may be accomplished by varying the height of the vent being tested or the height of the test-fuel pan.

15.704.5.3 Test method. Test units shall be end-supported 35 inches (890 mm) above the fire test floor. Two Type K, chrome alumel 18-gauge thermocouples shall be attached to the inside of the vent, 1 inch (25.4 mm) below the highest point of the cavity. The leads shall be connected to a recording potentiometer, 0°F to 2,000°F (−18°C. to 1093°C.) range multipoint.

A one-square-foot (305 mm by 305 mm) steel test-fuel pan shall be centered under the test unit on the floor. Isopropyl alcohol shall be poured into the pan to a depth of 1/2 inch (13 mm). The alcohol shall be ignited and a determination made as to the ability of the test unit to meet the test requirements.

During the test there shall not be any flame impingement on the test unit lid or dropout glazing.

15.704.5.4 Repetitions. Each unit tested shall successfully pass five simulated fire tests per mode of operation without mechanical or structural failure. Modes of operation tested shall include (i) activation of the manual release mechanism on units so equipped, and (ii) activation of the heat-sensing device.

**EXCEPTION:** Drop-out glazing vents need be tested only once per unit. Release of the glazing is a normal test response.

Necessary resetting or replacement of the heat-sensing device shall not be considered a mechanical or structural failure.

**SECTION 15.705 — MARKING**

Each unit shall bear a durable, visible label stating the name and location of the manufacturer, the model designation and the year of manufacture.
UNIFORM BUILDING CODE STANDARD 18-1
SOILS CLASSIFICATION


See Sections 1801.2 and 1803.1, Uniform Building Code

SECTION 18.101 — SCOPE
This standard describes a system for classifying mineral and organomineral soils for engineering purposes based on laboratory determination of particle-size characteristics, liquid limit and plasticity index.

SECTION 18.102 — APPARATUS
Apparatus of an approved type shall be used to perform the following tests and procedures: Preparation of soil samples, liquid limit test, plastic limit test and particle-size analysis.

SECTION 18.103 — SAMPLING
Sampling shall be conducted in accordance with approved methods for soil investigation and sampling by auger borings, for Penetration Test and Split-barrel Sampling of Soils, and for Thin-walled Tube Sampling of Soils.

The sample shall be carefully identified as to origin by a boring number and sample number in conjunction with a job number, a geologic stratum, a pedologic horizon or a location description with respect to a permanent monument, a grid system or a station number and offset with respect to a stated center line.

The sample should also be described in accordance with an approved visual-manual procedure. (A soil which is composed primarily of undecayed or partially decayed organic matter and has a fibrous texture, dark brown to black color, and organic odor should be designated as a highly organic soil, PT, and not subjected to the classification procedures described hereafter.)

SECTION 18.104 — TEST SAMPLE
Test samples shall represent that portion of the field sample finer than the 3-inch (76 mm) sieve and shall be obtained as follows:

Air dry the field sample; weigh the field sample; and separate the field sample into two fractions on a 3-inch (76 mm) sieve. Weigh the fraction retained on the 3-inch (76 mm) sieve. Compute the percentage of plus 3-inch (76 mm) material in the field sample and note this percentage as auxiliary information. Thoroughly mix the fraction passing the 3-inch (76 mm) sieve and select test samples.

SECTION 18.105 — PRELIMINARY CLASSIFICATION PROCEDURE
Procedure for the determination of percentage finer than the No. 200 (75 μm) sieve is as follows:

1. From the material passing the 3-inch (76 mm) sieve, select a test sample and determine the percentage of the test sample finer than the No. 200 (75 μm) sieve. (This step may be omitted if the soil can obviously be classified as fine-grained by visual inspection.)

2. Classify the soil as coarse-grained if more than 50 percent of the test sample is retained on the No. 200 (75 μm) sieve.
3. Classify the soil as fine-grained if 50 percent or more of the test sample passes the No. 200 (75 μm) sieve.

**SECTION 18.106 — PROCEDURE FOR CLASSIFICATION OF COARSE-GRAINED SOILS (MORE THAN 50 PERCENT RETAINED)**

Select test samples from the material passing the 3-inch (76 mm) sieve for the determination of particle-size characteristics, liquid limit and plasticity index. Determine the cumulative particle-size distribution of the fraction coarser than the No. 200 (75 μm) sieve.

Classify the sample as gravel, G, if 50 percent or more of the coarse fraction [plus No. 200 (75 μm) sieve] is retained on the No. 4 (4.75 mm) sieve. Classify the sample as sand, S, if more than 50 percent of the coarse fraction [plus No. 200 (75 μm) sieve] passes the No. 4 (75 mm) sieve.

If less than 5 percent of the test sample passed the No. 200 (75 μm) sieve, compute the coefficient of uniformity, Cu, and coefficient of curvature, Cz, as given in Formulas 18-1-1 and 18-1-2:

\[
Cu = \frac{D_{50}}{D_{10}} \quad (18-1-1)
\]

\[
Cz = \frac{(D_{25})^2}{D_{10} \times D_{60}} \quad (18-1-2)
\]

in which \(D_{10}, D_{30}\) and \(D_{60}\) are the particle size diameters corresponding respectively to 10, 30 and 60 percent passing on the cumulative particle size distribution curve.

Classify the sample as well-graded gravel, GW, or well-graded sand, SW, if \(Cu\) is greater than 4 for gravel and 6 for sand, and \(Cz\) is between 1 and 3. Classify the sample as poorly graded gravel, GP, or poorly graded sand, SP, if either the \(Cu\) or the \(Cz\) criteria for well-graded soils are not satisfied.

If more than 12 percent of the test sample passed the No. 200 (75 μm) sieve, determine the liquid limit and the plasticity index of a portion of the test sample passing the No. 40 (425 μm) sieve in accordance with approved methods.

Classify the sample as silty gravel, GM, or silty sand, SM, if the results of the limits tests show that the fines are silty, that is, the plot of the liquid limit versus plasticity index falls below the “A” line (see Plasticity Table 18-1-A) or the plasticity index is less than 4.

Classify the sample as clayey gravel, GC, or clayey sand, SC, if the fines are clayey, that is, the plot of liquid limit versus plasticity index falls above the “A” line and the plasticity index is greater than 7.

If the fines are intermediate between silt and clay, that is, the plot of liquid limit versus plasticity index falls on or practically on the “A” line or falls above the “A” line but the plasticity index is in the range of 4 to 7, the soil should be given a borderline classification, such as GM-GC or SM-SC.

If 5 to 12 percent of the test sample passed the No. 200 (75 μm) sieve, the soil should be given a borderline classification based on both its gradation and limit test characteristics, such as GW-GC or SP-SM. (In doubtful cases the rule is to favor the less plastic classification. Example: A gravel with 10 percent fines, a \(Cu\) of 20, a \(Cz\) of 2.0, and a plasticity index of 6 would be classified as GW-GM rather than GW-GC.)

**SECTION 18.107 — PROCEDURE FOR CLASSIFICATION OF FINE-GRAINED SOILS (50 PERCENT OR MORE PASSING)**

From the material passing the 3-inch (76 mm) sieve, select a test sample for the determination of the liquid limit and plasticity index. The method for wet preparation shall be used for soils containing organic matter or irreversible mineral colloids.
Determine the liquid limit and the plasticity index of a portion of the test sample passing the No. 40 (425 μm) sieve.

Classify the soil as inorganic clay, C, if the plot of liquid limit versus plasticity index falls above the “A” line and the plasticity index is greater than 7.

Classify the soil as inorganic clay of low to medium plasticity, CL, if the liquid limit is less than 50 and the plot of liquid limit versus plasticity index falls above the “A” line and the plasticity index is greater than 7. See area identified as CL on the Plasticity Chart of Table 18-1-A.

Classify the soil as inorganic clay of high plasticity, CH, if the liquid limit is greater than 50 and the plot of liquid limit versus plasticity index falls above the “A” line. In cases where the liquid limit exceeds 100 or the plasticity index exceeds 60, the plasticity chart may be expanded by maintaining the same scales on both axes and extending the “A” line at the indicated slope. See areas identified as CH on the Plasticity Chart, Table 18-1-A.

Classify the soil as inorganic silt, M, if the plot of liquid limit versus plasticity index falls below the “A” line or if the plasticity index is less than 4, unless it is suspected that organic matter is present in sufficient amounts to influence the soil properties, then tentatively classify the soil as organic silt or clay, O.

If the soil has a dark color and an organic odor when moist and warm, a second liquid limit test should be performed on a test sample which has been oven dried at 110°C ± 5°C for 24 hours.

Classify the soil as organic silt or clay, O, if the liquid limit after oven drying is less than three fourths of the liquid limit of the original sample determined before drying.

Classify the soil as inorganic silt of low plasticity, ML, or as organic silt of low plasticity, ML, or as organic silt or silt-clay of low plasticity, OL, if the liquid limit is less than 50 and the plot of liquid limit versus plasticity index falls below the “A” line or the plasticity index is less than 4. See area identified as ML and OL on the Plasticity Chart, Table 18-1-A.

Classify the soil as inorganic silt of medium to high plasticity, MH, or as organic clay or silt-clay of medium to high plasticity, OH, if the liquid limit is more than 50 and the plot of liquid limit versus plasticity index falls below the “A” line. See area identified as MH and OH on the Plasticity Chart of Table 18-1-A.

In order to indicate their borderline characteristics, some fine-grained soils should be classified by dual symbols.

If the plot of liquid limit versus plasticity index falls on or practically on the “A” line or above the “A” line where the plasticity index is in the range of 4 to 7, the soil should be given an appropriate borderline classification such as CL-ML or CH-OH.

If the plot of liquid limit versus plasticity index falls on or practically on the line liquid limit = 50, the soil should be given an appropriate borderline classification such as CL-CH or ML-MH. (In doubtful cases the rule for classification is to favor the more plastic classification. Example: a fine-grained soil with a liquid limit of 50 and a plasticity index of 22 would be classified as CH-MH rather than CL-ML.)
<table>
<thead>
<tr>
<th>MAJOR DIVISIONS</th>
<th>GROUP SYMBOLS</th>
<th>TYPICAL NAMES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COARSE-GRAINED SOILS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than 50% retained on No. 200 (75 μm) sieve*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GRAVELS 50% or more of coarse fraction retained on No. 4 (4.75 mm) sieve</td>
<td>GW</td>
<td>Well-graded gravels and gravel-sand mixtures, little or no fines</td>
</tr>
<tr>
<td></td>
<td>GP</td>
<td>Poorly graded gravels and gravel-sand mixtures, little or no fines</td>
</tr>
<tr>
<td>GRAVELS WITH FINES</td>
<td>GM</td>
<td>Silty gravels, gravel-sand-silt mixtures</td>
</tr>
<tr>
<td></td>
<td>GC</td>
<td>Clayey gravels, gravel-sand-clay mixtures</td>
</tr>
<tr>
<td><strong>SANDS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More than 50% of coarse fraction passes No. 4 (4.75 mm) sieve</td>
<td>SW</td>
<td>Well-graded sands and gravelly sands, little or no fines</td>
</tr>
<tr>
<td></td>
<td>SP</td>
<td>Poorly graded sands and gravelly and sands, little or no fines</td>
</tr>
<tr>
<td>SANDS WITH FINES</td>
<td>SM</td>
<td>Silty sands, sand-silt mixtures</td>
</tr>
<tr>
<td></td>
<td>SC</td>
<td>Clayey sands, sand-clay mixtures</td>
</tr>
<tr>
<td><strong>FINE-GRAINED SOILS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50% or more passes No. 200 (75 μm) sieve*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SILTS AND CLAYS Liquid limit 50% or less</td>
<td>ML</td>
<td>Inorganic silts, very fine sands, rock flour, silty or clayey fine sands</td>
</tr>
<tr>
<td></td>
<td>CL</td>
<td>Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays</td>
</tr>
<tr>
<td></td>
<td>OL</td>
<td>Organic silts and organic siltic clays of low plasticity</td>
</tr>
<tr>
<td>SILTS AND CLAYS Liquid limit greater than 50%</td>
<td>MH</td>
<td>Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts</td>
</tr>
<tr>
<td></td>
<td>CH</td>
<td>Inorganic clays of high plasticity, fat clays</td>
</tr>
<tr>
<td></td>
<td>OH</td>
<td>Organic clays of medium to high plasticity</td>
</tr>
<tr>
<td>Highly Organic Soils</td>
<td>PT</td>
<td>Peat, muck and other highly organic soils</td>
</tr>
</tbody>
</table>

*Based on the material passing the 3-inch (76 mm) sieve.
TABLE 18-1-A—SOIL CLASSIFICATION CHART—(Continued)

<table>
<thead>
<tr>
<th>CLASSIFICATION ON BASIS OF PERCENTAGE OF FINES</th>
<th>CLASSIFICATION CRITERIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 5%, Pass No. 200 (75 μm) sieve</td>
<td>Cu = D_60/D_{10} Greater than 4</td>
</tr>
<tr>
<td>More than 12%, Pass N. 200 (75 μm) sieve</td>
<td>C_2 (D_{30})^3</td>
</tr>
<tr>
<td>5% to 12%, Pass No. 200 (75 μm) sieve</td>
<td>Between 1 and 3</td>
</tr>
<tr>
<td>GW, GP, SW, SP</td>
<td>Not meeting both criteria for GW</td>
</tr>
<tr>
<td>GM, GC, SM, SC</td>
<td>Atterberg limits plot below “A” line or plasticity index less than 4</td>
</tr>
<tr>
<td>Borderline Classification requiring use of dual symbols</td>
<td>Atterberg limits plot below “A” line and plasticity index greater than 7</td>
</tr>
</tbody>
</table>

\[
C_u = \frac{D_{60}}{D_{10}} \text{ Greater than 4} \\
C_2 = \frac{(D_{30})^3}{D_{10} \times D_{D_0}} \text{ Between 1 and 3} \\
\]

CLASSIFICATION ON BASIS OF PERCENTAGE OF FINES

For classification of fine-grained soils and fine fraction of coarse-grained soils

Equation of A-line:

\[ \text{PI} = 0.73 (\text{LL} - 20) \]

Visual-Manual Identification

3-558
UNIFORM BUILDING CODE STANDARD 18-2
EXPANSION INDEX TEST
Based on Recommendations of the Los Angeles
Section ASCE Soil Committee
See Sections 1801.2 and 1803.1, *Uniform Building Code*

SECTION 18.201 — SCOPE
The expansion index test is designed to measure a basic index property of the soil and in this respect is comparable to other index tests such as the Atterberg limits. In formulating the test procedures no attempt has been made to duplicate any particular moisture or loading conditions which may occur in the field. Rather, an attempt has been made to control all variables which influence the expansive characteristics of a particular soil and still retain a practical test for general engineering usage.

SECTION 18.202 — APPARATUS

18.202.1 Mold. The mold shall be cylindrical in shape, made of metal and have the capacity and dimensions indicated in Figure 18-2-1. It shall have a detachable collar inscribed with a mark 2.00 inches (50.8 mm) above the base. The lower section of the mold is designed to retain a removable stainless steel ring 1.00 inch (25.4 mm) in height, 4.01-inch (101.85 mm) internal diameter and 0.120-inch (3.048 mm) wall thickness.

18.202.2 Tamper. A metal tamper having a 2-inch-diameter (50.8 mm) circular face and weighing 5.5 pounds (2.5 kg) shall be equipped with a suitable arrangement to control height of drop to a free fall of 12 inches (305 mm) above the top of the soil.

18.202.3 Balance. A balance or scale of at least 1,000-gram capacity sensitive to 0.1 gram.


18.202.5 Straight Edge. Steel straight edge 12 inches (305 mm) in length and having one bevelled edge.

18.202.6 Sieves. A No. 4 (4.75 mm) sieve conforming to the requirements of the specifications for sieves for testing purposes.

18.202.7 Mixing Tools. Miscellaneous tools such as mixing pans, spoons, trowels, spatula, etc., or a suitable mechanical device for thoroughly mixing the sample of soil with increments of water.

SECTION 18.203 — SAMPLE PREPARATION

18.203.1 Preparation for Sieving. If the soil sample is damp when received from the field, dry it until it becomes friable under a trowel. Drying may be in air or by use of drying apparatus such that the temperature of the sample does not exceed 140°F. (60°C.). Then thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of the individual particles. If particles larger than 1/4 inch (6.4 mm) are possibly expansive, such as claystone, shale or weathered volcanic rock, they should be broken down so as to pass the No. 4 (4.75 mm) sieve.

18.203.2 Sieving. Sieve an adequate quantity of the representative pulverized soil over the No. 4 (4.75 mm) sieve. Record the percentage of coarse material retained on the No. 4 (4.75 mm) sieve and discard.

18.203.3 Sample. Select a representative sample, weighing approximately 2 pounds (0.91 kg) or more, of the soil prepared as described in Sections 18.203.1 and 18.203.2 above.
SECTION 18.204 — SPECIMEN PREPARATION

18.204.1 Moisture Determination. Thoroughly mix the selected representative sample with sufficient distilled water to bring the soil to approximately optimum moisture content. After mixing, take a representative sample of the material for moisture determination and seal the remainder of the soil in a close-fitting airtight container for a period of at least six hours.

Weigh the moisture sample immediately and dry in an oven at 230°F ± 9°F (110°C ± 5°C.), for at least 12 hours or to a constant weight to determine the moisture content. Moisture sample shall not weigh less than 300 grams.

18.204.2 Specimen Molding. Form a specimen by compacting the cured soil in the 4-inch-diameter (102 mm) mold in two equal layers to give a total compacted depth of approximately 2 inches (51 mm). Compact each layer by 15 uniformly distributed blows of the tamper dropping free from a height of 12 inches (305 mm) above the top of the soil, when a sleeve-type rammer is used, or from 12 inches (305 mm) above the approximate elevation of each finally compacted layer when a stationary mounted type of tamper is used. During the compaction the mold shall rest on a uniform, rigid foundation, such as provided by a cube of concrete weighing at least 200 pounds (90.72 kg).

18.204.3 Trim Specimen. Following compaction, remove the upper and lower portions of the mold from the inner ring and carefully trim the top and bottom of the ring by means of the straight edge.

18.204.4 Saturation. Weigh the compacted sample and determine the percent saturation. Adjust the moisture content to achieve 50 percent saturation by the addition of water or air drying the sample. Repeat Sections 18.204.2 and 18.204.3 above.

\[ \text{FIGURE 18-2-1} \]

18.204.5 Specific Gravity. Repeat Section 18.204.4 until the saturation of the compacted sample is between 49 percent and 51 percent for a specific gravity of 2.7.

SECTION 18.205 — EXPANSION MEASUREMENT

18.205.1 Consolidometer. Place the soil specimen in a consolidometer or equivalent loading device with porous stones at the top and bottom. Place on the specimen a total load of 12.63 pounds.
(56.2 N), including the weight of the upper porous stone and any unbalanced weight of the loading machine. Allow the specimen to consolidate under this load for a period of 10 minutes, after which time make the initial reading on the consolidometer dial indicator to an accuracy of 0.0005 inch (0.010 mm).

18.205.2 Sample Submersion. Submerge the sample in distilled water, making periodic readings on the dial indicator for a period of 24 hours or until the rate of expansion becomes less than 0.0002 inch (0.0051 mm) per hour but not less than three hours submerged time.

18.205.3 Weighing. Remove the sample from the loading machine after the final reading and weigh the specimen to the nearest 0.1 gram.

SECTION 18.206 — CALCULATIONS AND REPORT

18.206.1 Expansion Index. Calculate the expansion index as follows:

\[
E.I. = \frac{(\text{final thickness} - \text{initial thickness})}{\text{initial thickness}} \times 1,000
\]

Report the expansion index to the nearest whole number. If the initial sample thickness is greater than the final sample thickness, report the expansion index as 0. The molding moisture content and initial dry density of the specimen should accompany the expansion index in the complete presentation of results.

18.206.2 Weighted Expansion Index. The weighted expansion index for a particular soil profile shall be determined as the summation of the products obtained by multiplying the expansion index by the factor appropriate to its elevation as indicated in Table 18-I-C of this code.
UNIFORM BUILDING CODE STANDARD 19-1
PORTLAND CEMENT AND BLENDED HYDRAULIC CEMENTS


See Sections 1903.2 and 1905.4, Uniform Building Code
Part I—Portland Cement

SECTION 19.101 — SCOPE

This part of the standard covers eight types of portland cement as follows:

Type I—For use in general concrete construction when the special properties specified for Types II, III, IV and V are not required.

Type IA. Same use as Type I where air entrainment is required.

Type II—For use in general concrete construction exposed to moderate sulfate action, or where moderate heat of hydration is required.

Type IIA. Same use as Type II where air entrainment is required.

Type III—For use when high early strength is required.

Type IIIA. Same use as Type III where air entrainment is required.

Type IV—For use when a low heat of hydration is required.

Type V—For use when high sulfate resistance is required.

SECTION 19.102 — DEFINITION

Portland cement is a hydraulic cement produced by pulverizing clinker consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulfate as an interground addition.

Air-entrained portland cement is a hydraulic cement produced by pulverizing clinker consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulfate as an interground addition, and with which there has been an interground air-entrained addition.

The cement shall contain no addition, except that water or calcium sulfate, or both, may be added in amounts such that the limits shown in Table 19-1-A for sulfur trioxide, and loss-on-ignition shall not be exceeded. Processing additions may be used in the manufacture of the cement, provided such materials in the amounts used have been shown to not be harmful by nationally recognized tests carried out or reviewed by an approved laboratory.

SECTION 19.103 — CHEMICAL REQUIREMENTS

Portland cement of each of the eight types shown in Section 19.101 shall conform to the respective chemical requirements prescribed in Table 19-1-A. In addition, optional chemical requirements are shown in Table 19-1-D.

SECTION 19.104 — PHYSICAL REQUIREMENTS

Portland cement of each of the eight types shown in Section 19.101 shall conform to the respective physical requirements prescribed in Table 19-1-B.
<table>
<thead>
<tr>
<th>TABLE 19-1-A—CHEMICAL REQUIREMENTS FOR CEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>STANDARD REQUIREMENTS</strong></td>
</tr>
<tr>
<td><strong>PORTLAND CEMENT TYPES</strong></td>
</tr>
<tr>
<td><strong>I and IA</strong></td>
</tr>
<tr>
<td>Silicon dioxide (SiO₂), min., %</td>
</tr>
<tr>
<td>Aluminum oxide (Al₂O₃), max., %</td>
</tr>
<tr>
<td>Ferric oxide (Fe₂O₃), max., %</td>
</tr>
<tr>
<td>Magnesium oxide (MgO), max., %</td>
</tr>
<tr>
<td>Sulfur trioxide (SO₃), max., %</td>
</tr>
<tr>
<td>When (C₃A)₂ is 8% or less</td>
</tr>
<tr>
<td>When (C₃A)₂ is more than 8%</td>
</tr>
<tr>
<td>Loss on ignition, max., %</td>
</tr>
<tr>
<td>Insoluble residue, max., %</td>
</tr>
<tr>
<td>Tricalcium silicate (C₃S), max., %</td>
</tr>
<tr>
<td>Dicalcium silicate (C₂S), min., %</td>
</tr>
<tr>
<td>Tricalcium aluminate (C₃A), max., %</td>
</tr>
<tr>
<td>Tetracalcium aluminoferrite plus twice the tricalcium aluminate² [C₄AF + 2(C₃A)], or solid solution (C₄AF + C₃F), as applicable, max., %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>OPTIONAL REQUIREMENTS</strong>³</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I and IA</strong></td>
</tr>
<tr>
<td>Tricalcium aluminate (C₃A), max., %</td>
</tr>
<tr>
<td>Tricalcium aluminate (C₃A), max., %</td>
</tr>
<tr>
<td>Sum of tricalcium silicate and tricalcium aluminate, max., %</td>
</tr>
<tr>
<td>Alkalis (Na₂O + 0.658K₂O), max., %</td>
</tr>
</tbody>
</table>

¹There are cases where optimum SO₃ for a particular cement is close to or exceeds the limit in this standard. Where it has been demonstrated that this condition exists, an additional amount of SO₃ is permissible, provided that when the cement with the additional calcium sulfate is tested in accordance with nationally recognized standards, the calcium sulfate in the hydrated mortar at 24 ± ½ hour expressed as SO₃ does not exceed 0.50 gram/liter. The supporting data shall be submitted to the building official upon request.

²The expressing of chemical limitations by means of calculated assumed compounds does not necessarily mean that the oxides are actually or entirely present as such compounds.

When expressing compounds, C = CaO, S = SiO₂, A = Al₂O₃, F = Fe₂O₃. For example, C₃A = 3CaO x Al₂O₃.

Titanium dioxide and phosphorus pentoxide (TiO₂ and P₂O₅) shall be included with the Al₂O₃ content. The value historically and traditionally used for Al₂O₃ in calculating potential compounds for specification purposes is the ammonium hydroxide group minus ferric oxide (R₂O₃-Fe₂O₃) as obtained by classical wet chemical methods. This procedure includes as Al₂O₃ the TiO₂P₂O₅ and other trace oxides which precipitate with the ammonium hydroxide group in the classical wet chemical methods. Many modern instrumental methods of cement analysis determine aluminum or aluminum oxide directly without the minor and trace oxides included by the classical method. Consequently, for consistency and to provide comparability with historic data and among various analytical methods, when calculating potential compounds for specification purposes, those using methods which determine A1 or Al₂O₃ directly should add to the determined Al₂O₃ weight quantities of P₂O₅, TiO₂.
and any other oxide except Fe$_2$O$_3$ which would precipitate with the ammonium hydroxide group when analyzed by the classical method and which is present in an amount of 0.05 weight percent or greater. The weight percent of minor trace oxides to be added to Al$_2$O$_3$ by those using direct methods may be obtained by actual analysis of those oxides in the sample being tested or estimated from historical data on those oxides on cements from the same source, provided that the estimated values are identified as such.

When the ratio of percentages of aluminum oxide to ferric oxide is 0.64 or more, the percentages of tricalcium silicate, dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite shall be calculated from the chemical analysis as follows:

- **Tricalcium silicate**: $(4.071 \times \% \text{CaO}) - (7.600 \times \% \text{SiO}_2) - (6.718 \times \% \text{Al}_2\text{O}_3) - (1.430 \times \% \text{Fe}_2\text{O}_3) - (2.852 \times \% \text{SO}_3)$
- **Dicalcium silicate**: $(2.867 \times \% \text{SiO}_2) - (0.7544 \times \% \text{C}_3\text{S})$
- **Tricalcium aluminate**: $(2.650 \times \% \text{Al}_2\text{O}_3) - (1.692 \times \% \text{Fe}_2\text{O}_3)$
- **Tetracalcium aluminoferrite**: $3.043 \times \% \text{Fe}_2\text{O}_3$

When the alumina-ferric oxide ratio is less than 0.64, a calcium aluminoferrite solid solution [expressed as ss(C$_4$AF + C$_2$F)] is formed. Contents of this solid solution and of tricalcium silicate shall be calculated by the following formulas:

- **ss(C$_4$AF + C$_2$F)**: $(2.100 \times \% \text{Al}_2\text{O}_3) + (1.702 \times \% \text{Fe}_2\text{O}_3)$
- **Tricalcium silicate**: $(4.071 \times \% \text{CaO}) - (7.600 \times \% \text{SiO}_2) - (4.479 \times \% \text{Al}_2\text{O}_3) - (2.859 \times \% \text{Fe}_2\text{O}_3) - (2.852 \times \% \text{SO}_3)$

No tricalcium aluminate will be present in cements of this composition. Dicalcium silicate shall be calculated as previously shown.

In the calculation of all of C$_3$A, the values of Al$_2$O$_3$ and Fe$_2$O$_3$ determined to the nearest 0.01 percent shall be used. In the calculation of other compounds, the oxides determined to the nearest 0.1 percent shall be used.

All values calculated as described in this note shall be reported to the nearest 1 percent.

3NA—Not applicable.

4For high sulfate resistance.

5Does not apply when the sulfate expansion limit in the "Optional Requirements" section of this table is specified.

6These optional requirements apply only when specifically requested.

7For moderate sulfate resistance.

8For moderate heat of hydration.

9This limit does not apply when the heat of hydration limit in the "Optional Requirements" section of this table is specified.

10For low-alkali cement.

11This limit may be specified when the cement is to be used on concrete with aggregates that may be deleteriously reactive.
### TABLE 19-1-B—PHYSICAL REQUIREMENTS

<table>
<thead>
<tr>
<th>STANDARD REQUIREMENTS</th>
<th>PORTLAND CEMENT TYPES</th>
<th>I</th>
<th>IA</th>
<th>II</th>
<th>BIA</th>
<th>III</th>
<th>BIA</th>
<th>IVa</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air content of mortar, volume percent:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>max.</td>
<td>12</td>
<td>22</td>
<td>12</td>
<td>12</td>
<td>22</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>min.</td>
<td>—</td>
<td>16</td>
<td>—</td>
<td>16</td>
<td>—</td>
<td>16</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Fineness, specific surface, m²/kg (alternative methods):</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turbidimeter test, min.</td>
<td>160</td>
<td>160</td>
<td>160</td>
<td>160</td>
<td>—</td>
<td>—</td>
<td>160</td>
<td>160</td>
<td>—</td>
</tr>
<tr>
<td>Air permeability test, min.</td>
<td>280</td>
<td>280</td>
<td>280</td>
<td>280</td>
<td>—</td>
<td>—</td>
<td>280</td>
<td>280</td>
<td>—</td>
</tr>
<tr>
<td>Autoclave expansion, max., percent</td>
<td>0.80</td>
<td>0.80</td>
<td>0.80</td>
<td>0.80</td>
<td>0.80</td>
<td>0.80</td>
<td>0.80</td>
<td>0.80</td>
<td>—</td>
</tr>
<tr>
<td>Strength, not less than the values shown for the ages indicated below:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compressive strength, psi (× 0.00689 for MPa):</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 day</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>3 days</td>
<td>1,800</td>
<td>1,450</td>
<td>1,500</td>
<td>1,200</td>
<td>1,800</td>
<td>1,450</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>7 days</td>
<td>2,800</td>
<td>2,250</td>
<td>2,500</td>
<td>2,000</td>
<td>—</td>
<td>—</td>
<td>1,000</td>
<td>2,200</td>
<td>—</td>
</tr>
<tr>
<td>28 days</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>2,500</td>
<td>3,000</td>
<td>—</td>
</tr>
<tr>
<td>Time of setting (alternative methods):</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gillmore test:</td>
<td></td>
<td></td>
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<tr>
<td>Initial set, min., not less than</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Final set, h., not more than</td>
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<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
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<td>Vicat test:</td>
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</tr>
<tr>
<td>Initial set, min., not less than</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>—</td>
</tr>
<tr>
<td>Final set, h., not more than</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
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<tr>
<td>Optional Requirements²</td>
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<tr>
<td>False set, final penetration, min., percent</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
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<td>Heat of hydration:</td>
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<td></td>
</tr>
<tr>
<td>7 days, max., cal/g (× 4.19 for kJ/kg)</td>
<td>—</td>
<td>—</td>
<td>70⁶</td>
<td>70⁶</td>
<td>—</td>
<td>—</td>
<td>60</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>28 days, max., cal/g</td>
<td>—</td>
<td>—</td>
<td>80⁶</td>
<td>80⁶</td>
<td>—</td>
<td>—</td>
<td>70</td>
<td>—</td>
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</tr>
<tr>
<td>Strength, not less than the values shown:</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Compressive strength, psi (× 0.00689 for MPa) 28 days</td>
<td>4,000</td>
<td>3,200</td>
<td>4,000</td>
<td>3,200</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Sulfate expansion, 7 14 days, max., percent</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.040</td>
</tr>
</tbody>
</table>

¹ See Table 19-1-A.
² See Table 19-1-C.
³ See Table 19-1-D.
⁴ See Table 19-1-E.
FOOTNOTES TO TABLE 19-1-B

1 Compliance with the requirements of this specification does not necessarily ensure that the desired air content will be obtained in concrete.
2 Either of the two alternative fineness methods may be used at the option of the testing laboratory. However, when the sample fails to meet the requirements of the air-permeability test, the turbidimeter test shall be used, and the requirements in this table for the turbidimetric method shall govern.
3 The strength at any specified test age shall not be less than that attained at any previous specified test age.
4 When the optional heat of hydration or the chemical limit on the sum of tricalcium silicate and tricalcium aluminate requirements are requested.
5 These optional requirements apply only when specifically requested.
6 The optional limit for the sum of the tricalcium silicate and tricalcium aluminate in Table 19-1-B shall not be requested when this optional limit is requested. These strength requirements apply when either heat of hydration or the sum of tricalcium silicate and tricalcium aluminate requirements are specified.
7 When the sulfate expansion is specified, it shall be instead of the limits of C3A and C4AF + 2C3A listed in Table 19-1-A.
8 When the heat of hydration limit is specified, it shall be used instead of the limits of C3S, C2S and C3A listed in Table 19-1-A.
Part II—Blended Hydraulic Cement

SECTION 19.105 — SCOPE

This part of the standard covers five classes of blended hydraulic cements using slag or pozzolan, or both, with portland cement or portland cement clinker or slag with lime.

The types of blended cement covered by this specification are as follows:

Portland Blast-furnace Slag Cement—One type with three optional provisions is covered as follows:

Type IS—Portland blast-furnace slag cement for use in general concrete construction.

Type IP—Portland-pozzolan cement for use in general concrete construction.

Type P—Portland-pozzolan cement for use in concrete construction where high strengths at early ages are not required.

Slag Cement—One type is covered as follows:

Type S—Slag cement for use in combination with portland cement in making concrete and in combination with hydrated lime in making masonry mortar.

Air entraining can be specified by adding the suffix (A).

Pozzolan-modified Portland Cement—One type is covered as follows:

Type 1 (PM)—Pozzolan-modified portland cement for use in general concrete construction.

Pozzolan-modified portland cement should not be used when special characteristics attributable to the larger quantities of pozzolan in portland-pozzolan cement are desired.

Slag-modified Portland Cement—One type is covered as follows:

Type 1 (SM)—Slag-modified portland cement for use in general construction.

SECTION 19.106 — DEFINITIONS

Certain words and terms used in this standard are defined as follows:

AIR-ENTRAINING PORTLAND BLAST-FURNACE SLAG CEMENT, TYPE IS-A, is portland blast-furnace slag cement as defined, except that sufficient air-entraining addition, as specified in Section 19.107, has been used so that the resulting product complies with the air content of mortar requirements given in Table 19-1-C.

AIR-ENTRAINING PORTLAND-POZZOLAN CEMENT, TYPE IP-A, is portland-pozzolan cement, except that sufficient air-entraining addition, as specified in Section 19.107, has been
used so that the resulting product complies with the air content of mortar requirements given in Table 19-1-C.

**AIR-ENTRAINING POZZOLAN-MODIFIED PORTLAND CEMENT TYPE I (PM)-A**, is air-entraining pozzolan portland cement Type IP-A, except that sufficient air-entraining addition, as specified in Section 19.107, has been used so that the resulting product complies with the air content of mortar requirements given in Table 19-1-C.

**AIR-ENTRAINING SLAG CEMENTS, TYPE SA**, is slag cement Type S, except that sufficient air-entraining addition, as specified in Section 19.107, has been used so that the resulting product complies with the air content of mortar requirements given in Table 19-1-C.

**AIR-ENTRAINING SLAG-MODIFIED PORTLAND CEMENT, TYPE I (SM)-A**, is Type I (SM) slag-modified portland cement, except that sufficient air-entraining addition, as specified in Section 19.107, has been used so that the resulting product complies with the air content of mortar requirements given in Table 19-1-C.

**BLAST-FURNACE SLAG** is the nonmetallic product consisting essentially of silicates and aluminosilicates of calcium and of other bases that is developed in a molten condition simultaneously with iron in a blast furnace.

**GRANULATED BLAST-FURNACE SLAG** is the glassy granular material formed when molten blast-furnace slag is rapidly chilled, as by immersion in water.

Granulation may be achieved by quenching blast-furnace slag from its original molten state or by quenching air-cooled blast-furnace slag after remelting. Small percentages of silica and alumina may be added while the slag is molten to enhance desired characteristics.

**HYDRATED LIME** is the product described as Type N of U.B.C. Standard 21-13, except that it must meet the chemical composition requirements of Type S of the same standard.

**PORTLAND BLAST-FURNACE SLAG CEMENT, TYPE IS**, is a hydraulic cement consisting of an intimate and uniform blend of portland cement and fine granulated blast-furnace slag produced either by intergrinding portland cement clinker and granulated blast-furnace slag or by blending portland cement and finely ground granulated blast-furnace slag, in which the slag constituent is between 25 and 70 percent of the weight of portland blast-furnace slag cement.

**PORTLAND CEMENT** is the product obtained by pulverizing clinker consisting essentially of hydraulic calcium silicates meeting the requirements of Part I of this standard. Portland cement or other hydraulic materials, or both, containing high free lime may be used as long as the autoclave test limits for the blended cement are met.

**PORTLAND CEMENT CLinker** is partially fused clinker consisting primarily of hydraulic calcium silicates.

**PORTLAND-POZZOLAN CEMENT, TYPE IP**, is a hydraulic cement consisting of an intimate and uniform blend of portland cement or portland blast-furnace slag cement and fine pozzolan produced either by intergrinding portland cement clinker and pozzolan, by blending portland cement or portland blast-furnace slag cement and finely divided pozzolan, or a combination of intergrinding and blending, in which the pozzolan constituent is between 15 and 40 weight percent of the portland-pozzolan cement.

**POZZOLAN** is a siliceous or siliceous and aluminous material, which in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

**POZZOLAN-MODIFIED PORTLAND CEMENT, TYPE I (PM)**, is an intimate and uniform blend of portland cement or portland blast-furnace slag cement and fine pozzolan produced either by intergrinding portland cement clinker and pozzolan, by blending portland cement or portland blast-furnace slag cement and finely divided pozzolan, or a combination of intergrinding and
blending, in which the pozzolan constituent is less than 15 weight percent of the pozzolan-modified portland cement.

SLAG CEMENT, TYPE S, is a blended hydraulic cement consisting mostly of an intimate and uniform blend of granulated blast-furnace slag and portland cement, or hydrated lime, or both, in which the slag constituent is at least 70 percent of the weight of the slag cement.

SLAG-MODIFIED PORTLAND CEMENT, TYPE I (SM), is an intimate and uniform blend of portland cement and granulated blast-furnace slag produced either by intergrinding portland cement clinker and granulated blast-furnace slag, by blending portland cement and finely ground granulated blast-furnace slag, or a combination of intergrinding and blending in which the slag constituent is less than 25 percent of the weight of the slag-modified portland cement.

SECTION 19.107 — ADDITIONS
19.107.1 Air-entraining Addition. When air-entraining cement is specified, an addition meeting the requirements of nationally recognized standards shall be used.

19.107.2 Processing Additions. At the option of the manufacturer, processing additions may be used in the manufacture of cement, provided such materials in the amounts used have been shown to meet the requirement of nationally recognized standards.

19.107.3 Other Additions. The cement covered by this standard shall contain no additions except as provided for above except that water or calcium sulfate, or both, may be added in amounts so that the limits shown in Table 19-1-A for sulfate reported as $\text{SO}_3$ and loss on ignition are not exceeded.

SECTION 19.108 — CHEMICAL REQUIREMENTS
19.108.1 General. Cement of the type specified shall conform to the chemical requirements prescribed in Table 19-1-C.

19.108.2 Moderate Sulfate Resistance. When moderate sulfate resistance (MS) is specified, the tricalcium aluminate ($3\text{CaO} \cdot \text{Al}_2\text{O}_3$) content of the portland cement calculated as in Part I shall not exceed 8.0 percent and the sum of the amounts of silicon dioxide ($\text{SiO}_2$), aluminum oxide ($\text{Al}_2\text{O}_3$), and iron oxide ($\text{Fe}_2\text{O}_3$) in the pozzolan used in portland-pozzolan cement shall not be less than 70 percent.

SECTION 19.109 — PHYSICAL PROPERTIES
19.109.1 Blended Cement. Blended cement of the type specified shall conform to the applicable physical requirements prescribed in Table 19-1-D.

19.109.2 Pozzolan or Slag. Pozzolan or slag that is to be blended with cement shall be tested in the same state of subdivision as that in which it is to be blended. Pozzolan shall conform to the fineness requirement and the pozzolanic activity requirement of Table 19-1-E. Slag that is to be used for slag-modified portland cements shall conform to the slag activity requirement of Table 19-1-E. Such pozzolan or slag that is to be interground with portland cement clinker shall, before testing for conformance with requirements of Table 19-1-E, be ground in the laboratory to a fineness at which it is believed to be present in the finished cement.

Pozzolan for use in the manufacture of pozzolan-modified portland cement, Types I (PM) and I (PM)-A, shall meet the requirements of Table 19-1-E when tested for mortar expansion of pozzolan. If the alkali content of the clinker to be used for the production lots changes by more than 0.2 percent total as equivalent Na$_2$O, calculated as Na$_2$O + 0.658 K$_2$O, from that of the clinker with which the acceptance tests were carried out, the pozzolan shall be retested to show compliance with the requirements of Table 19-1-E.
SECTION 19.110 — TESTING LOCAL SUPPLY

Every 90 days, each lime producer shall retain an approved agency to obtain a random sample of bagged cement from a local point of supply in the market area served by the producer.

The agency shall test the cement for compliance with the physical requirements of Tables 19-1-B and 19-1-D.

Upon request of the building official, the producer shall furnish (at no cost) test results to the building official, architect, structural engineer, general contractor and masonry contractor.
### TABLE 19-1-C—CHEMICAL REQUIREMENTS

<table>
<thead>
<tr>
<th>CHEMICAL</th>
<th>I(SM), I(SM)-A, IS, IS-A (max. percent)</th>
<th>S, SA (max. percent)</th>
<th>I(PM), I(PM)-A (max. percent)</th>
<th>P, PA, IP, IP-A (max. percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnesium oxide (MgO)</td>
<td>—</td>
<td>—</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Sulfur reported as sulfate (SO₃)</td>
<td>3.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Sulfide sulfur (S)</td>
<td>1.0</td>
<td>2.0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Insoluble residue</td>
<td>1.0</td>
<td>1.0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>3.0</td>
<td>4.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Water-soluble alkali</td>
<td>—</td>
<td>0.031</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

1. Applicable only when the cement is specified to be nonstaining to limestone. The amount and nature of the staining material in limestone may vary with the stone. The alkali in any cement may, therefore, induce markedly different staining on different stone, even though the stone may have come apparently from the same source. The amount of alkali permitted by the specification should not cause stain unless stone high in staining material has been used or unless insufficient means have been used to prevent infiltration of water into the masonry.

2. When it has been demonstrated by test that the optimum SO₃ exceeds a value 0.5 percent less than the specification limit, an additional amount of SO₃ is permissible, provided that when the cement with the additional calcium sulfate is tested, the calcium sulfate in the hydrated mortar at 24 hours ± 1/₄ hour, expressed as SO₃, does not exceed 0.50 g/L. When the manufacturer supplies cement under this provision, the manufacturer will, upon request, supply support data to the purchaser.
### TABLE 19-1-D—PHYSICAL REQUIREMENTS

<table>
<thead>
<tr>
<th>STANDARD REQUIREMENTS</th>
<th>(SM), IS</th>
<th>(SM)-A, IS-A</th>
<th>(SM)-A, IS-P</th>
<th>S</th>
<th>SA</th>
<th>(PM), IP</th>
<th>(PM)-A, IP-P</th>
<th>P</th>
<th>PA</th>
<th>IP-P</th>
<th>IP-P-A, IP-P-A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autoclave expansion, max. percent</td>
<td>0.50 0.50 0.50</td>
<td>0.50 0.50 0.50</td>
<td>0.50 0.50 0.50</td>
<td>0.50 0.50 0.50</td>
<td>0.50 0.50 0.50</td>
<td>0.50 0.50 0.50</td>
<td>0.50 0.50 0.50</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Autoclave contraction, max. percent</td>
<td>0.20 0.20 0.20</td>
<td>0.20 0.20 0.20</td>
<td>0.20 0.20 0.20</td>
<td>0.20 0.20 0.20</td>
<td>0.20 0.20 0.20</td>
<td>0.20 0.20 0.20</td>
<td>0.20 0.20 0.20</td>
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<tr>
<td>Time of setting, Vicat test:</td>
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<tr>
<td>Set, minutes, not less than</td>
<td>45 45 45</td>
<td>45 45 45</td>
<td>45 45 45</td>
<td>45 45 45</td>
<td>45 45 45</td>
<td>45 45 45</td>
<td>45 45 45</td>
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<tr>
<td>Set, hours, not more than</td>
<td>7 7 7</td>
<td>7 7 7</td>
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<tr>
<td>Air content of mortar volume, percent</td>
<td>12 max 19 ± 3</td>
<td>12 max 19 ± 3</td>
<td>12 max 19 ± 3</td>
<td>12 max 19 ± 3</td>
<td>12 max 19 ± 3</td>
<td>12 max 19 ± 3</td>
<td>12 max 19 ± 3</td>
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<tr>
<td>Compressive strength, min., psi</td>
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<tr>
<td>(× 0.00689 for MPa)</td>
<td>3 days</td>
<td>1,800 1,450 1,200</td>
<td>2,800 2,250 2,000</td>
<td>2,800 2,250 2,000</td>
<td>1,800 1,450 1,200</td>
<td>1,800 1,450 1,200</td>
<td>1,800 1,450 1,200</td>
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<tr>
<td>7 days</td>
<td>3,500 3,000 2,800</td>
<td>3,500 3,000 2,800</td>
<td>2,000 1,500 1,250</td>
<td>1,500 1,250 1,200</td>
<td>2,500 2,000 2,000</td>
<td>3,500 3,000 2,800</td>
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<tr>
<td>28 days</td>
<td>2,800 2,250 2,000</td>
<td>2,800 2,250 2,000</td>
<td>1,800 1,450 1,200</td>
<td>1,500 1,250 1,200</td>
<td>2,000 2,000 2,000</td>
<td>3,500 3,000 2,800</td>
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<tr>
<td>Heat of hydration</td>
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<tr>
<td>7 days, max., cal/g (× 4.19 for kJ/kg)</td>
<td>70 70 70</td>
<td>70 70 70</td>
<td>70 70 70</td>
<td>70 70 70</td>
<td>70 70 70</td>
<td>70 70 70</td>
<td>70 70 70</td>
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<tr>
<td>28 days, max., cal/g</td>
<td>80 80 80</td>
<td>80 80 80</td>
<td>80 80 80</td>
<td>80 80 80</td>
<td>80 80 80</td>
<td>80 80 80</td>
<td>80 80 80</td>
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<tr>
<td>Water requirement, max. weight percent of cement</td>
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<td>Drying shrinkage, max., percent</td>
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</tr>
<tr>
<td>Mortar expansion</td>
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<tr>
<td>At age of 14 days, max., percent</td>
<td>0.020 0.020 0.020</td>
<td>0.020 0.020 0.020</td>
<td>0.020 0.020 0.020</td>
<td>0.020 0.020 0.020</td>
<td>0.020 0.020 0.020</td>
<td>0.020 0.020 0.020</td>
<td>0.020 0.020 0.020</td>
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<tr>
<td>At age of 8 weeks, max., percent</td>
<td>0.060 0.060 0.060</td>
<td>0.060 0.060 0.060</td>
<td>0.060 0.060 0.060</td>
<td>0.060 0.060 0.060</td>
<td>0.060 0.060 0.060</td>
<td>0.060 0.060 0.060</td>
<td>0.060 0.060 0.060</td>
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</tr>
</tbody>
</table>

1. The specimens shall remain firm and hard and show no signs of distortion, cracking, checking, pitting or disintegration when subject to the autoclave expansion test.
2. Applicable only when moderate (MH) or low (LH) heat of hydration is specified, in which case the strength requirements shall be 80 percent of the values shown in the table.
3. The test for mortar expansion is an optional requirement unless the cement will be used with alkali-reactive aggregate.

### TABLE 19-1-E—PHYSICAL REQUIREMENTS FOR POZZOLAN FOR USE IN BLENDED CEMENTS AND FOR SLAG FOR USE IN SLAG-MODIFIED PORTLAND CEMENTS

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TABLE 19-1-E</strong> — PHYSICAL REQUIREMENTS FOR POZZOLAN FOR USE IN BLENDED CEMENTS AND FOR SLAG FOR USE IN SLAG-MODIFIED PORTLAND CEMENTS</td>
<td></td>
</tr>
<tr>
<td><strong>Fineness:</strong></td>
<td></td>
</tr>
<tr>
<td>Amount retained when wet sieved on 45 micron (No. 325) sieve, maximum, percent</td>
<td>20.0</td>
</tr>
<tr>
<td>Alkali reactivity of pozzolan for use in Types 1 (PM) and 1 (PM)-A cements, six tests, mortar bar expansion at 91 days, maximum, percent</td>
<td>0.05</td>
</tr>
<tr>
<td>Slag or pozzolan activity index: with portland cement, at 28 days, minimum, percent</td>
<td>75</td>
</tr>
</tbody>
</table>

**NOTE:** A pozzolan has acceptable pozzolanic activity under this specification if it meets either of the two alternative limits. All activity tests shall be conducted in accordance with nationally recognized tests and may be subject to the approval of the building official.
UNIFORM BUILDING CODE STANDARD 19-2
WELDING REINFORCING STEEL, METAL INSERTS AND CONNECTIONS IN REINFORCED CONCRETE CONSTRUCTION

See Sections 1903.5.2, 1903.10, and 1912.14, Uniform Building Code

SECTION 19.201 — ADOPTION OF AWS CODE

2.101.1 Except for the limitations, deletions, modifications or amendments set forth in Section 19.202 of this standard, the welding of concrete reinforcing steel for splices (prestressing steel excepted), steel connection devices, inserts, anchors and anchorage details, as well as any other welding required in reinforced concrete construction, shall be in accordance with the Structural Welding Code—Reinforcing Steel, ANSI/AWS D1.4-92, published by the American Welding Society, Inc., Copyright 1992, 550 North LeJeune Road, Miami, Florida 33135, as if set out at length herein.

SECTION 19.202 — DELETIONS AND AMENDMENTS


19.202.2 Deletions. The following sections and chapters are deleted:

Section 1.6
Section 1.7
Section 3.7
Section 5.6.3
Chapter 7

19.202.3 Amendments

1. Sec. 1.2.1 is amended by changing the last sentence to read as follows:

When reinforcing steel is welded to primary structural steel members, welding procedures, welder qualification requirements and welding electrodes shall be in accordance with Chapter 22, Divisions V, VIII and IX or X, of this code and approved national standards.

2. Sec. 1.2.3 is amended to read as follows:

1.2.3. All references to the need for approval shall be interpreted to mean approval by the building official.

3. Sec. 1.2.4 is amended to read as follows:

1.2.4 When structural steel base metals make up the entire weld joint, the engineer may select the use of welding procedures and welder qualifications in accordance with Chapter 22, Divisions V, VIII and IX or X, of this code and approved national standards to perform that weld, provided other relevant provisions of U.B.C. Standard 19-2 are considered.

4. Sec. 1.3.3 is amended to read as follows:

1.3.3 Base metal, other than those previously listed, shall be one of the structural steels listed in Chapter 22, Divisions V, VIII and IX or X, of this code.

5. Sec. 1.5 is amended to read as follows:
1.5 Definitions

The welding terms used in this code shall be interpreted in accordance with the definitions given in Chapter 22, Divisions V, VIII and IX or X, of this code and approved national standards.

6. Sec. 2.1 is amended to read as follows:

2.1 Base Metal Stresses. The allowable base metal stresses shall be those specified in this code for reinforced concrete construction.
UNIFORM BUILDING CODE STANDARD 19-3
READY-MIXED CONCRETE


See Sections 108, 1701.4, 1903.9 and 1905.8, Uniform Building Code

SECTION 19.301 — SCOPE

This standard covers requirements for ready-mixed concrete. Requirements for quality of materials and for proportions and quality of concrete shall conform to this code and U.B.C. Standard 19-1. Where the requirements are in conflict with this standard, the requirements of this code shall govern.

For the purpose of these specifications, ready-mixed concrete is portland cement concrete, manufactured for delivery to a purchaser in a plastic and unhardened state and delivered as herein-after specified.

SECTION 19.302 — QUALITY OF CONCRETE

19.302.1 General. The quality of ready-mixed concrete and the material used to make the concrete shall conform to the requirements of Chapter 19 of this code and this standard.

19.302.2 Water. Water shall be clear and apparently clean. If it contains quantities of substances which discolor it or make it smell or taste unusual or objectionable or cause suspicion, it shall not be used unless service records of concrete made with it or other information indicates that it is not injurious to the quality of the concrete. Water of questionable quality shall be subject to the acceptance criteria of Table 19-3-A.

Wash water from mixer washout operations may be used for mixing concrete, provided tests of wash water comply with the physical tests mentioned in this item. Wash water shall be tested at a weekly interval for approximately four weeks and thereafter at a monthly interval, provided no single test exceeds the applicable limit. Optional chemical tests in Table 19-3-B may be specified by the purchaser, using the same testing frequency of chemical limits. When recycled wash water is used, attention shall be given to effects on the dosage rate and batch sequence of air-entraining and other chemical admixtures, and a uniform amount shall be used in consecutive batches.

19.302.3 Admixtures. Admixtures shall conform to applicable specifications acceptable to the building official.

SECTION 19.303 — TOLERANCES IN SLUMP

Unless other tolerances are included in the project specifications, the following shall apply.

1. When the project specifications for slump are written as a “maximum” or “not to exceed” requirement:

<table>
<thead>
<tr>
<th>SPECIFIED SLUMP:</th>
<th>SPECIFIED SLUMP:</th>
</tr>
</thead>
<tbody>
<tr>
<td>If 3 inches (76 mm) or less</td>
<td>if more than 3 inches (76 mm)</td>
</tr>
<tr>
<td>Plus tolerance:</td>
<td>0</td>
</tr>
<tr>
<td>Minus tolerance:</td>
<td>1 1/2 inches (38 mm) 2 1/2 inches (63 mm)</td>
</tr>
</tbody>
</table>

   This option is to be used if one addition of water is permitted on the job provided such addition does not increase the water-cement ratio above the maximum permitted by the specifications.
2. When the project specifications for slump are not written as a “maximum” or “not to exceed” requirement:

<table>
<thead>
<tr>
<th>TOLERANCES FOR NOMINAL SLUMPS</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>For Specified Slump of:</td>
<td></td>
</tr>
<tr>
<td>2 inches (51 mm) and less</td>
<td>$\pm \frac{1}{2}$ inch (13 mm)</td>
</tr>
<tr>
<td>More than 2 through 4 inches (51 to 102 mm)</td>
<td>$\pm$ 1 inch (25 mm)</td>
</tr>
<tr>
<td>More than 4 inches (102 mm)</td>
<td>$\pm \frac{3}{4}$ inches (38 mm)</td>
</tr>
</tbody>
</table>

Concrete shall be available, within the permissible range of slump, for a period of 30 minutes starting either on arrival at the job site or after the initial slump adjustment permitted in Section 19.309.6, third paragraph, whichever is later. The first and last $\frac{1}{4}$ cubic yard ($0.19$ m$^3$) discharged are exempt from this requirement. If the user is unprepared for discharge of the concrete from the vehicle, the producer shall not be responsible for the limitation of minimum slump after 30 minutes have elapsed, starting either on arrival of the vehicle at the prescribed destination or at the requested delivery time, whichever is later.

SECTION 19.304 — AIR-ENTRAINED CONCRETE

When air-entrained concrete is used, the total air content shall be in accordance with Section 19.406 of U.B.C. Standard 19-4.

SECTION 19.305 — MANUFACTURER’S STATEMENT

Prior to the actual delivery of the concrete, the manufacturer shall furnish a statement available to the building official giving the properties of the materials and the proportions by weight (dry) of cement and of fine and coarse aggregates that are proposed to be used in the manufacture of each class of concrete, the water content, the type and amount of admixture, and the maximum and minimum limits of air content ordered for the job.

SECTION 19.306 — MEASURING MATERIALS

Except as otherwise specifically permitted, cement shall be measured by weight. When fly ash or other pozzolans are specified in the mix design, they may be weighed cumulatively with cement. Cement and pozzolan shall be weighed on a scale and in a weigh hopper which is separate and distinct from those used for other materials. Cement shall be weighed before pozzolan. When the quantity of cement in a batch of concrete exceeds 30 percent of the full capacity of the scale, the quantity of cement, and the cumulative quantity of cement plus pozzolan, shall be within $\pm$ 1 percent of the required weight. For smaller batches to a minimum of 1 cubic yard ($0.76$ m$^3$), the quantity of cement and the quantity of cement plus pozzolan used shall not be less than the required amount or more than 4 percent in excess. Under special circumstances, cement may be measured in bags of standard weight. No fraction of a bag of cement shall be used unless weighed.

Aggregate shall be measured by weight. Batch weights shall be based on dry materials and shall be the required weights of dry materials plus the total weight of moisture (both absorbed and surface) contained in the aggregate. The quantity of aggregate used in any batch of concrete as indicated by the scale shall be within $\pm$ 2 percent of the required weight when weighed in individual aggregate weigh batchers. In a cumulative aggregate weigh batcher, the cumulative weight after each successive weighing shall be within $\pm$ 1 percent of the required cumulative amount when the scale is used in excess of 30 percent of its capacity. For cumulative weights for less than 30 percent of scale capacity, the tolerance shall be $\pm$ 0.3 percent of scale capacity or $\pm$ 3 percent of the required cumulative weight, whichever is less.

Mixing water shall consist of water added to the batch, ice added to the batch, water occurring as surface moisture on the aggregates, and water introduced in the form of admixtures. The added
water shall be measured by weight or volume to an accuracy of 1 percent of the required total mixing water. Added ice shall be measured by weight. In the case of truck mixers, any wash water retained in the drum for use in the next batch of concrete shall be accurately measured; if this proves impractical or impossible, the wash water shall be discharged prior to loading the next batch of concrete. Total water (including any wash water) shall be measured or weighed to an accuracy of ±3 percent of the specified total amount.

Powdered admixtures shall be measured by weight, and paste or liquid admixtures by weight or volume. Accuracy of weighing admixtures shall be within ±3 percent of the required weight. Volumetric measurement shall be within an accuracy of ±3 percent of the total amount required or plus or minus the volume of dose required for one sack of cement, whichever is greater.

SECTION 19.307 — BATCHING PLANT

Bins with adequate separate compartments for fine aggregates and for each required size of coarse aggregate shall be provided in the batching plant. Each bin compartment shall be designed and operated so as to discharge efficiently and freely, with minimum segregation, into the weighing hopper. Means of control shall be provided so that, as the quantity desired in the weighing hopper is approached, the material may be shut off with precision. Weighing hoppers shall be constructed so as to eliminate accumulations of tare materials and to discharge fully.

Scales for batching concrete ingredients may be either beam or springless dial scales. All weighing and indicating devices shall be in full view and near enough to be read accurately by the operator while charging the hopper, and the operator shall have convenient access to all controls.

Scales in use shall be accurate when static load tested to ±0.4 percent of the total capacity of the scale.

Methods for weighing (electric, hydraulic, load cells, etc.) other than beam or springless dial scales which meet the above weighing tolerances are also acceptable.

Adequate standard test weights shall be available for checking accuracy. All exposed fulcrums, clevises and similar working parts of scales shall be kept clean. Beam-type scales shall be equipped with a balance indicator sensitive enough to show movement when a weight equal to 0.1 percent of the nominal capacity of the scale is placed in the batch hopper. Pointer travel shall be a minimum of 5 percent of the net rated capacity of the largest weigh beam for underweight and 4 percent for over-weight.

The device for the measurement of the added water shall be capable of delivering to the batch the quantity required within the accuracy required in Section 19.306, paragraph three. The device shall be so arranged that the measurements will not be affected by variable pressures in the water supply line. Measuring tanks shall be equipped with outside taps and valves to provide for checking their calibration unless other means are provided for readily and accurately determining the amount of water in the tank.

SECTION 19.308 — MIXERS AND AGITATORS

Mixers may be stationary mixers or truck mixers. Agitators may be truck mixers or truck agitators.

1. Stationary mixers shall be equipped with a metal plate or plates on which are plainly marked the mixing speed of the drum or paddles and the maximum capacity in terms of the volume of mixed concrete. When used for the complete mixing of concrete, stationary mixers shall be equipped with an acceptable timing device that will not permit the batch to be discharged until the specified mixing time has elapsed.

2. Each truck mixer or agitator shall have attached thereto in a prominent place a metal plate or plates on which are plainly marked the gross volume of the drum, the capacity of the drum or container in terms of the volume of mixed concrete and the minimum and maximum mixing speeds of
rotation of the drum, blades or paddles. When the concrete is truck mixed or shrink mixed, the volume of mixed concrete shall not exceed 63 percent of the total volume of the drum or container. When the concrete is central mixed as described in Section 19.309.3, the volume of concrete in the truck mixer or agitator shall not exceed 80 percent of the total volume of the drum or container. Truck mixers and agitators shall be equipped with means by which the number of revolutions of the drum, blades or paddles may be readily verified.

All stationary and truck mixers shall be capable of combining the ingredients of the concrete within the specified time or the number of revolutions specified in Section 19.309.5 into a thoroughly mixed and uniform mass.

The agitator shall be capable of maintaining the mixed concrete in a thoroughly mixed and uniform mass and of discharging the concrete with a satisfactory degree of uniformity.

Slump tests of individual samples taken after discharge of approximately 15 percent and 85 percent of the load may be made for a quick check of the probable degree of uniformity. In order to provide samples that are representative of widely separated portions, but not the beginning and end of the load, no samples should be taken before 10 percent or after 90 percent of the batch has been discharged. These two samples shall be obtained within an elapsed time of not more than 15 minutes. If these slumps differ more than that specified, the mixer or agitator shall not be used unless the condition is corrected.

Use of the equipment may be permitted when operation with a longer mixing time, a smaller load or a more efficient charging sequence will permit meeting specified requirements.

Mixers and agitators shall be examined or weighed routinely as frequently as necessary to detect changes in condition due to accumulations of hardened concrete or mortar and examined to detect wear of blades. When such changes are extensive enough to affect the mixer performance, proof tests shall be performed to show whether the correction of the deficiencies is required.

SECTION 19.309 — MIXING AND DELIVERY

19.309.1 General. Ready-mixed concrete shall be mixed and delivered by means of one of the following combinations of operations:

1. Central-mixed concrete.
2. Shrink-mixed concrete.
3. Truck-mixed concrete.

19.309.2 Operation. Mixers and agitators shall be operated within the limits of capacity and speed of rotation designated by the manufacturer of the equipment.

19.309.3 Central-mixed Concrete. Concrete that is mixed completely in a stationary mixer and transported to the point of delivery either in a truck agitator or a truck mixer operating at agitating speed, or in nonagitating equipment meeting the requirements of Section 19.310, shall conform to the following: The mixing time shall be counted from the time all the solid materials are in the drum. The batch shall be so charged into the mixer that some water will enter in advance of the cement and aggregate, and all water shall be in the drum by the end of the first one fourth of the specified mixing time.

1. Where no mixer performance tests are made, the acceptable mixing time for mixers having capacities of 1 cubic yard (0.76 m³) or less shall not be less than one minute. For mixers of greater capacity, this minimum shall be increased 15 seconds for each cubic yard or fraction thereof of additional capacity.

2. Where mixer performance tests have been made on given concrete mixtures in accordance with the testing program set forth in the following paragraphs, and the mixers have been charged to their rated capacity, the acceptable mixing time may be reduced for those particular circumstances.
to a point at which satisfactory mixing defined in paragraph three below shall have been accomplished. When the mixing time is so reduced, the maximum time of mixing shall not exceed this reduced time by more than 60 seconds for air-entrained concrete.

3. Samples of concrete for comparative purposes shall be obtained immediately after arbitrarily designated mixing times, in accordance with one of the following procedures:

   Alternative procedure 1. The mixer shall be stopped, and the required samples removed by any suitable means from the concrete at approximately equal distances from the front and back of the drum, or

   Alternative procedure 2. As the mixer is being emptied, individual samples shall be taken after discharge of approximately 15 percent and 85 percent of the load. Any appropriate method of sampling may be used, provided the samples are representative of widely separated portions, but not the very ends of the batch.

4. The samples of concrete shall be tested in accordance with nationally recognized tests. Mixer performance tests shall be repeated whenever the appearance of the concrete or the coarse aggregate content of samples selected as outlined in this section indicates that adequate mixing has not been accomplished.

19.309.4 Shrink-mixed Concrete. Concrete that is first partially mixed in a stationary mixer, and then mixed completely in a truck mixer, shall conform to the following: The time of mixing shall be the minimum required to intermingle the ingredients. After transfer to a truck mixer the amount of mixing at the designated mixing speed will be that necessary to meet the requirements for uniformity of concrete. Tests to confirm such performance may be made in accordance with Sections 19.309.3, Item 3 and 4. Additional turning of the mixer, if any, shall be at a designated agitation speed.

19.309.5 Truck-mixed Concrete. Concrete is completely mixed in a truck mixer, 70 to 100 revolutions at the mixing speed designated by the manufacturer, to produce the specified uniformity of concrete. Concrete uniformity tests may be made in accordance with Section 19.309.6 below and if requirements for uniformity of concrete are not met with 100 revolutions of mixing, after all ingredients, including water, are in the drum, that mixer shall not be used until the condition is corrected, except as provided in Section 19.308, seventh paragraph. When satisfactory performance is found in one truck mixer, the performance of mixers of substantially the same design and condition of blades may be regarded as satisfactory. Additional revolutions of the mixer beyond the number found to produce the required uniformity of concrete shall be at a designated agitating speed.

19.309.6 Sampling for Uniformity of Concrete Produced in Truck Mixers. The concrete shall be discharged at the normal operating rate for the mixer being tested, with care being exercised not to obstruct or retard the discharge by an incompletely opened gate or seal. A minimum of two samples, each consisting of approximately 2 cubic feet (0.06 m³ approximately), shall be taken after discharge of approximately 15 percent and 85 percent of the load. These samples shall be obtained within an elapsed time of not more than 15 minutes. The samples shall be secured, but shall be kept separate to represent specific points in the batch rather than combined to form a composite sample. Between samples, where necessary to maintain slump, the mixer may be turned in mixing direction at agitating speed. During sampling the receptacle shall receive the full discharge of the chute. Additional samples may be taken at other points in the load, if desired. Regardless of the number of samples, sufficient personnel must be available to perform the required tests promptly. Segregation during sampling and handling must be avoided. Each sample shall be remixed the minimum amount to ensure uniformity before specimens are molded for a particular test.

When a truck mixer or truck agitator is used for transporting concrete that has been completely mixed in a stationary mixer, any turning during transportation shall be at the speed designated by the manufacturer of the equipment as agitating speed.

When a truck mixer or agitator is approved for mixing or delivery of concrete, no water from the truck water system or elsewhere shall be added after the initial introduction of the mixing water for
the batch except when, on arrival at the job site, the slump of the concrete is less than that specified. Such additional water to bring the slump within required limits shall be injected into the mixer under such pressure and direction of flow that the requirements for uniformity are met. The drum or blades shall be turned an additional 30 revolutions or more if necessary, at mixing speed, until the uniformity of the concrete is within these limits. Water shall not be added to the batch at any later time. Discharge of the concrete shall be completed within one and one-half hours or before the drum has revolved 300 revolutions, whichever comes first, after the introduction of the mixing water to the cement and aggregates or the introduction of the cement to the aggregates. These limitations may be waived if the concrete is of such slump after the one and one-half hour time or 300-revolution limit has been reached that it can be placed, without the addition of water, to the batch. In hot weather, or under conditions contributing to quick stiffening of the concrete, a time less than one and one-half hours may be required.

Concrete delivered in cold weather shall have the applicable minimum temperature indicated in the following table.

<table>
<thead>
<tr>
<th>AIR TEMPERATURE (°F)</th>
<th>MINIMUM CONCRETE TEMPERATURE (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thin Sections and Uniform Slabs</td>
</tr>
<tr>
<td></td>
<td>– 32 °F or greater °C.</td>
</tr>
<tr>
<td>30 to 45</td>
<td>60</td>
</tr>
<tr>
<td>0 to 30</td>
<td>65</td>
</tr>
<tr>
<td>Below 0</td>
<td>70</td>
</tr>
</tbody>
</table>

The maximum temperature of concrete produced with heated aggregates, heated water, or both, shall at no time during its production or transportation exceed 90°F (32°C).

Every effort should be made to maintain the temperature of the concrete produced during hot weather as low as practicable. In some situations, difficulty may be encountered when concrete temperatures approach 90°F (32°C).

**SECTION 19.310 — USE OF NONAGITATING EQUIPMENT**

Central-mixed concrete may be transported in suitable nonagitating equipment. The proportions of the concrete shall be approved and the following limitations shall apply:

1. Bodies of nonagitating equipment shall be smooth, watertight, metal containers equipped with gates that will permit control of the discharge of the concrete. Covers shall be provided for protection against the weather.

2. The concrete shall be delivered to the worksite in a thoroughly mixed and uniform mass and discharged with a satisfactory degree of uniformity.

3. Slump tests of individual samples taken after discharge of approximately 15 percent and 85 percent of the load may be made for a quick check of the probable degree of uniformity. These two samples shall be obtained within an elapsed time of not more than 15 minutes. If these slumps differ more than that specified, the nonagitating equipment shall not be used unless the conditions are corrected. Use of the equipment may be permitted when operated using shorter hauls, longer mixing times, or combinations thereof that will result in meeting the specified requirements.

**SECTION 19.311 — INSPECTION**

**19.311.1 Manufacturer’s Site.** Proper facilities shall be provided to inspect ingredients and processes used in the manufacture and delivery of the concrete. The manufacturer shall afford the inspector all reasonable access, without charge, for making necessary checks of the production facilities and for securing necessary samples to determine if the concrete is being produced in...
accordance with this standard. All tests and inspections shall be so conducted as not to interfere unnecessarily with the manufacture and delivery of the concrete.

19.311.2 Construction Site. Slump and air-content tests shall be made at the time of placement at the option of the inspector as often as is necessary for control checks and acceptance purposes, and always when strength specimens are made.

If the measured slump or air content falls outside the specified limits, a check test shall be made immediately on another portion of the same sample. In the event of a second failure, the concrete shall be considered to have failed the requirements of the specification.

SECTION 19.312 — CERTIFICATION

19.312.1 Delivery Ticket. The manufacturer of the concrete shall furnish to the purchaser with each batch of concrete before unloading at the site, a delivery ticket on which is printed, stamped or written information concerning said concrete as follows:

1. Name of ready-mix batch plant,
2. Serial number of ticket,
3. Date and truck number,
4. Name of contractor,
5. Specific designation of job (name and location),
6. Specific class or designation of concrete in conformance with that employed in job specifications,
7. Amount of concrete [cubic yards (m$^3$)],
8. Time loaded or of first mixing of cement and aggregates, and
9. Water added by receiver of concrete and the receiver’s initials.

19.312.2 Additional Information. Additional information designated and required by the job specifications shall also be furnished on request, and such information may include:

1. Reading of revolution counter at first addition of water,
2. Signature or initials of ready-mix representative,
3. Type and brand of cement,
4. Amount of cement,
5. Information necessary to calculate the total mixing water added by the producer. Total mixing water includes free water on the aggregates, water, and ice batched at the plant and water added by the truck operator from the mixer tank.
6. Admixtures and amount of same,
7. Maximum size of aggregate,
8. Weights of fine and coarse aggregate, and
9. Ingredients certified as being previously approved.

SECTION 19.313 — STRENGTH

When strength is used as a basis for acceptance of concrete, standard specimens shall be made. The specimens shall be cured under standard moisture and temperature conditions. Strength tests shall be made frequently and, in general, not less frequently than one strength test as well as slump and air content tests as stated in Chapter 19 of this code.
For a strength test, two standard test specimens shall be made from a composite sample. The test result shall be the average of the strengths of the two specimens except that, if one specimen in a test shows definite evidence of improper sampling, handling, curing, molding or testing, it shall be discarded and the remaining cylinder shall be considered the test result.

Additional tests may be made at other ages to obtain information on the adequacy of the strength development or to check the adequacy of curing and protection of the concrete. Specimens made to check the adequacy of curing and protection should be properly cured.

The delivery ticket number for the concrete and the exact location in the work at which each load represented by a strength test is deposited shall be recorded.

To conform to the requirements of this standard, the average of all the strength tests representing each class of concrete shall be sufficient to ensure that the following requirements are met:

1. For concrete in structures designed by the working stress method and all construction other than that covered below, not more than 20 percent of the strength tests shall have values less than the specified strength, $f'\text{c}$, and the average of any six consecutive strength tests shall be equal to or greater than the specified strength.

2. For concrete in structures designed by the ultimate strength method and in prestressed structures, not more than 10 percent of the strength tests shall have values less than the specified strength, $f'\text{c}$, and the average of any three consecutive strength tests shall be equal to or greater than the specified strength.

3. Due to variations in materials, operations and testing, the average strength necessary to meet these requirements will be substantially higher than the specified strength. The amount increases as these variations increase and decreases as they are reduced. This is a function of the coefficient of variation and other factors of control. Pertinent data are found in Table 19-3-C.

When the number of tests made of any class of concrete total six or less, the average of all the tests shall be equal to or greater than the specified strength divided by the appropriate value shown in the following table:

<table>
<thead>
<tr>
<th>No. of Tests</th>
<th>Sec. 19.313 Item 1</th>
<th>Sec. 19.313 Item 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.79</td>
<td>0.86</td>
</tr>
<tr>
<td>2</td>
<td>0.90</td>
<td>0.97</td>
</tr>
<tr>
<td>3</td>
<td>0.94</td>
<td>1.02</td>
</tr>
<tr>
<td>4</td>
<td>0.97</td>
<td>1.05</td>
</tr>
<tr>
<td>5</td>
<td>0.99</td>
<td>1.07</td>
</tr>
<tr>
<td>6</td>
<td>1.00</td>
<td>1.08</td>
</tr>
</tbody>
</table>

**TABLE 19-3-A—ACCEPTANCE CRITERIA FOR QUESTIONABLE WATER SUPPLIES**

<table>
<thead>
<tr>
<th>Limits</th>
<th>Compressive strength, min. % control at 7 days</th>
<th>Time of set, deviation from control, h:min.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>90</td>
<td>from 1:00 early to 1:30 later</td>
</tr>
</tbody>
</table>

1Comparisons shall be based on fixed proportions and the same volume of test water compared to control mix using city water or distilled water and following nationally recognized test procedures.
**TABLE 19-3-B—CHEMICAL LIMITATIONS FOR WASH WATER**

<table>
<thead>
<tr>
<th>Chemical requirements, maximum concentration in mixing water, ppm</th>
<th>LIMITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride as Cl, ppm:</td>
<td></td>
</tr>
<tr>
<td>Prestressed concrete or in bridge decks</td>
<td>500&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>Other reinforced concrete in moist environments or containing aluminum embedments or dissimilar metals or with stay-in-place galvanized metal forms</td>
<td>1,000&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sulfate as SO₄, ppm</td>
<td>3,000</td>
</tr>
<tr>
<td>Alkalies as (Na₂O ± 0.658 K₂O), ppm</td>
<td>600</td>
</tr>
<tr>
<td>Total solids, ppm</td>
<td>50,000</td>
</tr>
</tbody>
</table>

<sup>1</sup>Testing shall follow nationally recognized test procedures.

<sup>2</sup>Wash water reused as mixing water in concrete may exceed the listed concentrations of chloride and sulfate if it can be shown that the concentration calculated in the total mixing water, including mixing water on the aggregates and other sources, does not exceed the stated limits.

<sup>3</sup>For conditions allowing use of CaCl₂ accelerator as an admixture, the chloride limitation may be waived by the purchaser.

**TABLE 19-3-C—STRENGTH REQUIREMENTS**

<table>
<thead>
<tr>
<th>AVERAGE STRENGTH REQUIREMENTS FOR LIMITING PROBABILITY OF TESTS FALLING BELOW THE SPECIFIED STRENGTH, f&lt;sub&gt;c&lt;/sub&gt;, TO ONE OUT OF EVERY 10 TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient of Variation</td>
</tr>
<tr>
<td>Required Overdesign Factor</td>
</tr>
<tr>
<td>Design Strength</td>
</tr>
<tr>
<td>× 6.89 for kPa</td>
</tr>
<tr>
<td>2,000 psi</td>
</tr>
<tr>
<td>2,500 psi</td>
</tr>
<tr>
<td>3,000 psi</td>
</tr>
<tr>
<td>3,500 psi</td>
</tr>
<tr>
<td>4,000 psi</td>
</tr>
<tr>
<td>4,500 psi</td>
</tr>
<tr>
<td>5,000 psi</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AVERAGE STRENGTH REQUIREMENTS FOR LIMITING PROBABILITY OF TESTS FALLING BELOW THE SPECIFIED STRENGTH, f&lt;sub&gt;c&lt;/sub&gt;, TO ONE OUT OF EVERY FIVE TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient of Variation</td>
</tr>
<tr>
<td>Required Overdesign Factor</td>
</tr>
<tr>
<td>Design Strength</td>
</tr>
<tr>
<td>× 6.89 for kPa</td>
</tr>
<tr>
<td>2,000 psi</td>
</tr>
<tr>
<td>2,500 psi</td>
</tr>
<tr>
<td>3,000 psi</td>
</tr>
<tr>
<td>3,500 psi</td>
</tr>
<tr>
<td>4,000 psi</td>
</tr>
<tr>
<td>4,500 psi</td>
</tr>
<tr>
<td>5,000 psi</td>
</tr>
</tbody>
</table>

<sup>1</sup>In the absence of statistical experience, a coefficient of variation of 20 percent shall be assumed.
UNIFORM BUILDING CODE STANDARD 19-4
CONCRETE MADE BY VOLUMETRIC BATCHING
AND CONTINUOUS MIXING


See Sections 1903.9 and 1905.11, Uniform Building Code

SECTION 19.401 — SCOPE
This standard covers concrete made from materials continuously batched by volume, mixed in a continuous mixer, and delivered in a freshly mixed and unhardened state.

SECTION 19.402 — MATERIALS

19.402.1 General. The materials used to make concrete by the volumetric batching and continuous mixing process shall comply with the requirements of Chapter 19 of this code and this standard.

19.402.2 Water. The mixing water shall be clear and apparently clean. If it contains quantities of substances that discolor it or make it smell or taste unusual or objectionable, or cause suspicion, it shall not be used unless service records of concrete made with it indicate that it is not injurious to the quality of the concrete.

Water of questionable quality shall be subject to the acceptance criteria of Table 19-3-A of U.B.C. Standard 19-3. Wash water from mixer washout operation may be used for mixing concrete, provided it meets the requirements of Section 19.302 of U.B.C. Standard 19-3.

19.402.3 Admixtures. Admixtures shall conform to applicable specifications acceptable to the building official.

SECTION 19.403 — MEASURING MATERIALS

19.403.1 General. Cement, fine and coarse aggregates, water, and admixtures may be measured by weight or by volume. If volume proportioning is employed, devices such as counters, calibrated gate openings, or flowmeters shall be available for controlling and determining the quantities of the ingredients discharged. In operation, the entire measuring and dispensing mechanism shall produce the specified proportions of each ingredient.

The recommendations of the equipment manufacturer for the operation of the equipment and for calibrating and using the various gages, revolution counters, speed indicators, or other control devices shall be followed.

Indicating devices that bear on the accuracy of proportioning and mixing of concrete shall be in full view and near enough to be read by the operator while concrete is being produced. The operator shall have convenient access to controls.

Proportioning and indicating devices shall be individually checked by following the equipment manufacturer’s recommendations as related to each individual concrete batching and mixing unit. Adequate standard volume measures, scales, and weights shall be available for the checking accuracy of the proportioning mechanism. The device for the measurement of the added water shall be capable of delivering to the batch the required quantity within the accuracy of ±1 percent; the device shall be so arranged that the measurements will not be affected by variable pressures in the water supply line.

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19.403.2 Yield Check. The volume of concrete discharged from the mixer is checked by first weighing the amount of concrete discharged during some number of revolutions, or as determined by another output indicator; this is then followed immediately by a determination of the weight of concrete per cubic foot. The weight of concrete discharged divided by the weight per cubic foot is equal to the number of cubic feet mixed and discharged during the chosen interval. The accuracy of the output indicator is thus checked.

About 2.5 to 3.0 cubic feet (0.070 m³ to 0.085 m³) shall be discharged for this purpose; this amount of concrete will weigh from 350 pounds to 500 pounds (160 kg to 225 kg) and can be discharged into and contained in a 35- or 55-gallon (132 L or 208 L) drum or other suitable container which in turn can be placed on a weighing scale of adequate capacity. The output of a batcher-mixer unit may be indicated by the number of revolutions, travel of a belt, or changes in gage readings; if so, these figures may be used as a measure of output.

19.403.3 Proportioning Check. Whenever the sources or characteristics of the ingredients are changed, or the characteristics of the mixture have changed, a check of the fine aggregate content and the coarse aggregate content by use of the washout test shall be performed. In the washout test, 1 cubic foot (0.03 m³) of concrete is washed through a No. 4 (4.75 mm) sieve and through a No. 100 (150 μm) sieve; that retained on the No. 4 (4.75 mm) sieve is coarse aggregate whereas that passing the No. 4 (4.75 mm) and retained on the No. 100 (150 μm) sieve is fine aggregate.

Corrections to the quantity of aggregates per cubic foot (cubic meter) of concrete can be made if the original sieve analysis of each aggregate is available.

The rate of water supplied a continuous mixer shall be measured by a calibrated flowmeter coordinated with the cement and aggregate feeding mechanism, and with the mixer. The rate shall be capable of being adjusted in order to control slump at the desired levels and to determine that the water-cement ratios are being met.

Liquid admixtures shall be dispensed through a controlled flowmeter.

Tolerances in proportioning the various ingredients shall be as follows:

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>0 to +4</td>
</tr>
<tr>
<td>Fine Aggregate</td>
<td>±2</td>
</tr>
<tr>
<td>Coarse Aggregate</td>
<td>±2</td>
</tr>
<tr>
<td>Admixtures</td>
<td>±3</td>
</tr>
<tr>
<td>Water</td>
<td>±1</td>
</tr>
</tbody>
</table>

The tolerances shall be based on a volume/weight relationship established by calibration of the measuring devices furnished as an integral part of the whole equipment.

SECTION 19.404 — MIXING MECHANISMS

The continuous mixer shall be an auger-type mixer or other type suitable for mixing concrete to meet the required consistency and uniformity requirements.

Each batching or mixing unit, or both, shall carry in a prominent place a metal plate or plates on which are plainly marked the gross volume of the unit in terms of mixed concrete, discharge speed, and the weight-calibrated constant of the machine in terms of a revolution counter or other output indicator. The mixer shall produce a thoroughly mixed and uniform concrete.

Slump and air content tests of samples shall be made for a quick check of the probable degree of uniformity.

SECTION 19.405 — MIXING AND DELIVERY

19.405.1 General. The batch-mixer unit shall contain in separate compartments all the necessary ingredients needed for the manufacture of concrete. The unit shall be equipped with calibrated
proportioning devices to vary the mix proportions and it shall produce concrete as required by this standard and specifications for the project.

**19.405.2 Cold Weather Concrete.** Concrete delivered in cold weather shall have the applicable minimum temperature indicated in the following table.

<table>
<thead>
<tr>
<th>AIR TEMPERATURE, °F (°C.)</th>
<th>MINIMUM CONCRETE TEMPERATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin Sections and Unformed Slabs, °F (°C.)</td>
<td>Heavy Sections and Mass Concrete, °F (°C.)</td>
</tr>
<tr>
<td>30 to 45 (−1 to 7)</td>
<td>60 (16)</td>
</tr>
<tr>
<td>0 to 30 (−18 to −1)</td>
<td>65 (18)</td>
</tr>
<tr>
<td>Below 0 (−18)</td>
<td>70 (21)</td>
</tr>
</tbody>
</table>

The maximum temperature of concrete produced with heated aggregates, heated water, or both, shall at no time during its production or transportation exceed 90°F (32°C). The temperature of the concrete produced during hot weather shall be as low as practicable.

**SECTION 19.406 — SLUMP AND AIR CONTENT**

**19.406.1 General.** Slump and air-content tests shall be made at the time of placement as often as is necessary for control checks and acceptance purposes, and always when strength specimens are made.

If the measured slump or air content falls outside the specified limits, a check test shall be made immediately on another portion of the same sample. In the event of a second failure, the concrete shall be considered to have failed the requirements of the specification.

**19.406.2 Tolerances in Slump.** Unless other tolerances are included in the project specifications, the following shall apply:

When the project specifications for slump are written as a “maximum” or “not to exceed” requirement:

<table>
<thead>
<tr>
<th>SPECIFIED SLUMP</th>
<th>TOLERANCE, IN.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 in. (76 mm) or less</td>
<td>+ 0 - 1/12 (38 mm)</td>
</tr>
<tr>
<td>More than 3 in. (76 mm)</td>
<td>+ 0 - 11/2 (63 mm)</td>
</tr>
</tbody>
</table>

This option may be used only if one addition of water is permitted on the job, provided such addition does not increase the water-cement ratio above the maximum permitted by the project specifications.

When the project specifications for slump are not written as a “maximum” or “not to exceed” requirement:

<table>
<thead>
<tr>
<th>SPECIFIED SLUMP</th>
<th>TOLERANCE, IN.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 in. (50 mm) and less</td>
<td>± 1/4 (13 mm)</td>
</tr>
<tr>
<td>More than 2 in. (50 mm) through 4 in. (100 mm)</td>
<td>± 1 (25 mm)</td>
</tr>
<tr>
<td>More than 4 in. (100 mm)</td>
<td>± 11/2 (38 mm)</td>
</tr>
</tbody>
</table>

Except when project specifications provide otherwise, air content shall comply with Table 19.4-A.

The air content of air-entrained concrete when sampled from the transportation unit at the point of discharge shall be within a tolerance of ± 1.5 of the specified value.

**SECTION 19.407 — STRENGTH**

**19.407.1 General.** When strength is used as a basis for acceptance of the concrete, standard specimens shall be made and cured under standard moisture and temperature conditions.
One strength test set of two cylinders and the accompanying slump and air content tests shall be made for each 25 cubic yards (19 m³) of concrete or fraction thereof, or whenever significant changes have been made in the proportioning controls. There shall be at least one strength test made for each class of concrete placed in one day.

For each strength test, two standard-size cylinders shall be made. The test result shall be the average of the strength of the two specimens except that, if any specimen shows definite evidence other than low strength, of improper sampling, molding, handling, curing, or testing, it shall be discarded and the strength of the remaining cylinder shall then be considered the test result.

The delivery ticket number for the concrete and the exact location in the work where the concrete represented by each strength test was deposited shall be recorded.

19.407.2 Specifications. To conform to the requirements of this standard, the average of all of the strength tests representing each class of concrete shall be sufficient to ensure that the following requirements are met.

1. For concrete in structures designed by the working stress method and all construction other than that covered in Item 2 following, not more than 20 percent of the strength tests shall have values less than the specified strength, \( f'_c \), and the average of any six consecutive strength tests shall be equal to or greater than the specified strength.

2. For concrete in structures designed by the ultimate strength method, and in prestressed structures, not more than 10 percent of the strength tests shall have values less than the specified strength, \( f'_c \), and the average of any three consecutive strength tests shall be equal to or greater than the specified strength.

3. Table 19-4-B shall be used to determine the average strength necessary to assure that the design strength is achieved with a high degree of assurance.

When the number of tests made of any class of concrete totals six or less, the average of all the tests shall be equal to or greater than the following:

<table>
<thead>
<tr>
<th>NO. OF TESTS</th>
<th>REQUIRED AVERAGE STRENGTH OF CONSECUTIVE TEST, ( f'_c ) WORKING STRESS METHOD</th>
<th>ULTIMATE STRENGTH METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.79</td>
<td>0.86</td>
</tr>
<tr>
<td>2</td>
<td>0.90</td>
<td>0.97</td>
</tr>
<tr>
<td>3</td>
<td>0.94</td>
<td>1.02</td>
</tr>
<tr>
<td>4</td>
<td>0.97</td>
<td>1.05</td>
</tr>
<tr>
<td>5</td>
<td>0.99</td>
<td>1.07</td>
</tr>
<tr>
<td>6</td>
<td>1.00</td>
<td>1.08</td>
</tr>
</tbody>
</table>

SECTION 19.408 — TEST METHODS

Cure concrete in accordance with a method approved by the building official.

SECTION 19.409 — INSPECTION

19.409.1 Materials, Batching Facilities and Mixing Facilities. The manufacturer shall afford the inspector reasonable access without charge for obtaining necessary samples of materials used in the concrete, and for making necessary checks of the batching and mixing facilities to determine if the concrete is being produced in accordance with this standard. All tests and inspection shall be conducted so as not to interfere with the batching, mixing and discharge of the concrete.

19.409.2 Fresh Concrete. The inspector shall be accorded reasonable access without charge for the procurement of samples of fresh concrete at the time of placement so as to determine conformance of the concrete to this standard.
At any time after at least 2 cubic feet (approximately 0.06 m³) of concrete have been discharged, one sample of concrete shall be taken for the slump test, the air content test, if required, and the strength test. The sample shall be at least 2 cubic feet (approximately 0.06 m³) in volume. Two cylinders for each age of test shall be made. Tests for slump or air content or both shall be started within five minutes of sampling; these tests should then be completed expeditiously. Molding of specimens for strength tests shall be started within 15 minutes of sampling.

Samples for determining the uniformity of mixing shall be taken at arbitrarily designated times. After at least 2 cubic feet (0.06 m³) have been discharged, a sample of at least 4 cubic feet (0.11 m³) shall be taken followed by another sample being taken no sooner than after four minutes of continuous discharge or 1 cubic yard (0.76 m³), whichever is smaller. These samples shall be checked for conformance to the criteria set forth in Section 19.410.

SECTION 19.410 — CONCRETE UNIFORMITY REQUIREMENTS

19.410.1 Variation. The variation within a batch as provided in Table 19-4-C shall be determined for each property listed as the difference between the highest value and the lowest value obtained from the different portions of the same batch. For this standard, the comparison will be between two samples representing the first and last portions of the batch being tested. Test results conforming to the limits of five of the six tests listed in Table 19-4-C shall indicate uniform concrete within the limits of this specification.

19.410.2 Coarse Aggregate Content. Coarse aggregate content using the washout test, shall be computed from the following relations:

\[
P = (c/b) \times 100
\]

WHERE:
- \( b \) = weight of sample of fresh concrete in unit weight container, lb. (kg).
- \( c \) = saturated surface-dry weight, lb. (kg), of aggregate retained on the No. 4 (4.75 mm) sieve, resulting from washing all material finer than this sieve from the fresh concrete, and
- \( P \) = weight % of coarse aggregate in concrete.

19.410.3 Unit Weight of Air-free Mortar. Shall be calculated as follows:

Inch-pound units:

\[
M = \frac{b - c}{V - \left( \frac{V \times A}{100} + \frac{c}{G \times 62.4} \right)}
\]

For SI:

\[
M = \frac{b - c}{V - \left( \frac{V \times A}{100} + \frac{c}{1000G} \right)}
\]

WHERE:
- \( A \) = air content of concrete, %.
- \( b \) = weight of concrete sample in unit weight container, lb. (kg).
- \( c \) = saturated surface-dry weight of aggregate retained on No. 4 (4.75 mm) sieve, lb. (kg).
- \( G \) = specific gravity of coarse aggregate (saturated surface dry).
- \( M \) = unit weight of air-free mortar, lb./ft.³ (kg/m³).
- \( V \) = volume of unit weight container, ft.³ (m³).
SECTION 19.411 — BATCH TICKET INFORMATION

19.411.1 General. The producer of the concrete shall furnish with each increment of discharged concrete a delivery ticket or a statement of particulars on which is shown the following:

1. Name of concrete producer,
2. Serial number of the delivery ticket or statement,
3. Date, starting time and finishing time,
4. Identification number of batching or mixing equipment, or both,
5. Name of the consignee,
6. Specific designation of the job (name and location),
7. Specific class or designation of the concrete in conformance with that employed in the job specification,
8. Amount of concrete in cubic yards and reading of the revolution counter or other device that indicates quantity of concrete.

19.411.2 Additional Information. Additional information designated by the consignee and required by the job specifications shall be furnished when requested. Such information may include the following:

1. Type, brand, and amount of cement,
2. Type, name, and amount of each admixture,
3. Information necessary to calculate total mixing water added by the producer. Total mixing water includes free water on the aggregates and water batched by the producer from the mixing equipment or other sources,
4. Maximum size of aggregate,
5. Weights or volumes of fine and coarse aggregate,
6. Notation of calibrated settings for flow control of fine and coarse aggregate, added water, and admixtures,
7. Ingredients certified as being previously approved, and
8. Signature or initials of the person operating the batching or mixing apparatus.

<table>
<thead>
<tr>
<th>Exposure Condition</th>
<th>$\frac{3}{4}$ (19.0)</th>
<th>$\frac{1}{2}$ (12.5)</th>
<th>$\frac{3}{4}$ (19.0)</th>
<th>1 (25.0)</th>
<th>$\frac{1}{2}$ (37.5)</th>
<th>2 (60.0)</th>
<th>3 (75.0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negligible</td>
<td>4.5</td>
<td>4.0</td>
<td>3.5</td>
<td>3.0</td>
<td>2.5</td>
<td>2.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Moderate</td>
<td>6.0</td>
<td>5.5</td>
<td>5.0</td>
<td>4.5</td>
<td>4.5</td>
<td>4.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Severe</td>
<td>7.5</td>
<td>7.0</td>
<td>6.0</td>
<td>6.0</td>
<td>5.5</td>
<td>5.0</td>
<td>4.5</td>
</tr>
</tbody>
</table>
TABLE 19-4-B—STRENGTH REQUIREMENTS
Average Strength Requirements for Limiting Probability of Tests Falling below the Specified Strength, $f'_c$, to One Out of Every Ten Tests

<table>
<thead>
<tr>
<th>Coefficient of Variation</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required Overdesign Factor</td>
<td>1.07</td>
<td>1.15</td>
<td>1.24</td>
<td>1.34</td>
<td>1.47</td>
</tr>
<tr>
<td>Design Strength, psi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Required Average Strength, psi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>× 6.89 for kPa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2,000</td>
<td>2,140</td>
<td>2,300</td>
<td>2,480</td>
<td>2,680</td>
<td>2,940</td>
</tr>
<tr>
<td>2,500</td>
<td>2,675</td>
<td>2,875</td>
<td>3,100</td>
<td>3,350</td>
<td>3,675</td>
</tr>
<tr>
<td>3,000</td>
<td>3,210</td>
<td>3,450</td>
<td>3,720</td>
<td>4,030</td>
<td>4,420</td>
</tr>
<tr>
<td>3,500</td>
<td>3,745</td>
<td>4,025</td>
<td>4,340</td>
<td>4,690</td>
<td>5,145</td>
</tr>
<tr>
<td>4,000</td>
<td>4,270</td>
<td>4,590</td>
<td>4,960</td>
<td>5,380</td>
<td>5,890</td>
</tr>
<tr>
<td>4,500</td>
<td>4,815</td>
<td>5,175</td>
<td>5,580</td>
<td>6,030</td>
<td>6,615</td>
</tr>
<tr>
<td>5,000</td>
<td>5,340</td>
<td>5,740</td>
<td>6,200</td>
<td>6,720</td>
<td>7,300</td>
</tr>
</tbody>
</table>

Average Strength Requirements for Limiting Probability of Tests Falling below the Specified Strength, $f'_c$, to One Out of Every Five Tests

<table>
<thead>
<tr>
<th>Coefficient of Variation</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required Overdesign Factor</td>
<td>1.04</td>
<td>1.09</td>
<td>1.14</td>
<td>1.20</td>
<td>1.27</td>
</tr>
<tr>
<td>Design Strength, psi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Required Average Strength</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>× 6.89 for kPa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2,000</td>
<td>2,080</td>
<td>2,180</td>
<td>2,280</td>
<td>2,400</td>
<td>2,540</td>
</tr>
<tr>
<td>2,500</td>
<td>2,600</td>
<td>2,725</td>
<td>2,850</td>
<td>3,000</td>
<td>3,180</td>
</tr>
<tr>
<td>3,000</td>
<td>3,120</td>
<td>3,270</td>
<td>3,420</td>
<td>3,600</td>
<td>3,810</td>
</tr>
<tr>
<td>3,500</td>
<td>3,640</td>
<td>3,820</td>
<td>3,990</td>
<td>4,200</td>
<td>4,450</td>
</tr>
<tr>
<td>4,000</td>
<td>4,160</td>
<td>4,360</td>
<td>4,560</td>
<td>4,800</td>
<td>5,080</td>
</tr>
<tr>
<td>4,500</td>
<td>4,680</td>
<td>4,910</td>
<td>5,130</td>
<td>5,400</td>
<td>5,720</td>
</tr>
<tr>
<td>5,000</td>
<td>5,200</td>
<td>5,450</td>
<td>5,700</td>
<td>6,000</td>
<td>6,350</td>
</tr>
</tbody>
</table>

1Computed from Formula (4.1) and values of "t" for more than 30 samples from Table 4.1 (ACI 214-77). In the absence of statistical experience, a coefficient of variation of 20 percent shall be assumed.

TABLE 19-4-C—REQUIREMENTS FOR UNIFORMITY OF CONCRETE

<table>
<thead>
<tr>
<th>TEST</th>
<th>Requirement Expressed as Maximum Permissible Difference in Results of Tests of Samples Taken from Two Locations in the Concrete Batch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight per cubic foot (weight per cubic meter) calculated to an air-free basis, lb./ft.² (kg/m³)</td>
<td>1.0 (16)</td>
</tr>
<tr>
<td>Air content, volume % of concrete</td>
<td>1.0</td>
</tr>
<tr>
<td>Slumps: If average slump is 4 in. (102 mm) or less, in. (mm)</td>
<td>1.0 (25)</td>
</tr>
<tr>
<td>If average slump is 4 to 6 in. (102 to 152 mm)</td>
<td>1.5 (38)</td>
</tr>
<tr>
<td>Coarse aggregate content, portion by weight of each sample retained on No. 4 (4.75 mm) sieve, %</td>
<td>6.0</td>
</tr>
<tr>
<td>Unit weight of air-free mortar¹ based on average for all comparative samples tested, %</td>
<td>1.6</td>
</tr>
<tr>
<td>Average compressive strength at seven days for each sample,² based on average strength of all comparative test specimens, %</td>
<td>7.5³</td>
</tr>
</tbody>
</table>


²Not less than three cylinders will be molded and tested from each of the samples.

³Tentative approval of the mixer may be granted pending results of the seven-day compressive strength tests.
UNIFORM BUILDING CODE STANDARD 19-5
MILL-MIXED GYPSUM CONCRETE AND Poured Gypsum Roof Diaphragms


See Sections 1903.9 and 1927.3, Uniform Building Code

Part I—Mill-mixed Gypsum Concrete

SECTION 19.501 — SCOPE
This part covers mill-mixed gypsum concrete. Gypsum concrete supplied under this standard shall be mill-mixed gypsum concrete, consisting essentially of calcined gypsum and suitable aggregate, requiring the addition of water only at the job. Gypsum concrete is intended for use in construction of poured-in-place roof decks or slabs. Two classes, based on the compressive strength and density, are covered.

SECTION 19.502 — COMPOSITION
Gypsum concrete shall consist essentially of calcined gypsum and wood chips or wood shavings, proportioned to meet the applicable requirements of this standard. Calcined gypsum used in the mill mixed gypsum concrete shall conform to the requirements of ASTM C 28-76a. Wood chips or wood shavings shall be of dry wood, uniform and clean in appearance, shall pass a 1-inch (25 mm) sieve, and shall not be more than $\frac{1}{16}$ inch (1.6 mm) in thickness.

SECTION 19.503 — TIME OF SETTING
Gypsum concrete shall not set in less than 20 minutes nor more than 90 minutes.

SECTION 19.504 — COMRESSIVE STRENGTH AND DENSITY
Gypsum concrete shall have the following compressive strength and density for the respective classes:

<table>
<thead>
<tr>
<th>Class</th>
<th>Minimum psi (MPa)</th>
<th>Density Pounds per Cubic Foot (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>500 (3.5)</td>
<td>60 (960)</td>
</tr>
<tr>
<td>B</td>
<td>1,000 (6.9)</td>
<td></td>
</tr>
</tbody>
</table>

SECTION 19.505 — METHODS OF TESTING
The physical properties of gypsum concrete shall be determined in accordance with approved methods.

Part II—Poured-in-place Reinforced Gypsum Concrete

SECTION 19.506 — SCOPE
This part covers the design of poured-in-place reinforced gypsum concrete roof decks when used as a horizontal diaphragm.
SECTION 19.507 — DESIGN

19.507.1 General. The gypsum roof diaphragm shall consist of sub-purlins welded transversely to primary purlins. Formboard is then placed on the flanges of the subpurlins. Wire mesh reinforcement is then placed over the subpurlins and formboard and lapped at least 4 inches (102 mm) or one mesh on ends and edges, whichever is greater. Gypsum concrete meeting the requirements of Part I of this standard is then placed to a minimum thickness of 2 inches (51 mm) over the formboard and 5/8 inch (16 mm) over the subpurlins and doweling elements. The bulb section or top flange of the subpurlin shall be fully embedded in the gypsum concrete.

19.507.2 Diaphragm Shear. Shear in poured gypsum concrete diaphragms shall be determined by the formula:

For SI:
\[ Q = 1.36f_K t C_1 + 17.86 (k_1 d_1 + k_2 d_2) \]

WHERE:
- \( C_1 = 1.0 \) for Class A gypsum; 1.5 for Class B gypsum.
- \( d_1 = \) diameter of mesh wires passing over subpurlins, in inches (mm), except hexagonal mesh.
- \( d_2 = \) diameter, in inches (mm), of mesh wires parallel to subpurlins or of hexagonal wires.
- \( f_K = \) oven-dry compressive strength of gypsum in pounds per square inch (MPa) as determined by tests conforming to this standard.
- \( k_1 = \) number of mesh wires per foot (m) passing over subpurlins.
- \( k_2 = \) number of mesh wires per foot (m) parallel to subpurlins or .7 times the number of hexagonal wires. Note: \( k_2 = 8.5 \) (27.9) for 2-inch (51 mm) hexagonal mesh woven of No. 19 gage galvanized wire with additional longitudinal No. 16 gage galvanized wires spaced every 3 inches (76 mm) across the width of the mesh.
- \( Q = \) allowable shear on diaphragm in pounds per linear foot (kg/m), which includes a one-third increase for short-time loading.
- \( t = \) thickness of gypsum concrete between subpurlins, in inches (mm). For the purpose of computing diaphragm shear values, \( t \) shall not exceed 4 inches (102 mm).

The solution of the above equation for commonly used thickness and mesh types for each class of gypsum would give the values set forth in Table 19-5-A.

19.507.3 Shear Transfer. Bolts, dowels or other approved elements may be used to transfer diaphragm shears to perimeter or other structural members. Allowable bolt and dowel stresses shall comply with Table 19-H and Section 1603 of this code.

### TABLE 19-5-A—ALLOWABLE SHEAR VALUES IN POUNDS PER FOOT USING BULB TEE SUBPURLINS

<table>
<thead>
<tr>
<th>CLASS OF GYPSUM CONCRETE</th>
<th>CONCRETE THICKNESS (INCHES)</th>
<th>MESH TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>4&quot; x 6&quot; (102 mm x 203 mm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No. 12-No. 14 (Galvanized)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No. 1D-No. 10 (Galvanized)</td>
</tr>
<tr>
<td>A</td>
<td>2</td>
<td>600</td>
</tr>
<tr>
<td>(500 psi)</td>
<td>21/2</td>
<td>640</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>920</td>
</tr>
<tr>
<td>(1,000 psi)</td>
<td>21/2</td>
<td>1,040</td>
</tr>
</tbody>
</table>

1 The tabulated shear values are for short-time loads due to wind or earthquake forces and are not permitted a one-third increase for duration of load.

2 Mesh shall be lapped at least 4 inches (102 mm) or one mesh on ends and edges, whichever is greater.

3 Two-inch (51 mm) hexagonal mesh woven of No. 19 gage galvanized wire with additional longitudinal No. 16 gage galvanized wires spaced every 3 inches (76 mm) across the width of the mesh.
SECTION 19.601 — SCOPE

This specification covers three strength grades of finely ground granulated iron blast-furnace slag for use as a cementitious material in concrete and mortar.

The material described in this specification may be used for blending with portland cement to produce a cement meeting the requirements of U.B.C. Standard 19-1 for mortar mixtures.

SECTION 19.602 — DEFINITIONS

GRANULATED IRON BLAST-FURNACE SLAG is the glassy granular material formed when molten blast-furnace slag is rapidly chilled. Compositional adjustments may be made while the slag is molten.

IRON BLAST-FURNACE SLAG is a nonmetallic product consisting essentially of silicates and aluminosilicates of calcium and of other bases that is developed in a molten condition simultaneously with iron in a blast furnace.

SECTION 19.603 — CLASSIFICATION

Finely ground iron blast-furnace slag is classified by performance in the slag activity test in three grades: Grade 80, Grade 100 and Grade 120 (see Table 19-6-B).

SECTION 19.604 — ADDITIONS

The ground slag covered by this specification shall contain no additions except as follows:

Calcium sulfate may be added in amounts such that the limits in Table 19-6-A for sulfur trioxide are not exceeded.

Processing additions may be used in the manufacture of the ground slag, provided such materials in the amounts used have been shown to meet the requirements of U.B.C. Standard 19-1 when tested using a 50-50 blend by weight with portland cement.

SECTION 19.605 — CHEMICAL COMPOSITION

Ground granulated blast-furnace slag shall conform to the chemical requirements prescribed in Table 19-6-A.

SECTION 19.606 — PHYSICAL REQUIREMENTS

Ground granulated blast-furnace slag shall conform to the fineness and air-content requirements in Table 19-6-B. A slag shall be assigned to the lowest activity grade realized based on the minimum activity index values in Table 19-6-B. The limits for individual samples shall govern until tests of five samples become available, after which time both limits shall apply.
SECTION 19.607 — SAMPLING AND TEST METHODS

Sampling and test methods shall be in accordance with approved standards.

### TABLE 19-6-A—CHEMICAL REQUIREMENTS

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfide sulfur (S), max., %</td>
<td>2.5</td>
</tr>
<tr>
<td>Sulfate ion reported as SO₃, max., %</td>
<td>4.0</td>
</tr>
</tbody>
</table>

### TABLE 19-6-B—PHYSICAL REQUIREMENTS

**Fineness:**
- Amount retained when wet screened on No. 325 (45 μm) sieve, max., %: 20
- Specific surface by air permeability shall be determined and reported although no limits are required.
- Air content of slag mortar, max., %: 12

**Slag activity index, min., %:**

<table>
<thead>
<tr>
<th>Index</th>
<th>Average of Last Five Consecutive Samples</th>
<th>Any Individual Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>7-Day Index</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade 80</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Grade 100</td>
<td>75</td>
<td>70</td>
</tr>
<tr>
<td>Grade 120</td>
<td>95</td>
<td>90</td>
</tr>
<tr>
<td><strong>28-Day Index</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade 80</td>
<td>75</td>
<td>70</td>
</tr>
<tr>
<td>Grade 100</td>
<td>95</td>
<td>90</td>
</tr>
<tr>
<td>Grade 120</td>
<td>115</td>
<td>110</td>
</tr>
</tbody>
</table>
UNIFORM BUILDING CODE STANDARD 19-7
SLUMP OF PORTLAND CEMENT CONCRETE


See Section 1903.3, Uniform Building Code

SECTION 19.701 — SCOPE

This standard covers the procedure for determining the slump of concrete, both in the laboratory and in the field. This test method is considered applicable to plastic concrete having coarse aggregate up to 1 1/2 inches (38 mm) in size and for larger size aggregate when sample is made on the fraction of concrete passing a 1 1/2-inch (38 mm) sieve with the larger aggregate removed in accordance with approved nationally recognized standards.

SECTION 19.702 — PREPARATION AND PROCEDURE

19.702.1 Mold. The test specimen shall be formed in a mold made of metal not readily attacked by the cement paste. The metal shall not be thinner than No. 16 gage (BWG) (0.065 inches) (1.65 mm), and if formed by the spinning process, there shall be no point on the mold at which the thickness is less than 0.045 inches (1.14 mm). The mold shall be in the form of the lateral surface of the frustum of a cone with the base 8 inches (203 mm) in diameter, the top 4 inches (102 mm) in diameter and the height 12 inches (305 mm). Individual diameters and heights shall be within ±1/8 inch (3.2 mm) of the prescribed dimensions. The base and the top shall be open and parallel to each other and at right angles to the axis of the cone. The mold shall be provided with foot pieces and handles similar to those shown in Figure 1. The mold may be constructed with or without a seam. When a seam is required, it should be essentially as shown in Figure 1. The interior of the mold shall be relatively smooth and free from projections such as protruding rivets. The mold shall be free of dents. A mold which clamps to a nonabsorbent base plate is acceptable instead of the one illustrated provided the clamping arrangement is such that it can be fully released without movement of the mold.

The tamping rod shall be a round, straight steel rod 5/8 inch (16 mm) in diameter and approximately 24 inches (600 mm) in length, having the tamping end rounded to a hemispherical tip, the diameter of which is 5/32 inch (16 mm).

19.702.2 Sample. The sample of concrete from which test specimens are made shall be representative of the entire batch.

19.702.3 Procedure. Dampen the mold and place it on a flat, moist, nonabsorbent (rigid) surface. It shall be held firmly in place during filling by the operator standing on the 2-foot (610 mm) pieces. From the sample of concrete obtained in accordance with Section 19.702.2, immediately fill the mold in three layers, each approximately one third the volume of the mold.

Rod each layer with 25 strokes of the tamping rod. Uniformly distribute the strokes over the cross section of each layer. For the bottom layer this will necessitate inclining the rod slightly and making approximately half of the strokes near the perimeter, and then progressing with vertical strokes spirally toward the center. Rod the bottom layer throughout its depth. Rod the second layer and top layer each throughout its depth so that the strokes just penetrate into the underlying layer.

In filling and rodding the top layer, heap the concrete above the mold before rodding is started. If the rodding operation results in subsidence of the concrete below the top edge of the mold, add additional concrete to keep an excess of concrete above the top of the mold at all times. After the top layer has been rodded, strike off the surface of the concrete by means of a screeing and rolling
motion of the tamping rod. Remove the mold immediately from the concrete by raising it carefully in a vertical direction. Raise the mold a distance of 12 inches (305 mm) in ± five seconds by a steady upward lift with no lateral or torsional motion. Complete the entire test from the start of the filling through removal of the mold without interruption and complete it within an elapsed time of two and one-half minutes.

Immediately measure the slump by determining the vertical difference between the top of the mold and the displaced original center of the top surface of the specimen. If a decided falling away or shearing off of concrete from one side or portion of the mass occurs, disregard the test and make a new test on another portion of the sample.

19.702.4 Report. Record the slump in terms of inches to the nearest $\frac{1}{4}$ inch (6.4 mm).
UNIFORM BUILDING CODE STANDARD 21-1
BUILDING BRICK, FACING BRICK AND HOLLOW BRICK
(MADE FROM CLAY OR SHALE)

Based on Standard Specifications C 62-89a, C 216-89, and C 652-89a of the
American Society for Testing and Materials. Extracted, with permission, from the
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Materials, 1916 Race Street, Philadelphia, PA 19103

See Section 2102.2, Item 4, Uniform Building Code

SECTION 21.101 — SCOPE

21.101.1 General. This standard covers brick made from clay or shale and subjected to heat treat-
ment at elevated temperatures (firing), and intended for use in brick masonry. In addition, this stan-
dard covers dimension and distortion tolerances for facing brick to be used in load-bearing or shear
walls.

21.101.2 Definition. BRICK is a solid clay masonry unit.

21.101.3 Grades. Three grades of brick are covered.

Grade SW. Brick intended for use where a high and uniform degree of resistance to disintegra-
tion by weathering is desired and the exposure is such that the brick may be frozen when saturated
with water.

Grade MW. Brick intended for use where it may be exposed to temperatures below freezing and
the units are unlikely to be saturated with water or where a moderate degree of resistance to frost
action is permissible.

Grade NW. Brick intended for use as backup or interior masonry; or, if exposed, for use where no
frost action occurs; or if frost action occurs, where the annual precipitation is less than 20 inches
(508 mm).

21.101.4 Grade Requirements for Face Exposure. The selection of the grade of brick for face
exposure of vertical or horizontal surfaces shall conform to Table 21-1-A and Figure 21-1-1.

SECTION 21.102 — PHYSICAL PROPERTIES

21.102.1 Durability. The brick shall conform to the physical requirements for the grade speci-
fied, as prescribed in Table 21-1-B.

21.102.2 Substitution of Grades. Grades SW and MW may be used in lieu of Grade NW, and
Grade SW in lieu of Grade MW.

21.102.3 Waiver of Saturation Coefficient. The saturation coefficient shall be waived provided
the average cold-water absorption of a random sample of five bricks does not exceed 8 percent, no
more than one brick of the sample exceeds 8 percent and its cold-water absorption must be less than
10 percent.

21.102.4 Freezing and Thawing. The requirements specified in this standard for water absorp-
tion (five-hour boiling) and saturation coefficient shall be waived, provided a sample of five bricks,
meeting all other requirements, complies with the following requirements when subjected to 50
cycles of the freezing-and-thawing test:

Grade SW  No breakage and not greater than 0.5 percent loss in dry weight of any indi-
vidual brick.
Brick is not required to conform to the provisions of this section, and these do not apply unless the sample fails to conform to the requirements for absorption and saturation coefficient prescribed in Table 21-1-B or the absorption requirements in Section 21.102.3.

A particular lot or shipment shall be given the same grading as a previously tested lot, without repeating the freezing-and-thawing test, provided the brick is made by the same manufacturer from similar raw materials and by the same method of forming; and provided also that a sample of five bricks selected from the particular lot has an average and individual minimum strength not less than a previously graded sample, and has average and individual maximum water absorption and saturation coefficient not greater than those of the previously tested sample graded according to the freezing-and-thawing test.

21.102.5 Waiver of Durability Requirements. If brick is intended for use exposed to weather where the weathering index is less than 50 (see Figure 21-1-1), unless otherwise specified, the requirements given in Section 21.102.1 for water absorption (five-hour boiling) and for saturation coefficient shall be waived and a minimum average strength of 2,500 pounds per square inch (17 200 kPa) shall apply.

SECTION 21.103 — SIZE, CORING AND FROGGING

21.103.1 Tolerances on Dimensions. The maximum permissible variation in dimensions of individual units shall not exceed those given in Table 21-1-C.

21.103.2 Coring. The net cross-sectional area of cored brick in any plane parallel to the bearing surface shall be at least 75 percent of the gross cross-sectional area measured in the same plane. No part of any hole shall be less than 3/4 inch (19.1 mm) from any edge of the brick.

21.103.3 Frogging. One bearing face of each brick may have a recess or panel (frog) not exceeding 3/8 inch (9.5 mm) in depth, except that in brick containing deep frogs any cross section through the frogs parallel to the bearing surface shall conform to the requirements of Section 21.103.2. No part of the recess shall be less than 3/4 inch (19.1 mm) from any edge of the brick.

SECTION 21.104 — VISUAL INSPECTION

21.104.1 The brick shall be free of defects, deficiencies and surface treatments, including coatings, that would interfere with the proper setting of the brick or significantly impair the strength or performance of the construction.

21.104.2 Minor indentations or surface cracks incidental to the usual method of manufacture, or the chipping resulting from the customary methods of handling in shipment and delivery should not be deemed grounds for rejection.

SECTION 21.105 — SAMPLING AND TESTING

The brick shall be sampled and tested in accordance with ASTM C 67.

SECTION 21.106 — FACING BRICK

21.106.1 General. Facing brick shall be of Grade SW or MW and shall comply with the degree of mechanical perfection and size variations specified in this section. Grade SW may be used in lieu of Grade MW.

21.106.2 Types. Three types of facing brick are covered:

Type FBS. Brick for general use in exposed exterior and interior masonry walls and partitions where wider color ranges and greater variation in sizes are permitted than are specified for Type FBX.
Type FBX. Brick for general use in exposed exterior and interior masonry walls and partitions where a high degree of mechanical perfection, narrow color range, and minimum permissible variation in size are required.

Type FBA. Brick manufactured and selected to produce characteristic architectural effects resulting from nonuniformity in size, color and texture of individual units.

When the type is not specified, the requirements for Type FBS shall govern.

21.106.3 Tolerances on Dimensions. The brick shall not depart from the specified size to be used by more than the individual tolerance for the type specified set forth in Table 21-1-B. Tolerances on dimensions for Type FBA shall be as specified by the purchaser.

21.106.4 Warpage. Tolerances for distortion or warpage of face or edges of individual brick from a plane surface and from a straight line, respectively, shall not exceed the maximum for the type specified as set forth in Table 21-1-E. Tolerances on distortion for Type FBA shall be as specified by the purchaser.

21.106.5 Coring. Brick may be cored. The net cross-sectional area of cored brick in any plane parallel to the bearing surface shall be at least 75 percent of the gross cross-sectional area measured in the same plane. No part of any hole shall be less than 3/4 inch (19.1 mm) from any edge of the brick.

21.106.6 Frogging. One bearing face of each brick may have a recess or panel (frog) not exceeding 3/8 inch (9.5 mm) in depth, except that in brick containing deep frogs, any cross section through the frogs parallel to the bearing surface shall conform to the requirements of Section 21.106.4. No part of the recess shall be less than 3/4 inch (19.1 mm) from any edge of the brick.

21.106.7 Visual Inspection. In addition to the requirements of Section 21.104, brick used in exposed wall construction shall have faces which are free of cracks or other imperfections detracting from the appearance of the designated sample when viewed from a distance of 15 feet (4600 mm) for Type FBX and a distance of 20 feet (6100 mm) for Types FBS and FBA.

SECTION 21.107 — HOLLOW BRICK

21.107.1 General. Hollow brick shall be of Grade SW or MW and comply with the physical requirements in Table 21-1-B and other requirements of this section. Grade SW may be used in lieu of Grade MW.

21.107.2 Definitions.

HOLLOW BRICK is a clay masonry unit whose net cross-sectional area (solid area) in any plane parallel to the bearing surface is less than 75 percent of its gross cross-sectional area measured in the same plane.

CORES are void spaces having a gross cross-sectional area equal to or less than 1 1/2 square inches (968 mm²).

CELLS are void spaces having a gross cross-sectional area greater than 1 1/2 square inches (968 mm²).

21.107.3 Types. Four types of hollow brick are covered:

Type HBS. Hollow brick for general use in exposed exterior and interior masonry walls and partitions where wider color ranges and greater variation in size are permitted than is specified for Type HBX.

Type HBX. Hollow brick for general use in exposed exterior and interior masonry walls and partitions where a high degree of mechanical perfection, narrow color range and minimum permissible variation in size are required.
**Type HBA.** Hollow brick manufactured and selected to produce characteristic architectural effects resulting from nonuniformity in size, color and texture of the individual units.

**Type HBB.** Hollow brick for general use in masonry walls and partitions where color and texture are not a consideration and a greater variation in size is permitted than is specified for Type HBX.

When the type is not specified, the requirements for Type HBS shall govern.

21.107.4 **Class.** Two classes of hollow brick are covered:

- **Class H40V.** Hollow brick intended for use where void areas or hollow spaces greater than 25 percent, but not greater than 40 percent, of the gross cross-sectional area of the unit measured in any plane parallel to the bearing surface. The void spaces, web thicknesses and shell thicknesses shall comply with the requirements of Sections 21.107.5 and 21.107.6.

- **Class H60V.** Hollow brick intended for use where larger void areas are desired. The sum of these void areas shall be greater than 40 percent, but not greater than 60 percent, of the gross cross-sectional area of the unit measured in any plane parallel to the bearing surface. The void spaces, web thicknesses and shell thicknesses shall comply with the requirements of Sections 21.107.5 and 21.107.6 and to the minimum requirements of Table 21-1-F.

When the class is not specified, the requirements for Class H40V shall govern.

21.107.5 **Hollow Spaces.** Core holes shall not be less than $\frac{5}{8}$ inch (15.9 mm) from any edge of the brick, except for cored-shell Hollow brick. Cored-shell hollow brick shall have a minimum shell thickness of $\frac{1}{2}$ inches (38 mm). Cores greater than 1 square inch (645 mm$^2$) in cored shells shall not be less than $\frac{1}{2}$ inch (13 mm) from any edge. Cores not greater than 1 inch square (645 mm$^2$) in shells cored not more than 35 percent shall not be less than $\frac{3}{8}$ inch (9.5 mm) from any edge.

Cells shall not be less than $\frac{3}{4}$ inch (19.1 mm) from any edge of the brick except for double-shell hollow brick.

Double-shell hollow brick with inner and outer shells not less than $\frac{1}{2}$ inch (13 mm) thick may not have cells greater than $\frac{5}{8}$ inch (15.9 mm) in width or 5 inches (127 mm) in length between the inner and outer shell.

21.107.6 **Webs.** The thickness for webs between cells shall not be less than $\frac{1}{2}$ inch (13 mm), $\frac{3}{8}$ inch (9.5 mm) between cells and cores or $\frac{1}{4}$ inch (6 mm) between cores. The distance of voids from unexposed edges, which are recessed not less than $\frac{1}{2}$ inch (13 mm), shall not be less than $\frac{1}{2}$ inch (13 mm).

21.107.7 **Frogging.** One bearing face of each brick may have a recess or panel (frog) not exceeding $\frac{3}{8}$ inch (9.5 mm) in depth. No part of the recess shall be less than $\frac{5}{8}$ inch (15.9 mm) from any edge of the brick, except that brick containing deep frogs shall comply with other requirements of Section 21.107.2 for void area and Section 21.107.5 for hollow spaces.

21.107.8 **Tolerances on Dimensions.** The hollow brick shall not depart from the specified size by more than the individual tolerance for specified size by more than individual tolerances for the type specified as set forth in Table 21-1-G. Tolerances and dimensions for Type HBA shall be as specified by the purchaser.

21.107.9 **Warpage.** Tolerances for distortion or warpage of face or edges of individual hollow brick from a plane surface and from a straight line, respectively, shall not exceed the maximum for the type specified in Table 21-1-H. Tolerances on distortion for Type HBA shall be as specified by the purchaser.

21.107.10 **Visual Inspection.** In addition to the requirements of Section 21.104, brick used in exposed wall construction shall have faces which are free of cracks or other imperfections detracting from the appearance of a sample wall when viewed from a distance of 15 feet (4600 mm) for Type HBX and a distance of 20 feet (6100 mm) for Types HBS and HBA.

3-600
<table>
<thead>
<tr>
<th>EXPOSURE</th>
<th>WEATHERING INDEX</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Less than 50</td>
</tr>
<tr>
<td>In vertical surfaces:</td>
<td></td>
</tr>
<tr>
<td>In contact with earth</td>
<td>MW</td>
</tr>
<tr>
<td>Not in contact with earth</td>
<td>MW</td>
</tr>
<tr>
<td>In other than vertical surfaces:</td>
<td>SW</td>
</tr>
<tr>
<td>In contact with earth</td>
<td>MW</td>
</tr>
<tr>
<td>Not in contact with earth</td>
<td></td>
</tr>
<tr>
<td>Type of Masonry</td>
<td>Grade</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>24-1. Building brick</td>
<td>SW</td>
</tr>
<tr>
<td></td>
<td>MW</td>
</tr>
<tr>
<td></td>
<td>NW</td>
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<tr>
<td>Hollow Brick</td>
<td>SW</td>
</tr>
<tr>
<td></td>
<td>MW</td>
</tr>
<tr>
<td>24-2. Sand-lime building brick</td>
<td>SW</td>
</tr>
<tr>
<td></td>
<td>MW</td>
</tr>
<tr>
<td>24-14. Unburned clay masonry units</td>
<td></td>
</tr>
</tbody>
</table>

1. Gross area of a unit shall be determined by multiplying the horizontal face dimension of the unit as placed in the wall by its thickness.
2. The saturation coefficient is the ratio of absorption by 24-hour submersion in cold water to that after five-hour submersion in boiling water.
3. If the average cold-water absorption of a random sample of five bricks does not exceed 8.0 percent, when no more than one brick unit of the sample exceeds 8.0 percent and its cold-water absorption must be less than 10.0 percent, the saturation coefficient shall be waived.
4. Based on net area of a unit which shall be taken as the area of solid material in shells and webs actually carrying stresses in a direction parallel to the direction of loading.
5. The range in percentage absorption for tile delivered to any one job shall not be more than 12.
### TABLE 21-1-C—TOLERANCES ON DIMENSIONS

<table>
<thead>
<tr>
<th>SPECIFIED DIMENSION (inches)</th>
<th>MAXIMUM PERMISSIBLE VARIATION FROM SPECIFIED DIMENSION, PLUS OR MINUS (inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 3, incl.</td>
<td>( \frac{3}{32} )</td>
</tr>
<tr>
<td>Over 3 to 4, incl.</td>
<td>( \frac{1}{16} )</td>
</tr>
<tr>
<td>Over 4 to 6, incl.</td>
<td>( \frac{1}{8} )</td>
</tr>
<tr>
<td>Over 6 to 8, incl.</td>
<td>( \frac{1}{4} )</td>
</tr>
<tr>
<td>Over 8 to 12, incl.</td>
<td>( \frac{5}{16} )</td>
</tr>
<tr>
<td>Over 12 to 16, incl.</td>
<td>( \frac{3}{8} )</td>
</tr>
</tbody>
</table>

### TABLE 21-1-D—TOLERANCES ON DIMENSIONS

<table>
<thead>
<tr>
<th>SPECIFIED DIMENSION (inches)</th>
<th>MAXIMUM PERMISSIBLE VARIATION FROM SPECIFIED DIMENSION, PLUS OR MINUS (inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specified Dimension</td>
<td>Type FBX</td>
</tr>
<tr>
<td></td>
<td>( \times 25.4 \text{ for mm} )</td>
</tr>
<tr>
<td>3 and under</td>
<td>( \frac{1}{16} )</td>
</tr>
<tr>
<td>Over 3 to 4, incl.</td>
<td>( \frac{1}{32} )</td>
</tr>
<tr>
<td>Over 4 to 6, incl.</td>
<td>( \frac{1}{8} )</td>
</tr>
<tr>
<td>Over 6 to 8, incl.</td>
<td>( \frac{5}{32} )</td>
</tr>
<tr>
<td>Over 8 to 12, incl.</td>
<td>( \frac{1}{32} )</td>
</tr>
<tr>
<td>Over 12 to 16, incl.</td>
<td>( \frac{1}{32} )</td>
</tr>
</tbody>
</table>

### TABLE 21-1-E—TOLERANCES ON DISTORTION

<table>
<thead>
<tr>
<th>MAXIMUM FACE DIMENSION (inches)</th>
<th>MAXIMUM PERMISSIBLE DISTORTION (inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specified Dimension</td>
<td>Type FBX</td>
</tr>
<tr>
<td></td>
<td>( \times 25.4 \text{ for mm} )</td>
</tr>
<tr>
<td>8 and under</td>
<td>( \frac{1}{16} )</td>
</tr>
<tr>
<td>Over 8 to 12, incl.</td>
<td>( \frac{1}{32} )</td>
</tr>
<tr>
<td>Over 12 to 16, incl.</td>
<td>( \frac{1}{16} )</td>
</tr>
</tbody>
</table>

### TABLE 21-1-F—HOLLOW BRICK (Class H60V) MINIMUM THICKNESS OF FACE SHELLS AND WEBS

<table>
<thead>
<tr>
<th>NOMINAL WIDTH OF UNIT (Inches)</th>
<th>FACE SHELL THICKNESS (Inches)</th>
<th>END SHELLS OR WEBS (Inches)</th>
<th>WEB THICKNESS PER FOOT, TOTAL (Inches per foot)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Solid</td>
<td>Cored or Double Shell</td>
<td></td>
</tr>
<tr>
<td>3 and 4</td>
<td>( \frac{3}{16} )</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>( \frac{1}{4} )</td>
<td>( \frac{1}{2} )</td>
<td>( \frac{1}{2} )</td>
</tr>
<tr>
<td>8</td>
<td>( \frac{1}{4} )</td>
<td>( \frac{1}{2} )</td>
<td>( \frac{1}{2} )</td>
</tr>
<tr>
<td>10</td>
<td>( \frac{1}{8} )</td>
<td>( \frac{1}{2} )</td>
<td>( \frac{1}{2} )</td>
</tr>
<tr>
<td>12</td>
<td>( \frac{1}{2} )</td>
<td>2</td>
<td>( \frac{1}{2} )</td>
</tr>
</tbody>
</table>

1 The sum of the measured thickness of all webs in the unit, multiplied by 12 (305 when using metric), and divided by the length of the unit. In the case of open-ended units where the open-end portion is solid grouted, the length of that open-ended portion shall be deducted from the overall length of the unit.

---

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### TABLE 21-1-G—TOLERANCES ON DIMENSIONS

<table>
<thead>
<tr>
<th>SPECIFIED DIMENSION (Inches)</th>
<th>MAXIMUM PERMISSIBLE VARIATION FROM SPECIFIED DIMENSION, PLUS OR MINUS (Inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type HBX</td>
</tr>
<tr>
<td></td>
<td>× 25.4 for mm</td>
</tr>
<tr>
<td>3 and under</td>
<td>1/16</td>
</tr>
<tr>
<td>Over 3 to 4, incl.</td>
<td>3/32</td>
</tr>
<tr>
<td>Over 4 to 6, incl.</td>
<td>1/8</td>
</tr>
<tr>
<td>Over 6 to 8, incl.</td>
<td>5/32</td>
</tr>
<tr>
<td>Over 8 to 12, incl.</td>
<td>7/32</td>
</tr>
<tr>
<td>Over 12 to 16, incl.</td>
<td>9/32</td>
</tr>
</tbody>
</table>

### TABLE 21-1-H—TOLERANCES ON DISTORTION

<table>
<thead>
<tr>
<th>MAXIMUM FACE DIMENSION (Inches)</th>
<th>MAXIMUM PERMISSIBLE DISTORTION (Inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type HBX</td>
</tr>
<tr>
<td></td>
<td>× 25.4 for mm</td>
</tr>
<tr>
<td>8 and under</td>
<td>1/16</td>
</tr>
<tr>
<td>Over 8 to 12, incl.</td>
<td>3/32</td>
</tr>
<tr>
<td>Over 12 to 16, incl.</td>
<td>1/8</td>
</tr>
</tbody>
</table>
FIGURE 21-1-1—WEATHERING INDEXES IN THE UNITED STATES
UNIFORM BUILDING CODE STANDARD 21-2
CALCIUM SILICATE FACE BRICK
(SAND-LIME BRICK)

Based on Standard Specification C 73-75 of the American Society for Testing
and Materials. Extracted, with permission, from the Annual Book of ASTM
Standards, copyright American Society for Testing and Materials,
1916 Race Street, Philadelphia, PA 19103
See Section 2102.2, Item 6, Uniform Building Code

SECTION 21.201 — SCOPE

21.201.1 Grades. This standard covers brick made from sand and lime and intended for use in
brick masonry. Two grades of brick are covered:

21.201.1.1 Grade SW. Brick intended for use where exposed to temperatures below freezing in
the presence of moisture.

21.201.1.2 Grade MW. Brick intended for use where exposed to temperature below freezing
but unlikely to be saturated with water.

21.201.2 Definition. The term “brick” used in this standard shall mean brick or a solid sand-lime
masonry unit.

SECTION 21.202 — PHYSICAL PROPERTIES

21.202.1 Durability. The brick shall conform to the physical requirements for the grade specified
as prescribed in Table 21-2-A.

21.202.2 Substitution of Grades. Unless otherwise specified, brick of Grade SW shall be ac­
cepted in lieu of Grade MW.

SECTION 21.203 — SIZE

The size of the brick shall be as specified by the purchaser, and the average size of brick furnished
shall approximate the size specified in the invitation for bids.

No overall dimension (width, height and length) shall differ by more than 1/8 inch (3.2 mm) from
the specified standard dimension. Standard dimensions of units are the manufacturer’s designated
dimensions.

SECTION 21.204 — VISUAL INSPECTION

Brick shall pass a visual inspection for soundness, compact structure, reasonably uniform shape,
and freedom from the following: cracks, warpage, large pebbles, balls of clay, or particles of lime
that would affect the serviceability or strength of the brick.

<table>
<thead>
<tr>
<th>TYPE OF MASONRY</th>
<th>GRADE</th>
<th>MINIMUM COMPRESSION STRENGTH PSI AVERAGE GROSS AREA</th>
<th>MINIMUM MODULUS OF RUPTURE (Brick Flatwise) psi</th>
<th>Average Gross Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Average of Five Tests</td>
<td>Individual</td>
<td>× 6.89 for kPa</td>
</tr>
<tr>
<td>Sand-lime Building brick</td>
<td>SW</td>
<td>4500</td>
<td>3500</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>MW</td>
<td>2500</td>
<td>2000</td>
<td>450</td>
</tr>
</tbody>
</table>

Gross area of a unit shall be determined by multiplying the horizontal face dimension of the unit as placed in the wall
by its thickness.

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UNIFORM BUILDING CODE STANDARD 21-3
CONCRETE BUILDING BRICK


See Section 2102.2, Item 5, Uniform Building Code

SECTION 21.301 — SCOPE
This standard covers concrete building brick and similar solid units made from portland cement, water and suitable mineral aggregates with or without the inclusion of other materials.

SECTION 21.302 — CLASSIFICATION
21.302.1 Types. Two types of concrete brick in each of two grades are covered, as follows:

21.302.1.1 Type I, moisture-controlled units. Concrete brick designated as Type I (Grades N-I and S-I) shall conform to all requirements of this standard, including the requirements of Table 21-3-A.

21.302.1.2 Type II, nonmoisture-controlled units. Concrete brick designated as Type II (Grades N-II and S-II) shall conform to all requirements of this standard except the requirements of Table 21-3-A.

21.302.2 Grades. Concrete brick manufactured in accordance with this standard shall conform to two grades as follows:

21.302.2.1 Grade N. For use as architectural veneer and facing units in exterior walls and for use where high strength and resistance to moisture penetration and severe frost action are desired.

21.302.2.2 Grade S. For general use where moderate strength and resistance to frost action and moisture penetration are required.

SECTION 21.303 — MATERIALS
21.303.1 Cementitious Materials. Materials shall conform to the following applicable U.B.C. standards:

1. Portland Cement—U.B.C. Standard 19-1 modified as follows:
   Limitation on insoluble residue—1.5 percent.
   Limitation on air content of mortar,
   Volume percent—22 percent maximum.
   Limitation on loss on ignition—7 percent maximum.
   Limestone with a minimum 85 percent calcium carbonate (CaCO₃) content may be added to the cement, provided the requirements of U.B.C. Standard 19-1 as modified above are met.


21.303.2 Other Constituents. Air-entraining agents, coloring pigments, integral water repellents, finely ground silica, etc., shall be previously established as suitable for use in concrete or shall be shown by test or experience not to be detrimental to the durability of the concrete.

SECTION 21.304 — PHYSICAL REQUIREMENTS
At the time of delivery to the work site, the concrete brick shall conform to the physical requirements prescribed in Table 21-3-B.
The moisture content of Type I concrete brick at the time of delivery shall conform to the requirements prescribed in Table 21-3-A.

SECTION 21.305 — DIMENSIONS AND PERMISSIBLE VARIATIONS

Overall dimensions (width, height, or length) shall not differ by more than \(\frac{1}{8}\) inch (3.2 mm) from the specified standard dimensions.

**NOTE:** Standard dimensions of concrete brick are the manufacturer's designated dimensions. Nominal dimensions of modular-size concrete brick are equal to the standard dimensions plus \(\frac{3}{8}\) inch (9.5 mm), the thickness of one standard mortar joint. Nominal dimensions of nonmodular size concrete brick usually exceed the standard dimensions by \(\frac{1}{8}\) inch to \(\frac{1}{4}\) inch (3.2 mm to 6.4 mm).

Variations in thickness of architectural units such as split-faced or slumped units will usually vary from the specified tolerances.

SECTION 21.306 — VISUAL INSPECTION

21.306.1 General. All concrete brick shall be sound and free of cracks or other defects that would interfere with the proper placing of the unit or impair the strength or permanence of the construction. Minor cracks incidental to the usual method of manufacture, or minor chipping resulting from customary methods of handling in shipment and delivery, shall not be deemed grounds for rejection.

21.306.2 Brick in Exposed Walls. Where concrete brick is to be used in exposed wall construction, the face or faces that are to be exposed shall be free of chips, cracks or other imperfections when viewed from 20 feet (6100 mm), except that if not more than 5 percent of a shipment contains slight cracks or small chips not larger than \(\frac{1}{8}\) inch (13 mm), this shall not be deemed grounds for rejection.

**TABLE 21-3-A—MOISTURE CONTENT REQUIREMENTS FOR TYPE I CONCRETE BRICK**

<table>
<thead>
<tr>
<th>Linear Shrinkage, Percent</th>
<th>Humid</th>
<th>Intermediate</th>
<th>Arid</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.03 or less</td>
<td>45</td>
<td>40</td>
<td>35</td>
</tr>
<tr>
<td>From 0.03 to 0.045</td>
<td>40</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>0.045 to 0.065, max.</td>
<td>35</td>
<td>30</td>
<td>25</td>
</tr>
</tbody>
</table>

1Arid—Average annual relative humidity less than 50 percent.
Intermediate—Average annual relative humidity 50 to 75 percent.
Humid—Average annual relative humidity above 75 percent.

**TABLE 21-3-B—STRENGTH AND ABSORPTION REQUIREMENTS**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Avg. of 3 Concrete Brick (Concrete Brick Tested Flatwise)</th>
<th>Lightweight Less Than 105</th>
<th>Medium Weight Less Than 125 to 105</th>
<th>Normal Weight 125 or More</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-1</td>
<td>3,500</td>
<td>15</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>N-2</td>
<td>3,500</td>
<td>15</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>S-1</td>
<td>2,500</td>
<td>18</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>S-2</td>
<td>2,500</td>
<td>18</td>
<td>15</td>
<td>13</td>
</tr>
</tbody>
</table>

\(3-608\)
UNIFORM BUILDING CODE STANDARD 21-4
HOLLOW AND SOLID LOAD-BEARING CONCRETE MASONRY UNITS


SECTION 21.401 — SCOPE

This standard covers solid (units with 75 percent or more net area) and hollow load-bearing concrete masonry units made from portland cement, water and mineral aggregates with or without the inclusion of other materials.

SECTION 21.402 — CLASSIFICATION

21.402.1 Grades. Concrete masonry units manufactured in accordance with this standard shall conform to two grades as follows:

21.402.1.1 Grade N. Units having a weight classification of 85 pcf (1360 kg/m³) or greater, for general use such as in exterior walls below and above grade that may or may not be exposed to moisture penetration or the weather and for interior walls and backup.

21.402.1.2 Grade S. Units having a weight classification of less than 85 pcf (1360 kg/m³), for uses limited to above-grade installation in exterior walls with weather-protective coatings and in walls not exposed to the weather.

21.402.2 Types. Two types of concrete masonry units in each of two grades are covered as follows:

21.402.2.1 Type I, moisture-controlled units. Units designated as Type I (Grades N-I and S-I) shall conform to all requirements of this standard including the moisture content requirements of Table 21-4-A.

21.402.2.2 Type II, nonmoisture-controlled units. Units designated as Type II (Grades N-II and S-II) shall conform to all requirements of this standard except the moisture content requirements of Table 21-4-A.

SECTION 21.403 — MATERIALS

21.403.1 Cementitious Materials. Materials shall conform to the following applicable standards:

1. Portland Cement—U.B.C. Standard 19-1 modified as follows:
   - Limitation on insoluble residue—1.5 percent maximum.
   - Limitation on air content of mortar, Volume percent—22 percent maximum.
   - Limitation on loss on ignition—7 percent maximum.
   - Limestone with a minimum 85 percent calcium carbonate (CaCO₃) content may be added to the cement, provided the requirements of U.B.C. Standard 19-1 as modified above are met.


21.403.2 **Other Constituents and Aggregates.** Air-entraining agents, coloring pigments, integral water repellents, finely ground silica, aggregates, and other constituents, shall be previously established as suitable for use in concrete or shall be shown by test or experience to not be detrimental to the durability of the concrete.

**SECTION 21.404 — PHYSICAL REQUIREMENTS**

At the time of delivery to the work site, the units shall conform to the physical requirements prescribed in Table 21-4-B. The moisture content of Type I concrete masonry units at time of delivery shall conform to the requirements prescribed in Table 21-4-A.

**SECTION 21.405 — MINIMUM FACE-SHELL AND WEB THICKNESSES**

Face-shell (FST) and web (WT) thicknesses shall conform to the requirements listed in Table 21-4-C.

**SECTION 21.406 — PERMISSIBLE VARIATIONS IN DIMENSIONS**

21.406.1 **Precision Units.** For precision units, no overall dimension (width, height and length) shall differ by more than $\frac{1}{8}$ inch (3.2 mm) from the specified standard dimensions.

21.406.2 **Particular Feature Units.** For particular feature units, dimensions shall be in accordance with the following:

1. For molded face units, no overall dimension (width, height and length) shall differ by more than $\frac{1}{8}$ inch (3.2 mm) from the specified standard dimension. Dimensions of molded features (ribs, scores, hex-shapes, patterns, etc.) shall be within $\frac{1}{16}$ inch (1.6 mm) of the specified standard dimensions and shall be within $\frac{1}{16}$ inch (1.6 mm) of the specified placement of the unit.

2. For split-faced units, all non-split overall dimensions (width, height and length) shall differ by no more than $\frac{1}{8}$ inch (3.2 mm) from the specified standard dimensions. On faces that are split, overall dimensions will vary. Local suppliers should be consulted to determine dimensional tolerances achievable.

3. For slumped units, no overall height dimension shall differ by more than $\frac{1}{8}$ inch (3.2 mm) from the specified standard dimension. On faces that are slumped, overall dimensions will vary. Local suppliers should be consulted to determine dimension tolerances achievable.

**NOTE:** Standard dimensions of units are the manufacturer's designated dimensions. Nominal dimensions of modular size units, except slumped units, are equal to the standard dimensions plus $\frac{1}{8}$ inch (9.5 mm), the thickness of one standard mortar joint. Slumped units are equal to the standard dimensions plus $\frac{1}{2}$ inch (13 mm), the thickness of one standard mortar joint. Nominal dimensions of nonmodular size units usually exceed the standard dimensions by $\frac{1}{8}$ inch to $\frac{3}{4}$ inch (3.2 mm to 6.4 mm).

**SECTION 21.407 — VISUAL INSPECTION**

All units shall be sound and free of cracks or other defects that would interfere with the proper placing of the unit or impair the strength or permanence of the construction. Units may have minor cracks incidental to the usual method of manufacture, or minor chipping resulting from customary methods of handling in shipment and delivery.

Units that are intended to serve as a base for plaster or stucco shall have a sufficiently rough surface to afford a good bond.

Where units are to be used in exposed wall construction, the face or faces that are to be exposed shall be free of chips, cracks or other imperfections when viewed from 20 feet (6100 mm), except that not more than 5 percent of a shipment may have slight cracks or small chips not larger than 1 inch (25.4 mm).
### TABLE 21-4-A—MOISTURE CONTENT REQUIREMENTS FOR TYPE I UNITS

<table>
<thead>
<tr>
<th>Linear Shrinkage, Percent</th>
<th>Moisture Content, Max. Percent of Total Absorption (Average of 3 Units)</th>
<th>Humidity Conditions at Job Site or Point of Use</th>
<th>Intermediate</th>
<th>Arid</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.03 or less</td>
<td>45</td>
<td>40</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>From 0.03 to 0.045</td>
<td>40</td>
<td>35</td>
<td>30</td>
<td>25</td>
</tr>
<tr>
<td>0.045 to 0.065, max.</td>
<td>35</td>
<td>30</td>
<td>25</td>
<td></td>
</tr>
</tbody>
</table>

1 Average annual relative humidity above 75 percent.
2 Average annual relative humidity 50 to 75 percent.
3 Average annual relative humidity less than 50 percent.

### TABLE 21-4-B—STRENGTH AND ABSORPTION REQUIREMENTS

<table>
<thead>
<tr>
<th>Grade</th>
<th>Average Net Area, psi</th>
<th>Water Absorption, Max. (Avg. of 3 Units)</th>
<th>Oven-Dry Weight of Concrete, Lb/ft³</th>
<th>Water Absorption, Max.</th>
<th>Oven-Dry Weight of Concrete, Lb/ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x 6.89 for kPa</td>
<td>x 15 for kg/m²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Average of 3 Units</td>
<td>Individual Unit</td>
<td>Lightweight</td>
<td>Medium Weight</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Less than 85</td>
<td>Less than 105</td>
<td>Less than 125 to 105</td>
<td>125 or More</td>
</tr>
<tr>
<td>N-I</td>
<td>1900</td>
<td>1500</td>
<td>—</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td>N-II</td>
<td>1900</td>
<td>1500</td>
<td>—</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td>S-I</td>
<td>1300</td>
<td>1100</td>
<td>20</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>S-II</td>
<td>1300</td>
<td>1100</td>
<td>20</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

1 Limited to use above grade in exterior walls with weather-protective coatings and in walls not exposed to the weather.

**NOTE:** To prevent water penetration, protective coating should be applied on the exterior face of basement walls and when required on the face of exterior walls above grade.

### TABLE 21-4-C—MINIMUM THICKNESS OF FACE-SHELLS AND WEBS

<table>
<thead>
<tr>
<th>Nominal Width (W) of Unit (Inches)</th>
<th>Face-Shell Thickness (FST)</th>
<th>Webs Thickness (WT)</th>
<th>Equivalent Web Thickness, Min. (In.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 and 4</td>
<td>3/16</td>
<td>3/16</td>
<td>1 1/8</td>
</tr>
<tr>
<td>6</td>
<td>1/4</td>
<td>1</td>
<td>2 1/4</td>
</tr>
<tr>
<td>8</td>
<td>1/2</td>
<td>1/8</td>
<td>2 1/2</td>
</tr>
<tr>
<td>10</td>
<td>1/4</td>
<td>1/8</td>
<td>2 1/2</td>
</tr>
<tr>
<td>12</td>
<td>1/2</td>
<td>1/4</td>
<td>2 1/2</td>
</tr>
</tbody>
</table>

1 Average of measurements on three units taken at the thinnest point.
2 Sum of the measured thickness of all webs in the unit, multiplied by 12 (305 when using metric), and divided by the length of the unit. In the case of open-ended units where the open-ended portion is solid grouted, the length of that open-ended portion shall be deducted from the overall length of the unit.
3 This face-shell thickness (FST) is applicable where allowable design load is reduced in proportion to the reduction in thicknesses shown, except that allowable design load on solid-grouted units shall not be reduced.
4 For split-faced units, a maximum of 10 percent of a shipment may have face-shell thicknesses less than those shown, but in no case less than 3/4 inch (19 mm).
UNIFORM BUILDING CODE STANDARD 21-5
NONLOAD-BEARING CONCRETE MASONRY UNITS


See Section 2102.2, Item 5, Uniform Building Code

SECTION 21.501 — SCOPE

This standard covers hollow and solid nonload-bearing concrete masonry units made from portland cement, water, and mineral aggregates with or without the inclusion of other materials. Such units are intended for use in nonload-bearing partitions but under certain conditions may be suitable for use in nonload-bearing exterior walls above grade, where effectively protected from the weather.

SECTION 21.502 — CLASSIFICATION

21.502.1 Weight Classifications. Nonload-bearing concrete masonry units manufactured in accordance with this standard shall conform to one of three weight classifications and two types as follows:

<table>
<thead>
<tr>
<th>WEIGHT CLASSIFICATION</th>
<th>OVEN-DRY WEIGHT OF CONCRETE lb./cu.ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lightweight</td>
<td>105 (1680 kg/m³) max.</td>
</tr>
<tr>
<td>Medium weight</td>
<td>105 - 125 (1680 - 2000 kg/m³)</td>
</tr>
<tr>
<td>Normal weight</td>
<td>125 (2000 kg/m³) min.</td>
</tr>
</tbody>
</table>

21.502.2 Types. Nonload-bearing concrete masonry units shall be of two types as follows:

21.502.2.1 Type I, moisture-controlled units. Type I units shall conform to all requirements of this standard, including the requirements of Table 21-5-A.

21.502.2.2 Type II, nonmoisture-controlled units. Type II units shall conform to all requirements of this standard, except the requirements listed in Table 21-5-A.

SECTION 21.503 — MATERIALS

21.503.1 Cementitious Materials. Cementitious materials shall conform to the following applicable U.B.C. standards:

1. Portland Cement—U.B.C. Standard 19-1 modified as follows:
   - Limitation on insoluble residue—1.5 percent.
   - Limitation on air content of mortar,
     Volume percent—22 percent maximum.
   - Limitation on loss on ignition—7 percent maximum.
   - Limestone with a minimum 85 percent calcium carbonate (CaCO₃) content may be added to the cement, provided the requirements of U.B.C. Standard 19-1 as modified above are met.


21.503.2 Other Constituents. Air-entraining agents, coloring pigments, integral water repellents, finely ground silica, etc., shall be previously established as suitable for use in concrete or shall be shown by test or experience not to be detrimental to the durability of the concrete.

3-612
SECTION 21.504 — PHYSICAL REQUIREMENTS

At the time of delivery to the work site, the units shall conform to the strength requirements prescribed in Table 21-5-B.

The moisture content of Type I concrete masonry units at the time of delivery shall conform to the requirements prescribed in Table 21-5-A.

SECTION 21.505 — DIMENSIONS AND PERMISSIBLE VARIATIONS

Minimum face-shell thickness shall not be less than \( \frac{1}{2} \) inch (13 mm).

No overall dimension (width, height or length) shall differ by more than \( \frac{1}{32} \) inch (3.2 mm) from the specified standard dimensions.

**NOTE:** Standard dimensions of units are the manufacturer’s designated dimensions. Nominal dimensions of modular-size units are equal to the standard dimensions plus \( \frac{3}{8} \) inch (9.5 mm), the thickness of one standard mortar joint. Nominal dimensions of nonmodular size units usually exceed the standard dimensions by \( \frac{1}{16} \) inch to \( \frac{1}{64} \) inch (3.2 mm to 6.4 mm).

Variations in thickness of architectural units such as split-faced or slumped units will usually exceed the specified tolerances.

SECTION 21.506 — VISUAL INSPECTION

21.506.1 General. All units shall be sound and free of cracks or other defects that would interfere with the proper placing of the units or impair the strength or permanence of the construction. Units may have minor cracks incidental to the usual method of manufacture, or minor chipping resulting from customary methods of handling in shipment and delivery.

21.506.2 Exposed Units. Where units are to be used in exposed wall construction, the face or faces that are to be exposed shall be free of chips, cracks or other imperfections when viewed from 20 feet (6100 mm), except that not more than 5 percent of a shipment may have slight cracks or small chips not larger than 1 inch (25 mm).

21.506.3 Identification. Nonloading concrete masonry units shall be clearly marked in a manner to preclude their use as load-bearing units.

**TABLE 21-5-A—MOISTURE CONTENT REQUIREMENTS FOR TYPE I UNITS**

<table>
<thead>
<tr>
<th>LINEAR SHRINKAGE, PERCENT</th>
<th>MOISTURE CONTENT, MAX. PERCENT OF TOTAL ABSORPTION (Average of 3 Units)</th>
<th>Humidity of Conditions at Jobsite or Point of Use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Humid</td>
<td>Intermediate</td>
</tr>
<tr>
<td>0.03 or less</td>
<td>45</td>
<td>40</td>
</tr>
<tr>
<td>From 0.03 to 0.045</td>
<td>40</td>
<td>35</td>
</tr>
<tr>
<td>0.045 to 0.065, max.</td>
<td>35</td>
<td>30</td>
</tr>
</tbody>
</table>

1 Aird—Average annual relative humidity less than 50 percent.
Intermediate—Average annual relative humidity 50 to 75 percent.
Humid—Average annual relative humidity above 75 percent.

**TABLE 21-5-B—STRENGTH REQUIREMENTS**

<table>
<thead>
<tr>
<th>COMPRESSIVE STRENGTH (Average Net Area) Min., psi</th>
<th>Compressive strength (Average Net Area) Min., psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \times 6.89 ) for kPa</td>
<td><em>6.89 for kPa</em></td>
</tr>
<tr>
<td>Average of 3 units</td>
<td>600</td>
</tr>
<tr>
<td>Individual units</td>
<td>500</td>
</tr>
</tbody>
</table>
UNIFORM BUILDING CODE STANDARD 21-6
IN-PLACE MASONRY SHEAR TESTS

Test Standard of the International Conference of Building Officials

See Appendix Chapter 1, Sections A106.3.3 and A107.2, Uniform Code for Building Conservation

SECTION 21.601 — SCOPE
This standard applies when the Uniform Code for Building Conservation requires in-place testing of the quality of masonry mortar.

SECTION 21.602 — PREPARATION OF SAMPLE
The bed joints of the outer wythe of the masonry shall be tested in shear by laterally displacing a single brick relative to the adjacent bricks in the same wythe. The head joint opposite the loaded end of the test brick shall be carefully excavated and cleared. The brick adjacent to the loaded end of the test brick shall be carefully removed by sawing or drilling and excavating to provide space for a hydraulic ram and steel loading blocks.

SECTION 21.603 — APPLICATION OF LOAD AND DETERMINATION OF RESULTS
Steel blocks, the size of the end of the brick, shall be used on each end of the ram to distribute the load to the brick. The blocks shall not contact the mortar joints. The load shall be applied horizontally, in the plane of the wythe, until either a crack can be seen or slip occurs. The strength of the mortar shall be calculated by dividing the load at the first cracking or movement of the test brick by the nominal gross area of the sum of the two bed joints.
UNIFORM BUILDING CODE STANDARD 21-7
TESTS OF ANCHORS IN UNREINFORCED MASONRY WALLS
Test Standard of the International Conference of Building Officials
See Appendix Chapter 1, Section A107.3 and A107.4, Uniform Code for Building Conservation

SECTION 21.701 — SCOPE
Shear and tension anchors in existing masonry construction shall be tested in accordance with this standard when required by the Uniform Code for Building Conservation.

SECTION 21.702 — DIRECT TENSION TESTING OF EXISTING ANCHORS AND NEW BOLTS
The test apparatus shall be supported by the masonry wall. The distance between the anchor and the test apparatus support shall not be less than one half the wall thickness for existing anchors and 75 percent of the embedment for new embedded bolts. Existing wall anchors shall be given a preload of 300 pounds (1335 N) prior to establishing a datum for recording elongation. The tension test load reported shall be recorded at 1/8 inch (3.2 mm) relative movement of the existing anchor and the adjacent masonry surface. New embedded tension bolts shall be subject to a direct tension load of not less than 2.5 times the design load but not less than 1,500 pounds (6672 N) for five minutes (10 percent deviation).

SECTION 21.703 — TORQUE TESTING OF NEW BOLTS
Bolts embedded in unreinforced masonry walls shall be tested using a torque-calibrated wrench to the following minimum torques:

- 1/2-inch-diameter (13 mm) bolts—40 foot pounds (54.2 N•m)
- 5/8-inch-diameter (16 mm) bolts—50 foot pounds (67.8 N•m)
- 3/4-inch-diameter (19 mm) bolts—60 foot pounds (81.3 N•m)

SECTION 21.704 — PREQUALIFICATION TEST FOR BOLTS AND OTHER TYPES OF ANCHORS
This section is applicable when it is desired to use tension or shear values for anchors greater than those permitted by Table A-1-E of the Uniform Code for Building Conservation. The direct-tension test procedure set forth in Section 24.802 for existing anchors may be used to determine the allowable tension values for new embedded or through bolts except that no preload is required. Bolts shall be installed in the same manner and using the same materials as will be used in the actual construction. A minimum of five tests for each bolt size and type shall be performed for each class of masonry in which they are proposed to be used. The allowable tension value for such anchors shall be 40 percent of the average value of the tests for each size and type of bolt and class of masonry.

Shear bolts may be similarly prequalified. The test procedure shall comply with ASTM E 488-90 or another approved procedure.

The allowable values determined in this manner may exceed those set forth in Table A-1-E of the Uniform Code for Building Conservation.

SECTION 21.705 — REPORTS
Results of all tests shall be reported. The report shall include the test results as related to anchor size and type, orientation of loading, details of the anchor installation and embedment, wall thickness, and joist orientation.
UNIFORM BUILDING CODE STANDARD 21-8
POINTING OF UNREINFORCED MASONRY WALLS

Construction Specification of the International Conference of Building Officials

See Appendix Chapter 1, Section A106.3.3.2,
Uniform Code for Building Conservation

SECTION 21.801 — SCOPE

Pointing of deteriorated mortar joints when required by the Uniform Code for Building Conservation shall be in accordance with this standard.

SECTION 21.802 — JOINT PREPARATION

The old or deteriorated mortar joint shall be cut out, by means of a toothing chisel or nonimpact power tool, to a uniform depth of 3/4 inch (19 mm) until sound mortar is reached. Care shall be taken not to damage the brick edges. After cutting is complete, all loose material shall be removed with a brush, air or water stream.

SECTION 21.803 — MORTAR PREPARATION

The mortar mix shall be Type N or Type S proportioned as required by the construction specifications. The pointing mortar shall be prehydrated by first thoroughly mixing all ingredients dry and then mixing again, adding only enough water to produce a damp unworkable mix which will retain its form when pressed into a ball. The mortar shall be kept in a damp condition for one and one-half hours; then sufficient water shall be added to bring it to a consistency that is somewhat drier than conventional masonry mortar.

SECTION 21.804 — PACKING

The joint into which the mortar is to be packed shall be damp but without freestanding water. The mortar shall be tightly packed into the joint in layers not exceeding 1/4 inch (6.4 mm) in depth until it is filled; then it shall be tooled to a smooth surface to match the original profile.
UNIFORM BUILDING CODE STANDARD 21-9
UNBURNED CLAY MASONRY UNITS AND STANDARD
METHODS OF SAMPLING AND TESTING UNBURNED
CLAY MASONRY UNITS
Test Standard of the International Conference of Building Officials
See Section 2102.2, Item 6, Uniform Building Code
Part I—Unburned Clay Masonry

SECTION 21.901 — SCOPE
This standard covers unburned clay masonry units made from a suitable mixture of soil, clay and
stabilizing agent, and intended for use in brick masonry.

SECTION 21.902 — COMPOSITION OF UNITS
21.902.1 Soil. The soil used shall contain not less than 25 percent and not more than 45 percent of
material passing a No. 200 mesh (75 μm) sieve. The soil shall contain sufficient clay to bind the
particles together, but shall contain not more than 0.2 percent of water-soluble salts.
21.902.2 Stabilizer. The stabilizing agent shall be emulsified asphalt. The stabilizing agent shall
be uniformly mixed with the soil in amounts sufficient to provide the required resistance to absorp­
tion.

SECTION 21.903 — PHYSICAL REQUIREMENTS
The units shall conform to the physical requirements prescribed in Table 21-1-B of U.B.C. Standard
21-1.

SECTION 21.904 — SHRINKAGE CRACKS
No units shall contain more than three shrinkage cracks, and no shrinkage crack shall exceed 3 in­
ches (76 mm) in length or 1/8 inch (3.2 mm) in width.

Part II—Sampling and Testing of Unburned Clay Masonry Units

SECTION 21.905 — SCOPE
These methods cover procedures for the sampling and testing of unburned clay masonry units for
compressive strength, modulus of rupture, absorption and moisture content.

Sampling

SECTION 21.906 — TEST SPECIMENS
For each of the tests prescribed in this standard, five sample units shall be selected at random from
each lot of 5,000 units or fraction thereof.

SECTION 21.907 — IDENTIFICATION
Each specimen shall be marked so that it may be identified at any time. Markings shall not cover
more than 5 percent of the superficial area of the specimen.
Compressive Strength

SECTION 21.908 — PROCEDURE

Five full-size specimens shall be tested for compressive strength according to the following procedure:

1. Dry the specimens at a temperature of 85°F ± 15°F (29°C ± 9°C) in an atmosphere having a relative humidity of not more than 50 percent. Weigh the specimens at one-day intervals until constant weight is attained.

2. Test the specimens in the position in which the unburned clay masonry unit is designed to be used, and bed on and cap with a felt pad not less than 1/8 inch (3.2 mm) nor more than 1/4 inch (6.4 mm) in thickness.

3. The specimens may be suitably capped with calcined gypsum mortar or the bearing surfaces of the tile may be planed or rubbed smooth and true. When calcined gypsum is used for capping, conduct the test after the capping has set and the specimen has been dried to constant weight in accordance with Item 1 of this section.

4. The loading head shall completely cover the bearing area of the specimen and the applied load shall be transmitted through a spherical bearing block of proper design. The speed of the moving head of the testing machine shall not be more than 0.05 inch (1.27 mm) per minute.

5. Calculate the average compressive strength of the specimens tested and report this as the compressive strength of the block.

Modulus of Rupture

SECTION 21.909 — PROCEDURE

Five full-size specimens shall be tested for modulus of rupture according to the following procedure:

1. Cured specimen shall be positioned on cylindrical supports 2 inches (51 mm) in diameter, located 2 inches (51 mm) from each end, and extending across the full width of the specimen.

2. A cylinder 2 inches (51 mm) in diameter shall be positioned on the specimen midway between and parallel to the cylindrical supports.

3. Load shall be applied to the cylinder at the rate of 500 pounds (2224 N) per minute until failure occurs.

4. Calculate modulus of rupture from the formula

$$S = \frac{3WL}{2Bd^2}$$

WHERE:

- \(B\) = width of specimen.
- \(d\) = thickness of specimen.
- \(L\) = distance between supports.
- \(S\) = modulus of rupture, psi (kPa).
- \(W\) = load at failure.

Absorption

SECTION 21.910 — PROCEDURE

A 4-inch (102 mm) cube cut from a sample unit shall be tested for absorption according to the following procedure:
1. Dry specimen to a constant weight in a ventilated oven at 212°F to 239°F (100°C to 115°C).
2. Place specimen on a constantly water-saturated porous surface for seven days. Weigh specimen.
3. Calculate absorption as a percentage of the initial dry weight.

**Moisture Content**

**SECTION 21.911 — PROCEDURE**

Five representative specimens shall be tested for moisture content according to the following procedure:

1. Obtain weight of each specimen immediately upon receiving.
2. Dry all specimens to constant weight in a ventilated oven at 212°F to 239°F (100°C to 115°C) and obtain dry weight.
3. Calculate moisture content as a percentage of the initial dry weight.
UNIFORM BUILDING CODE STANDARD 21-10
JOINT REINFORCEMENT FOR MASONRY

Specification Standard of the International Conference of Building Officials
See Sections 2102.2; 2104 and 2106.1.12.4, Item 2, Uniform Building Code
Part I—Joint Reinforcement for Masonry

SECTION 21.1001 — SCOPE
This standard covers joint reinforcement fabricated from cold-drawn steel wire for reinforcing masonry.

SECTION 21.1002 — DESCRIPTION
Joint reinforcement consists of deformed longitudinal wires welded to cross wires (Figure 21-10-1) in sizes suitable for placing in mortar joints between masonry courses.

SECTION 21.1003 — CONFIGURATION AND SIZE OF LONGITUDINAL AND CROSS WIRES
21.1003.1 General. The distance between longitudinal wires and the configuration of cross wires connecting the longitudinal wires shall conform to the design and the requirements of Figure 21-10-1.
21.1003.2 Longitudinal Wires. The diameter of longitudinal wires shall not be less than 0.148 inch (3.76 mm) or more than one half the mortar joint thickness.
21.1003.3 Cross Wires. The diameter of cross wires shall not be less than (No. 9 gage) 0.148-inch (3.76 mm) diameter nor more than the diameter of the longitudinal wires. Cross wires shall not project beyond the outside longitudinal wires by more than 1/8 inch (3.2 mm).
21.1003.4 Width. The width of joint reinforcement shall be the out-to-out distance between outside longitudinal wires. Variation in the width shall not exceed 1/8 inch (3.2 mm).
21.1003.5 Length. The length of pieces of joint reinforcement shall not vary more than 1/2 inch (13 mm) or 1.0 percent of the specified length, whichever is less.

SECTION 21.1004 — MATERIAL REQUIREMENTS
21.1004.1 Tensile Properties. Wire of the finished product shall meet the following requirements:
- Tensile strength, minimum 75,000 psi (517 MPa)
- Yield strength, minimum 60,000 psi (414 MPa)
- Reduction of area, minimum 30 percent

For wire testing over 100,000 psi (689 MPa), the reduction of area shall not be less than 25 percent.

21.1004.2 Bend Properties. Wire shall not break or crack along the outside diameter of the bend when tested in accordance with Section 21.1008.

21.1004.3 Weld Shear Properties. The least weld shear strength in pounds shall not be less than 25,000 (11.3 Mg) multiplied by the specified area of the smaller wire in square inches.

3–620
SECTION 21.1005 — FABRICATION

Wire shall be fabricated and finished in a workmanlike manner, shall be free from injurious imperfections and shall conform to this standard.

The wires shall be assembled by automatic machines or by other suitable mechanical means which will assure accurate spacing and alignment of all members of the finished product.

Longitudinal and cross wires shall be securely connected at every intersection by a process of electric-resistance welding.

Longitudinal wires shall be deformed. One set of four deformations shall occur around the perimeter of the wire at a maximum spacing of 0.7 times the diameter of the wire but not less than eight sets per inch (25.4 mm) of length. The overall length of each deformation within the set shall be such that the summation of gaps between the ends of the deformations shall not exceed 25 percent of the perimeter of the wire. The height or depth of the deformations shall be 0.012 inch (0.305 mm) for 7/16 inch (4.76 mm) diameter or larger wire, 0.011 inch (0.28 mm) for 0.162-inch (4.11 mm) diameter wire and 0.009 inch (0.23 mm) for 0.148-inch (3.76 mm) diameter wire.

SECTION 21.1006 — TENSION TESTS

Tension tests shall be made on individual wires cut from the finished product across the welds.

Tension tests across a weld shall have the welded joint located approximately at the center of the wire being tested.

Tensile strength shall be the average of four test values determined by dividing the maximum test load by the specified cross-sectional area of the wire.

Reduction of area shall be determined by measuring the ruptured section of a specimen which has been tested.

SECTION 21.1007 — WELD SHEAR STRENGTH TESTS

Test specimens shall be obtained from the finished product by cutting a section of wire which includes one weld.

Weld shear strength tests shall be conducted using a fixture of such design as to prevent rotation of the cross wire. The cross wire shall be placed in the anvil of the testing device which is secured in the tensile machine and the load then applied to the longitudinal wire.

Weld shear strength shall be the average test load in pounds of four tests.

SECTION 21.1008 — BEND TESTS

Test specimens shall be obtained from the finished product by cutting a section of wire without welds.

The test specimens shall be bent cold through 180 degrees around a pin, the diameter of which is equal to the diameter of the specimen.

The specimen shall not break nor shall there be visual cracks on the outside diameter of the bend.

SECTION 21.1009 — FREQUENCY OF TESTS

One set of tension tests, weld strength shear tests and bend tests shall be performed for each 2,000,000 lineal feet (610,000 m) of joint reinforcement, but not less than monthly.

SECTION 21.1010 — CORROSION PROTECTION

When corrosion protection of joint reinforcement is provided, it shall be in accordance with one of the following:
21.1010.1 **Brite Basic.** No coating.

21.1010.2 **Mill Galvanized.** Zinc coated, by the hot-dipped method, with no minimum thickness of zinc coating. The coating may be applied before fabrication.

21.1010.3 **Class I Mill Galvanized.** Zinc coated, by the hot-dipped method, with a minimum of 0.40 ounce of zinc per square foot (0.12 kg/m²) of surface area. The coating may be applied before fabrication.

21.1010.4 **Class III Mill Galvanized.** Zinc coated, by the hot-dipped method, with a minimum of 0.80 ounce of zinc per square foot (0.24 kg/m²) of surface area. The coating may be applied before fabrication.

21.1010.5 **Hot-dipped Galvanized.** Zinc coated, by the hot-dipped method, with a minimum of 1.50 ounces of zinc per square foot (0.45 kg/m²) of surface area. The coating shall be applied after fabrication.

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**FIGURE 21-10-1—JOINT REINFORCEMENT**

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**Part II—Cold-drawn Steel Wire for Concrete Reinforcement**


See Sections 2101.3; 2104 and 2106.1.12.4, Item 2, *Uniform Building Code*

**SECTION 21.1011 — SCOPE**

This standard covers cold-drawn steel wire to be used as such or in fabricated form, for the reinforcement as follows:

3–622
SECTION 21.1012 — PROCESS

The steel shall be made by one or more of the following processes: open hearth, electric furnace or basic oxygen.

The wire shall be cold drawn from rods that have been hot rolled from billets.

Unless otherwise specified, the wire shall be “as cold drawn,” except wire smaller than size number W 1.2 for welded fabric, which shall be galvanized at finish size.

SECTION 21.1013 — TENSILE PROPERTIES

The material, except as specified in this section, shall conform to the following tensile property requirements based on nominal area of wire:

- Tensile strength, minimum, psi ............ 80,000 (552 MPa)
- Yield strength, minimum, psi ............ 70,000 (483 MPa)
- Reduction of area, minimum, percent ........ 30

For material testing over 100,000 pounds per square inch (689 MPa) tensile strength, the reduction of area shall not be less than 25 percent.

For material to be used in the fabrication of welded fabric, the following tensile and yield strength properties based on nominal area of wire shall apply:

<table>
<thead>
<tr>
<th>Size Number</th>
<th>Nominal Diameter (inch)</th>
<th>Nominal Area (square inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 31</td>
<td>0.628</td>
<td>0.310</td>
</tr>
<tr>
<td>W 30</td>
<td>0.618</td>
<td>0.300</td>
</tr>
<tr>
<td>W 28</td>
<td>0.597</td>
<td>0.280</td>
</tr>
<tr>
<td>W 26</td>
<td>0.575</td>
<td>0.260</td>
</tr>
<tr>
<td>W 24</td>
<td>0.553</td>
<td>0.240</td>
</tr>
<tr>
<td>W 22</td>
<td>0.529</td>
<td>0.220</td>
</tr>
<tr>
<td>W 20</td>
<td>0.505</td>
<td>0.200</td>
</tr>
<tr>
<td>W 18</td>
<td>0.479</td>
<td>0.180</td>
</tr>
<tr>
<td>W 16</td>
<td>0.451</td>
<td>0.160</td>
</tr>
<tr>
<td>W 14</td>
<td>0.422</td>
<td>0.140</td>
</tr>
<tr>
<td>W 12</td>
<td>0.391</td>
<td>0.120</td>
</tr>
<tr>
<td>W 10</td>
<td>0.357</td>
<td>0.100</td>
</tr>
<tr>
<td>W 8</td>
<td>0.319</td>
<td>0.080</td>
</tr>
<tr>
<td>W 6</td>
<td>0.276</td>
<td>0.060</td>
</tr>
<tr>
<td>W 5.5</td>
<td>0.265</td>
<td>0.055</td>
</tr>
<tr>
<td>W 5</td>
<td>0.252</td>
<td>0.050</td>
</tr>
<tr>
<td>W 4.5</td>
<td>0.239</td>
<td>0.045</td>
</tr>
<tr>
<td>W 4</td>
<td>0.226</td>
<td>0.040</td>
</tr>
<tr>
<td>W 3.5</td>
<td>0.211</td>
<td>0.035</td>
</tr>
<tr>
<td>W 2.9</td>
<td>0.192</td>
<td>0.029</td>
</tr>
<tr>
<td>W 2.5</td>
<td>0.178</td>
<td>0.025</td>
</tr>
<tr>
<td>W 2</td>
<td>0.160</td>
<td>0.020</td>
</tr>
<tr>
<td>W 1.4</td>
<td>0.134</td>
<td>0.014</td>
</tr>
<tr>
<td>W 1.2</td>
<td>0.124</td>
<td>0.012</td>
</tr>
<tr>
<td>W 0.5</td>
<td>0.080</td>
<td>0.005</td>
</tr>
</tbody>
</table>

The yield strength shall be determined at an extension of 0.005 inch per inch (0.005 mm per mm) of gage length.
The material shall not exhibit a definite yield point as evidenced by a distinct drop of the beam or halt in the gage of the testing machine prior to reaching ultimate tensile load.

SECTION 21.1014 — BENDING PROPERTIES

The bend test specimen shall stand being bent cold through 180 degrees without cracking on the outside of the bent portion, as follows:

<table>
<thead>
<tr>
<th>SIZE NUMBER OF WIRE</th>
<th>BEND TEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 7 and smaller</td>
<td>Bend around a pin, the diameter of which is equal to the diameter of the specimen.</td>
</tr>
<tr>
<td>Larger than W 7</td>
<td>Bend around a pin, the diameter of which is equal to twice the diameter of the specimen.</td>
</tr>
</tbody>
</table>

SECTION 21.1015 — TEST SPECIMENS

Tension and bend test specimens shall be of the full section of the wire and shall be obtained from ends of wire coils.

SECTION 21.1016 — NUMBER OF TESTS

One tension test and one bend test shall be made from each 10 tons (89 kN) or less of each size of wire or fraction thereof in a lot, or a total of seven samples, whichever is less. A lot shall consist of all the coils of a single size offered for delivery at the same time.

If any test specimen shows imperfections or develops flaws, it may be discarded and another specimen substituted.

SECTION 21.1017 — PERMISSIBLE VARIATIONS IN WIRE DIAMETER

The permissible variation in the diameter of the wire shall conform to the following:

<table>
<thead>
<tr>
<th>SIZE NUMBER OF WIRE</th>
<th>PERMISSIBLE VARIATION PLUS AND MINUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smaller than W 5</td>
<td>0.003</td>
</tr>
<tr>
<td>W 5 to W 12, inclusive</td>
<td>0.004</td>
</tr>
<tr>
<td>Over W 12 to W 20, inclusive</td>
<td>0.006</td>
</tr>
<tr>
<td>Over W 20</td>
<td>0.008</td>
</tr>
</tbody>
</table>

The difference between the maximum and minimum diameter, as measured on any given cross section of the wire, shall be more than the tolerances shown above for the given wire size.

SECTION 21.1018 — FINISH

The wire shall be free from injurious imperfections and shall have a workmanlike finish with smooth surface.

Galvanized wire shall be completely covered in a workmanlike manner with a zinc coating.
UNIFORM BUILDING CODE STANDARD 21-11
CEMENT, MASONRY


See Section 2102.2, Item 2 and Table 21-A, Uniform Building Code

SECTION 21.1101 — SCOPE

This standard covers three types of masonry cement for use in masonry mortars.

SECTION 21.1102 — CLASSIFICATIONS

21.1102.1 General. Masonry cement complying with this standard shall be classified as one of the types set forth in this section.

21.1102.2 Type N. Type N cement is for use as the cementitious material in the preparation of U.B.C. Standard 21-15 Type N and Type O mortars. It is for use in combination with portland or blended hydraulic cements in the preparation of Type S or Type M mortars.

21.1102.3 Type S. Type S cement is for use as the cementitious material in the preparation of U.B.C. Standard 21-15 Type S mortar.

21.1102.4 Type M. Type M cement is for use as the cementitious material in the preparation of U.B.C. Standard 21-15 Type M mortar.

SECTION 21.1103 — PHYSICAL REQUIREMENTS

Masonry cement shall conform to the requirements set forth in Table 21-11-A for its classifications.

SECTION 21.1104 — PACKAGE LABELING

Masonry cement packages shall carry a statement indicating that the product conforms to requirements of this standard and shall include the brand, name of manufacturer, type of masonry cement and net weight of the package in pounds.

SECTION 21.1105 — CERTIFICATION

Certification shall be submitted upon request of the building official and shall certify compliance with the requirements of this standard.

SECTION 21.1106 — SAMPLING AND TESTING

Every 90 days, each masonry cement producer shall retain an approved agency to obtain a random sample from a local point of supply in the market area served by the producer.

The agency shall test the masonry cement for compliance with the physical requirements of Table 21-11-A.

Upon request of the building official, the producer shall furnish (at no cost) test results to the building official, architect, structural engineer, general contractor and masonry contractor.

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SECTION 21.1107 — TEMPERATURE AND HUMIDITY
The temperature of the air in the vicinity of the mixing slab and dry materials, molds, base plates and mixing bowl shall be maintained between 68°F. and 81.5°F. (20°C. and 27.5°C.). The temperature of the mixing water, moist cabinet or moist room, and water in the storage tank shall not vary from 73.4°F. (23°C.) by more than 3°F. (1.7°C.). The relative humidity of the laboratory air shall not be less than 50 percent. The moist cabinet or moist room atmosphere shall have a relative humidity of not less than 90 percent. The moist cabinet or moist room shall conform to applicable standards.

SECTION 21.1108 — FINENESS
The fineness of the cement shall be determined from the residue on the No. 325 (45 μm) sieve.

SECTION 21.1109 — NORMAL CONSISTENCY
Determine normal consistency by the Vicat apparatus.

SECTION 21.1110 — AUTOCLAVE EXPANSION
The autoclave expansion shall be determined. After molding, store the bars in the moist cabinet or room for 48 hours ± 30 minutes before removal from the molds for measurement and test in the autoclave. Calculate the difference in the lengths of the test specimen before and after autoclaving to the nearest 0.01 percent of the effective gage length and report as the autoclave expansion of the masonry cement.

SECTION 21.1111 — TIME OF SETTING
The time of setting shall be determined by the Gillmore needle method.

SECTION 21.1112 — DENSITY
The density of the masonry cement shall be determined by using kerosene as the liquid. Use the density so determined in the calculation of the air content of the mortars.

SECTION 21.1113 — APPARATUS FOR MORTAR TESTS
The apparatus for mortar tests shall be in accordance with applicable standards.

SECTION 21.1114 — BLENDED SAND
The sand shall be a blend of equal parts by weight of graded standard sand and Standard 20-30 sand.

SECTION 21.1115 — PREPARATION OF MORTAR
21.1115.1 Proportions for Mortar. Mortar for air entrainment, compressive strength and water-retention tests shall be proportioned to contain the weight of cement, in grams, equal to six times the printed bag weight in pounds (13.228 times the printed bag weight in kilograms) and 1,440 grams of sand. The sand shall consist of 720 grams of graded Ottawa sand and 720 grams of Standard 20-30 sand. The quantity of water, measured in milliliters, shall be such as to produce a flow of 110 ± 5 as determined by the flow table.
21.1115.2 Mixing of Mortars. The mortar shall be mixed in accordance with the applicable standards.

21.1115.3 Determination of Flow. The flow shall be determined in accordance with applicable standards.

SECTION 21.1116 — AIR ENTRAINMENT

21.1116.1 Procedure. If the mortar has the correct flow, use a separate portion of the mortar for the determination of entrained air. Determine the mass of 400 ml of the mortar.

21.1116.2 Calculation. Calculate the air content of the mortar and report it to the nearest 0.1 percent as follows:

\[
D = \left( \frac{W_1 + W_2 + V_w}{S_1} \right) \left( \frac{W_1}{S_1} + \frac{W_2}{S_2} + V_w \right)
\]

\[
A = 100 - \left( \frac{W_n}{4D} \right)
\]

WHERE:

- \(A\) volume percent of entrained air.
- \(D\) density of air-free mortar, g/ml.
- \(S_1\) density of cement, g/ml.
- \(S_2\) density of standard sand, 2.65 g/ml.
- \(V_w\) milliliters-grams of water used.
- \(W_n\) mass of 400 ml.
- \(W_1\) mass of cement, g.
- \(W_2\) mass of sand, g.

SECTION 21.1117 — COMPRRESSIVE STRENGTH

21.1117.1 Test Specimens.

21.1117.1.1 Molding. Immediately after determining the flow and the mass of 400 ml of mortar, return all the mortar to the mixing bowl and remix for 15 seconds at the medium speed. Then mold test specimens in accordance with applicable standards, except that elapsed time for mixing mortar, determining flow, determining air entrainment and starting the molding of cubes shall be within eight minutes.

21.1117.1.2 Storage. Store all test specimens immediately after molding in the molds on plane plates in a moist cabinet or moist room for 48 to 52 hours, in such a manner that the upper surfaces shall be exposed to the moist air. Then remove the cubes from the molds and place in the moist cabinet or moist room for five days in such a manner as to allow free circulation of air around at least five faces of the specimens. At the age of seven days, immerse the cubes for the 28-day tests in saturated lime water in storage tanks of noncorrodible materials.

21.1117.2 Procedure. Test the cube specimens immediately after their removal from the moist cabinet or moist room for seven-day specimens, and immediately after their removal from storage water for all other specimens. If more than one specimen at a time is removed from the moist cabinet or moist room for seven-day tests, cover these cubes with a damp cloth until time of testing. If more than one specimen at a time is removed from the storage water for testing, place these cubes in a pan of water at a temperature of 73.4°F ± 3°F (23°C ± 1.7°C), and of sufficient depth to completely immerse each cube until time of testing.

The remainder of the testing procedure shall conform to applicable standards.

SECTION 21.1118 — WATER RETENTION

21.1118.1 Apparatus. The water-retention test shall conform to applicable standards.
21.1118.2 Procedure. Adjust the mercury relief column to maintain a vacuum of 51 ± 3 mm as indicated by the manometer. Seat the perforated dish on the greased gasket or greased rim of the funnel. Place a wetted filter paper in the bottom of the dish. Turn the stopcock to apply the vacuum to the funnel and check the apparatus for leaks and to determine that the required vacuum is obtained. Then turn the stopcock to shut off the vacuum from the funnel.

Mix the mortar to a flow of 110 ± 5 percent in accordance with applicable standards. Immediately after making the flow test, return the mortar on the flow table to the mixing bowl and remix the entire batch for 15 seconds at medium speed. Immediately after remixing the mortar, fill the perforated dish with the mortar to slightly above the rim. Tamp the mortar 15 times with the tamper. Apply 10 of the tamping strokes at approximately uniform spacing adjacent to the rim of the dish and with the long axis of the tamping face held at right angles to the radius of the dish. Apply the remaining five tamping strokes at random points distributed over the central area of the dish. The tamping pressure shall be just sufficient to ensure filling of the dish. On completion of the tamping, the top of the mortar will extend slightly above the rim of the dish. Smooth off the mortar by drawing the flat side of the straightedge (with the leading edge slightly raised) across the top of the dish. Then cut off the mortar to a plane surface flush with the rim of the dish by drawing the straightedge with a sawing motion across the top of the dish in two cutting strokes, starting each cut from near the center of the dish. If the mortar is pulled away from the side of the dish during the process of drawing the straightedge across the dish, gently press the mortar back into contact with the side of the dish using the tamper.

Turn the stopcock to apply the vacuum to the funnel. The time elapsed from the start of mixing the cement and water to the time of applying the vacuum shall not exceed eight minutes. After suction for 60 seconds, quickly turn the stopcock to expose the funnel to atmospheric pressure. Immediately slide the perforated dish off from the funnel, touch it momentarily on a damp cloth to remove droplets of water, and set the dish on the table. Then, using the bowl scraper, plow and mix the mortar in the dish for 15 seconds. Upon completion of mixing, place the mortar in the flow mold and determine the flow. The entire operation shall be carried out without interruption and as quickly as possible, and shall be completed within an elapsed time of 11 minutes after the start of mixing the cement and water for the first flow determination. Both flow determinations shall be made in accordance with applicable standards.

21.1118.3 Calculation. Calculate the water-retention value for the mortar as follows:

Water-retention value = \((A/B) \times 100\)

WHERE:

\(A\) = flow after suction.
\(B\) = flow immediately after mixing.
### TABLE 21-11-A—PHYSICAL REQUIREMENTS

<table>
<thead>
<tr>
<th>MASONRY CEMENT TYPE</th>
<th>N</th>
<th>S</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fineness, residue on a No. 325 (45 μm) sieve, maximum percent</td>
<td>24</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Soundness:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autoclave expansion, maximum, percent</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Time of setting, Gillmore method:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial set, minimum, hour</td>
<td>2</td>
<td>1 1/2</td>
<td>1 1/2</td>
</tr>
<tr>
<td>Final set, maximum, hour</td>
<td>24</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Compressive strength (average of 3 cubes):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial compressive strength of mortar cubes, composed of 1 part cement and 3 parts blended sand (half Graded Ottawa sand, and half Standard 20-30 Ottawa sand) by volume, prepared and tested in accordance with this specification shall be equal to or higher than the values specified for the ages indicated below:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 days, psi</td>
<td>500 (3445 kPa)</td>
<td>1300 (8957 kPa)</td>
<td>1800 (12 402 kPa)</td>
</tr>
<tr>
<td>28 days, psi</td>
<td>900 (6201 kPa)</td>
<td>2100 (14 469 kPa)</td>
<td>2900 (19 981 kPa)</td>
</tr>
<tr>
<td>Air content of mortar:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum percent by volume</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Maximum percent by volume</td>
<td>22</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Water retention, flow after suction, minimum, percent of original flow</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
</tbody>
</table>
UNIFORM BUILDING CODE STANDARD 21-12
QUICKLIME FOR STRUCTURAL PURPOSES

See Section 2102.2, Item 3, Uniform Building Code

SECTION 21.1201 — SCOPE
This standard covers all classes of quicklime, such as crushed lime, granular lime, ground lime, lump lime, pebble lime and pulverized lime, used for structural purposes.

SECTION 21.1202 — GENERAL REQUIREMENTS
Quicklime shall be slaked and aged in accordance with the printed directions of the manufacturer. The resulting lime putty shall be stored until cool.

SECTION 21.1203 — CHEMICAL COMPOSITION
The quicklime shall conform to the following requirements as to chemical composition, calculated to the nonvolatile basis:

<table>
<thead>
<tr>
<th>Component</th>
<th>Calcium</th>
<th>Magnesium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium oxide, minimum, percent</td>
<td>75</td>
<td>—</td>
</tr>
<tr>
<td>Magnesium oxide, minimum, percent</td>
<td>—</td>
<td>20</td>
</tr>
<tr>
<td>Calcium and magnesium oxides, minimum, percent</td>
<td>95</td>
<td>95</td>
</tr>
<tr>
<td>Silica, alumina, and oxide of iron, maximum, percent</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Carbon dioxide, maximum, percent:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If sample is taken at the place of manufacture</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>If sample is taken at any other place</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

SECTION 21.1204 — RESIDUE
The quicklime shall not contain more than 15 percent by weight of residue.

SECTION 21.1205 — QUALITY CONTROL
Every 90 days, each lime producer shall retain an approved agency to obtain a random sample from a local point of supply in the market area served by the producer.

The agency shall test the lime for compliance with the physical requirements of Section 21.1204.

Upon request of the building official, the producer shall furnish (at no cost) test results to the building official, architect, structural engineer, general contractor and masonry contractor.
UNIFORM BUILDING CODE STANDARD 21-13
HYDRATED LIME FOR MASONRY PURPOSES

See Section 2102.2, Item 3, Uniform Building Code

SECTION 21.1301 — SCOPE
This standard covers four types of hydrated lime. Types N and S are suitable for use in mortar, in the scratch and brown coats of cement plaster, for stucco, and for addition to portland-cement concrete. Types NA and SA are air-entrained hydrated limes that are suitable for use in any of the above uses where the inherent properties of lime and air entrainment are desired. The four types of lime sold under this specification shall be designated as follows:

Type N—Normal hydrated lime for masonry purposes.
Type S—Special hydrated lime for masonry purposes.
Type NA—Normal air-entraining hydrated lime for masonry purposes.
Type SA—Special air-entraining hydrated lime for masonry purposes.

NOTE: Type S, special hydrated lime, and Type SA, special air-entraining hydrated lime, are differentiated from Type N, normal hydrated lime, and Type NA, normal air-entraining hydrated lime, principally by their ability to develop high, early plasticity and higher water retentivity and by a limitation on their unhydrated oxide content.

SECTION 21.1302 — DEFINITION
HYDRATED LIME. The hydrated lime covered by Type N or S in this standard shall contain no additives for the purpose of entraining air. The air content of cement-lime mortars made with Type N or S shall not exceed 7 percent. Types NA and SA shall contain an air-entraining additive as specified by Section 21.1305. The air content of cement-lime mortars made with Type NA or SA shall have a minimum of 7 percent and a maximum of 14 percent.

SECTION 21.1303 — ADDITIONS
Types NA and SA hydrated lime covered by this standard shall contain additives for the purpose of entraining air.

SECTION 21.1304 — MANUFACTURER’S STATEMENT
Where required, the nature, amount and identity of the air-entraining agent used and of any processing addition that may have been used shall be provided, as well as test data showing compliance of such air-entraining addition.

SECTION 21.1305 — CHEMICAL REQUIREMENTS COMPOSITION
Hydrated lime for masonry purposes shall conform to the requirements as to chemical composition set forth in Table 21-13-A.
TABLE 21-13-A—CHEMICAL REQUIREMENTS

<table>
<thead>
<tr>
<th>HYDRATE TYPES</th>
<th>N</th>
<th>NA</th>
<th>S</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium and magnesium oxides (nonvolatile basis), min. percent</td>
<td>95</td>
<td>95</td>
<td>95</td>
<td>95</td>
</tr>
<tr>
<td>Carbon dioxide (as-received basis), max. percent</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>If sample is taken at place of manufacture</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>If sample is taken at any other place</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Unhydrated oxides (as-received basis), max. percent</td>
<td>—</td>
<td>—</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

SECTION 21.1306 — RESIDUE, POPPING AND PITTING
The four types of hydrated lime for masonry purposes shall conform to one of the following requirements:
1. The residue retained on a No. 30 (600 μm) sieve shall not be more than 0.5 percent, or
2. If the residue retained on a No. 30 (600 μm) sieve is over 0.5 percent, the lime shall show no pops and pits when tested.

SECTION 21.1307 — PLASTICITY
The putty made from Type S, special hydrate, or Type SA, special air-entraining hydrate, shall have a plasticity figure of not less than 200 within 30 minutes after mixing with water, when tested.

SECTION 21.1308 — WATER RETENTION
Hydrated lime mortar made with Type N, normal hydrated lime, or Type NA, normal air-entraining hydrated lime, after suction for 60 seconds, shall have a water-retention value of not less than 75 percent when tested in a standard mortar made from the dry hydrate or from putty made from the hydrate which has been soaked for a period of 16 to 24 hours.

Hydrated lime mortar made with Type S, special hydrated lime, or Type SA, special air-entraining hydrated lime, after suction for 60 seconds, shall have a water-retention value of not less than 85 percent when tested in a standard mortar made from the dry hydrate.

SECTION 21.1309 — SPECIAL MARKING
When Type NA or SA air-entraining hydrated lime is delivered in packages, the type under this standard and the words “air-entraining” shall be plainly indicated thereon or, in case of bulk shipments, so indicated on shipping notices.

SECTION 21.1310 — QUALITY CONTROL
Every 90 days, each lime producer shall retain an approved agency to obtain a random sample from a local point of supply in the market area served by the producer.

The agency shall test the lime for compliance with the physical requirements of Sections 21.1306, 21.1307 and 21.1308.

Upon request of the building official, the producer shall furnish (at no cost) test results to the building official, architect, structural engineer, general contractor and masonry contractor.
UNIFORM BUILDING CODE STANDARD 21-14
MORTAR CEMENT
Test Standard of the International Conference of Building Officials
See Section 2102.2, Item 2, Uniform Building Code

SECTION 21.1401 — SCOPE
This standard covers mortar cement for use in masonry mortars.

SECTION 21.1402 — CLASSIFICATIONS
There are three types of mortar cement:
1. Type N. For use as the cementitious material in the preparation of U.B.C. Standard 21-15 Type N and Type O mortars. For use in combination with portland or blended hydraulic cements in the preparation of Type S or Type M mortars.
2. Type S. For use as the cementitious material in the preparation of U.B.C. Standard 21-15 Type S mortar.
3. Type M. For use as the cementitious material in the preparation of U.B.C. Standard 21-15 Type M mortar.

SECTION 21.1403 — PHYSICAL REQUIREMENTS
Mortar cement shall conform to the requirements set forth in Table 21-14-A for its classifications.

SECTION 21.1404 — CONSTITUENT MATERIALS
Upon request of the building official, the constituent materials shall be provided to the building official and engineer of record.

SECTION 21.1405 — RESTRICTED MATERIALS
Materials used in mortar cement shall conform to the requirements set forth in Table 21-14-B.

SECTION 21.1406 — DELETERIOUS MATERIAL
Materials listed in Table 21-14-C shall not be used in mortar cement.

SECTION 21.1407 — PACKAGE LABELING
Mortar cement packages shall carry a statement indicating that the product conforms to requirements of this standard and shall include the brand, name of manufacturer, type of mortar cement and net weight of the package in pounds.

SECTION 21.1408 — CERTIFICATION
Certification shall be submitted upon request of the building official and shall certify compliance with the requirements of this standard.

SECTION 21.1409 — SAMPLING AND TESTING
Every 90 days, each mortar cement producer shall retain an approved agency to obtain a random sample from a local point of supply in the market area served by the producer.
The agency shall test the mortar cement for compliance with the physical requirements of Table 21-14-A.

Upon request of the building official, the producer shall furnish (at no cost) test results to the building official, architect, structural engineer, general contractor and masonry contractor.

SECTION 21.1410 — TEMPERATURE AND HUMIDITY

The temperature of the air in the vicinity of the mixing slab and dry materials, molds, base plates and mixing bowl shall be maintained between 68°F and 81.5°F (20°C and 27.5°C). The temperature of the mixing water, moist cabinet or moist room, and water in the storage tank shall not vary from 73.4°F (23°C) by more than 3°F (1.7°C).

The relative humidity of the laboratory air shall not be less than 50 percent. The moist cabinet or moist room atmosphere shall have a relative humidity of not less than 90 percent.

The moist cabinet or moist room shall conform to applicable standards.

SECTION 21.1411 — FINENESS

Determine the residue on the No. 325 (45 μm) sieve.

SECTION 21.1412 — NORMAL CONSISTENCY

Determine normal consistency by the Vicat apparatus.

SECTION 21.1413 — AUTOCLAVE EXPANSION

Determine autoclave expansion. After molding, store bars in the moist cabinet or room for 48 hours, plus or minus 30 minutes, before removal from the molds for measurement and test in the autoclave. Calculate the difference in length of the test specimen before and after autoclaving to the nearest 0.01 percent of the effective gauge length and report as the autoclave expansion of the mortar cement.

SECTION 21.1414 — TIME OF SETTING

Determine the time of setting by the Gillmore needle method.

SECTION 21.1415 — DENSITY

Determine the density of the mortar cement using kerosene as the liquid. Use the density so determined in the calculation of the air content of the mortars.

SECTION 21.1416 — APPARATUS FOR MORTAR TESTS

Apparatus shall be in accordance with applicable standards.

SECTION 21.1417 — BLENDED SAND

The sand shall be a blend of equal parts by weight of graded Ottawa sand and Standard 20-30 Ottawa sand.

SECTION 21.1418 — PREPARATION OF MORTAR

21.1418.1 Proportions for Mortar. Mortar for air entrainment, compressive strength and water-retention tests shall be proportioned to contain the weight of cement, in grams, equal to six times the...
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21.1418.2 Mixing of Mortars. Mix the mortar in accordance with applicable standards.

21.1418.3 Determination of Flow. Determine the flow in accordance with applicable standards.

SECTION 21.1419 — AIR ENTRAINMENT

21.1419.1 Procedure. If the mortar has the correct flow, use a separate portion of the mortar for the determination of entrained air. Determine the weight of 400 cm³ of mortar.

21.1419.2 Calculation. Calculate the air content of the mortar and report it to the nearest 0.1 percent as follows:

\[
A = 100 - \left( \frac{W_m}{4D} \right)
\]

WHERE:

- \( A \) = volume percent of entrained air.
- \( D \) = density of air-free mortar, g/cm³.
- \( S_1 \) = density of cement, g/cm³.
- \( S_2 \) = density of standard sand, 2.65 g/cm³.
- \( V_w \) = milliliters-grams of water used.
- \( W_m \) = mass of 400 ml of mortar, g.
- \( W_1 \) = weight of cement, g.
- \( W_2 \) = weight of sand, g.

SECTION 21.1420 — COMPRRESSIVE STRENGTH OF TEST SPECIMENS

21.1420.1 Molding. Immediately after determining the flow and the weight of 400 cm³ of mortar, return all the mortar to the mixing bowl and remix for 15 seconds at the medium speed. Then mold test specimens in accordance with applicable standards, except that the elapsed time for mixing mortar, determining flow, determining air entrainment and starting the molding of cubes shall be within eight minutes.

21.1420.2 Storage. Store all test specimens immediately after molding in the molds on plane plates in a moist cabinet maintained at a relative humidity of 90 percent or more for 48 to 52 hours in such a manner that the upper surfaces shall be exposed to the moist air. Then remove the cubes from the molds and place in the moist cabinet for five days in such a manner as to allow free circulation of air around at least five faces of the specimen. At the age of seven days, immerse the cubes for the 28-day tests in saturated lime water in storage tanks of noncorrosible materials.

SECTION 21.1421 — PROCEDURE

Test the cube specimens immediately after their removal from the moist cabinet for seven-day specimens, and immediately after their removal from storage water for all other specimens. If more than one specimen at a time is removed from the moist closet for seven-day tests, cover these cubes with a damp cloth until time of testing. If more than one specimen at a time is removed from the storage water for testing, place these cubes in a pan of water at a temperature of 73.4°F ± 3°F. (23°C. ± 1.7°C.), and of sufficient depth to completely immerse each cube until time of testing.
The remainder of the testing procedure shall conform to applicable standards.

SECTION 21.1422 — WATER RETENTION

21.1422.1 Water-retention Apparatus. For the water-retention test, and apparatus essentially the same as that shown in Figure 21-14-1 shall be used. This apparatus consists of a water aspirator or other source of vacuum controlled by a mercury-relief column and connected by way of a three-way stopcock to a funnel upon which rests a perforated dish. The perforated dish shall be made of metal not attacked by masonry mortar. The metal in the base of the dish shall have a thickness of 1.7 to 1.9 mm and shall conform to the requirements given in Figure 21-14-1. The bore of the stopcock shall have a 4 mm plus or minus 0.5 mm diameter, and the connecting glass tubing shall have a minimum inside diameter of 4 mm. A mercury manometer, connected as shown in Figure 21-14-1, indicates the vacuum. The contact surface of the funnel and perforated dish shall be plane and shall be lapped to ensure intimate contact. An airtight seal shall be maintained between the funnel and the dish during a test. This shall be accomplished by either of the following procedures: (1) a synthetic (grease-resistant) rubber gasket may be permanently sealed to the top of the funnel, using petrolatum or light grease to ensure a seal between the funnel and dish, or (2) the top of the funnel may be lightly coated with petrolatum or light grease to ensure a seal between the funnel and dish. Care should be taken to ensure that none of the holes in the perforated dish are clogged from the grease. Hardened, very smooth, not rapid filter paper shall be used. It shall be of such diameter that it will lie flat and completely cover the bottom of the dish.

A steel straightedge not less than 8 inches (203 mm) long and not less than $\frac{1}{16}$ inch (1.6 mm) nor more than $\frac{1}{8}$-inch (3.2 mm) thickness shall be used.

Other apparatus required for the water-retention tests shall conform to the applicable requirements of Section 21.1416.

21.1422.2 Procedure. Adjust the mercury-relief column to maintain a vacuum of 50.8 mm as measured on the manometer. Seat the perforated dish on the greased gasket of the funnel. Place a wetted filter paper in the bottom of the dish. Turn the stopcock to apply the vacuum to the funnel and check the apparatus for leaks and to determine that the required vacuum is obtained. Then turn the stopcock to shut off the vacuum from the funnel.

Mix the mortar to a flow of 110 plus or minus 5 percent in accordance with applicable standards. Immediately after making the flow test, return the mortar on the flow table to the mixing bowl and remix the entire batch for 15 seconds at medium speed. Immediately after remixing the mortar, fill the perforated dish with the mortar to slightly above the rim. Tamper the mortar 15 times with the tamper. Apply 10 of the tamping strokes at approximately uniform spacing adjacent to the rim of the dish and with the long axis of the tamping face held at right angles to the radius of the dish. Apply the remaining five tamping strokes at random points distributed over the central area of the dish. The tamping pressure shall be just sufficient to ensure filling of the dish. On completion of the tamping, the top of the mortar should extend slightly above the rim of the dish. Smooth off the mortar by drawing the flat side of the straightedge (with the leading edge slightly raised) across the top of the dish. Then cut off the mortar to a plane surface flush with the rim of the dish by drawing the straightedge with a sawing motion across the top of the dish in two cutting strokes, starting each cut from near the center of the dish. If the mortar is pulled away from the side of the dish during the process of drawing the straightedge across the dish, gently press the mortar back into contact with the side of the dish using the tamper.

Turn the stopcock to apply the vacuum to the funnel. The time elapsed from the start of mixing the cement and water to the time of applying the vacuum shall not exceed eight minutes. After suction for 60 seconds, quickly turn the stopcock to expose the funnel to atmospheric pressure. Immediately slide the perforated dish off from the funnel, touch it momentarily on a damp cloth to remove droplets of water, and set the dish on the table. Then, using the bowl scraper, in accordance with applicable standards, plow and mix the mortar in the dish for 15 seconds. Upon completion of mix-
ing, place the mortar in the flow mold and determine the flow. The entire operation shall be carried out without interruption and as quickly as possible, and shall be completed within an elapsed time of 11 minutes after the start of mixing the cement and water for the first flow determination. Both flow determinations shall be made in accordance with applicable standards.

21.1422.3 Calculation. Calculate the water-retention value for the mortar as follows:

\[
\text{Water-retention value} = \left( \frac{a}{b} \right) \times 100
\]

WHERE:

\[a\] = flow after suction.
\[b\] = flow immediately after mixing.

### TABLE 21-14-A—PHYSICAL REQUIREMENTS

<table>
<thead>
<tr>
<th>MORTAR CEMENT TYPE</th>
<th>N</th>
<th>S</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fineness, residue on a No. 325 (45 \mu m) sieve</strong></td>
<td>24</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Maximum percent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Autoclave expansion</strong></td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Maximum, percent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Time of setting, Gillmore method:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial set, minimum, hour</td>
<td>2</td>
<td>1(\frac{1}{2})</td>
<td>1(\frac{1}{2})</td>
</tr>
<tr>
<td>Final set, maximum, hour</td>
<td>24</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td><strong>Compressive strength(^1)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 days, minimum psi</td>
<td>500 (3445 kPa)</td>
<td>1300 (8957 kPa)</td>
<td>1800 (12 402 kPa)</td>
</tr>
<tr>
<td>28 days, minimum psi</td>
<td>900 (6201 kPa)</td>
<td>2100 (14 469 kPa)</td>
<td>2900 (19 981 kPa)</td>
</tr>
<tr>
<td><strong>Flexural bond strength(^2)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28 days, minimum psi</td>
<td>71 (489 kPa)</td>
<td>104 (717 kPa)</td>
<td>116 (799 kPa)</td>
</tr>
<tr>
<td><strong>Air content of mortar</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum percent by volume</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Maximum percent by volume</td>
<td>16</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td><strong>Water retention</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum, percent</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
</tbody>
</table>

\(^1\)Compressive strength shall be based on the average of three mortar cubes composed of one part mortar cement and three parts blended sand (one half graded Ottawa sand, and one half Standard 20-30 Ottawa sand) by volume and tested in accordance with this standard.

\(^2\)Flexural bond strength shall be determined in accordance with U.B.C. Standard 21-20.

### TABLE 21-14-B

<table>
<thead>
<tr>
<th>Material</th>
<th>Maximum Limit (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride salts</td>
<td>0.06</td>
</tr>
<tr>
<td>Carboxylic acids</td>
<td>0.25</td>
</tr>
<tr>
<td>Sugars</td>
<td>1.00</td>
</tr>
<tr>
<td>Glycols</td>
<td>1.00</td>
</tr>
<tr>
<td>Lignin and derivatives</td>
<td>0.50</td>
</tr>
<tr>
<td>Stearates</td>
<td>0.50</td>
</tr>
<tr>
<td>Fly ash</td>
<td>No limit</td>
</tr>
<tr>
<td>Clay (except fireclay)</td>
<td>5.00</td>
</tr>
</tbody>
</table>
TABLE 21-14-C
DELETERIOUS MATERIALS NOT PERMITTED IN MORTAR CEMENT

| Epoxy resins and derivatives |
| Phenols                     |
| Asbestos fiber              |
| Fireclays                   |

FIGURE 21-14-1—APPARATUS ASSEMBLY FOR THE WATER-RETENTION TEST
UNIFORM BUILDING CODE STANDARD 21-15
MORTAR FOR UNIT MASONRY AND REINFORCED MASONRY OTHER THAN GYPSUM


See Section 2102.2, Item 8, Uniform Building Code

SECTION 21.1501 — SCOPE

These specifications cover the required properties of mortars determined by laboratory tests for use in the construction of reinforced brick masonry structures and unit masonry structures. Two alternative specifications are covered as follows:

21.1501.1 Property specifications. Property specifications are those in which the acceptability of the mortar is based on the properties of the ingredients (materials) and the properties (water retention and compressive strength) of samples of the mortar mixed and tested in the laboratory.

21.1501.2 Proportion specifications. Proportion specifications are those in which the acceptability of the mortar is based on the properties of the ingredients (materials) and a definite composition of the mortar consisting of fixed proportions of these ingredients.

Unless data are presented to show that the mortar meets the requirements of the physical property specifications, the proportion specifications shall govern. For field tests of grout and mortars see U.B.C. Standard 21-16.

Property Specifications

SECTION 21.1502 — MATERIALS

21.1502.1 General. Materials used as ingredients in the mortar shall conform to the requirements specified in the pertinent U.B.C. Standards.

21.1502.2 Cementitious Materials. Cementitious materials shall conform to the following specifications:


21.1502.3 Water. Water shall be clean and free of deleterious amounts of acids, alkalies or organic materials.

21.1502.4 Admixtures or Mortar Colors. Admixtures or mortar colors shall not be added to the mortar at the time of mixing unless provided for in the contract specifications and, after the material is so added, the mortar shall conform to the requirements of the property specifications.
Only pure mineral mortar colors shall be used.

21.1502.5 **Antifreeze Compounds.** No antifreeze liquid, salts or other substances shall be used in the mortar to lower the freezing point.

21.1502.6 **Storage of Materials.** Cementitious materials and aggregates shall be stored in such a manner as to prevent deterioration or intrusion of foreign material. Any material that has become unsuitable for good construction shall not be used.

**SECTION 21.1503 — MIXING MORTAR**

Mortar blended on the jobsite shall be mixed for a minimum period of three minutes, with the amount of water required to produce the desired workability, in a drum-type batch mixer. Factory-dry blended mortar shall be mixed with water in a mechanical mixer until workable but not to exceed 10 minutes.

**SECTION 21.1504 — MORTAR**

21.1504.1 **Mortar for Unit Masonry.** Mortar conforming to the proportion specifications shall consist of a mixture of cementitious material and aggregate conforming to the requirements of Section 21.1502, and the measurement and mixing requirements of Section 21.1503, and shall be proportioned within the limits given in Table 21-15-B for each mortar type specified.

21.1504.2 **Mortar for Reinforced Masonry.** In mortar used for reinforced masonry the following special requirements shall be met: Sufficient water has been added to bring the mixture to a plastic state. The volume of aggregate in mortar shall be at least two and one-fourth times but not more than three times the volume of cementitious materials.

21.1504.3 **Aggregate Ratio.** The volume of damp, loose aggregate in mortar used in brick masonry shall be not less than two and one-fourth times or more than three times the total separate volumes of cementitious materials used.

21.1504.4 **Water Retention.** Mortar shall conform to the water retention requirements of Table 21-15-A.

21.1504.5 **Air Content.** Mortar shall conform to the air content requirements of Table 21-15-A.

**SECTION 21.1505 — COMPRESSION STRENGTH**

The average compressive strength of three 2-inch (51 mm) cubes of mortar (before thinning) shall not be less than the strength given in Table 21-15-A for the mortar type specified.

**Proportion Specifications**

**SECTION 21.1506 — MATERIALS**

21.1506.1 **General.** Materials used as ingredients in the mortar shall conform to the requirements of Section 21.1502 and to the requirements of this section.

21.1506.2 **Portland Cement.** Portland cement shall conform to the requirements of U.B.C. Standard 19-1, Part I.

21.1506.3 **Blended Hydraulic Cements.** Blended hydraulic cements of Type IS, IS-A, IP, IP-A, I(PM) or I(PM)-A shall conform to the requirements of U.B.C. Standard 19-1, Part II, when used in lieu of masonry cement.


21.1506.7 Hydrated Lime. Hydrated lime shall conform to either of the two following requirements:

1. The total free (unhydrated) calcium oxide (CaO) and magnesium oxide (MgO) shall not be more than 8 percent by weight (calculated on the as-received basis for hydrates).

2. When the hydrated lime is mixed with portland cement in the proportion set forth in Table 21-15-B, the mixture shall give an autoclave expansion of not more than 0.50 percent.

Hydrated lime intended for use when mixed dry with other mortar ingredients shall have a plasticity figure of not less than 200 when tested 15 minutes after adding water.

21.1506.8 Lime Putty. Lime putty made from either quicklime or hydrated lime shall be soaked for a period sufficient to produce a plasticity figure of not less than 200 and shall conform to either the requirements for limitation on total free oxides of calcium and magnesium or the autoclave test specified for hydrated lime in Section 21.1506.5.

SECTION 21.1507 — MORTAR

Mortar shall consist of a mixture of cementitious materials and aggregate conforming to the requirements specified in Section 21.1504, mixed in one of the proportions shown in Table 21-15-B, to which sufficient water has been added to reduce the mixture to a plastic state.

<table>
<thead>
<tr>
<th>TABLE 21-15-A — PROPERTY SPECIFICATIONS FOR MORTAR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MORTAR</strong></td>
</tr>
<tr>
<td>Cement-lime or mortar cement</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Masonry cement</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

1Laboratory-prepared mortar only.

2Determined in accordance with applicable standards.

3When structural reinforcement is incorporated in cement-lime mortar or mortar-cement mortar, the maximum air content shall be 12 percent.
## TABLE 21-15-B—MORTAR PROPORTIONS FOR UNIT MASONRY

<table>
<thead>
<tr>
<th>MORTAR TYPE</th>
<th>PROPORTIONS BY VOLUME (CEMENTITIOUS MATERIALS)</th>
<th>AGGREGATE MEASURED IN A DAMP LOOSE CONDITION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Portland Cement or Blended Cement</td>
<td>Masonry Cement</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>S</td>
</tr>
<tr>
<td>Cement-lime</td>
<td>M</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>O</td>
<td>1</td>
</tr>
<tr>
<td>Mortar cement</td>
<td>M</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>1/2</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>—</td>
</tr>
<tr>
<td>Masonry cement</td>
<td>M</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>1/2</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>—</td>
</tr>
</tbody>
</table>

1 When plastic cement is used in lieu of portland cement, hydrated lime or putty may be added, but not in excess of one tenth of the volume of cement.
2 Mortar cement conforming to the requirements of U.B.C. Standard 21-11.
3 Mortar cement conforming to the requirements of U.B.C. Standard 21-14.
UNIFORM BUILDING CODE STANDARD 21-16
FIELD TESTS SPECIMENS FOR MORTAR

Test Standard of the International Conference of Building Officials
See Section 2102.2, Item 8, Uniform Building Code

SECTION 21.1601 — FIELD COMPRESSIVE TEST SPECIMEN FOR MORTAR

Spread mortar on the masonry units 1/2 inch to 5/8 inch (13 mm to 16 mm) thick, and allow to stand for one minute, then remove mortar and place in a 2-inch by 4-inch (51 mm by 102 mm) cylinder in two layers, compressing the mortar into the cylinder using a flat-end stick or fingers. Lightly tap mold on opposite sides, level off and immediately cover molds and keep them damp until taken to the laboratory. After 48 hours’ set, have the laboratory remove molds and place them in the fog room until tested in damp condition.

SECTION 21.1602 — REQUIREMENTS

Each such mortar test specimen shall exhibit a minimum ultimate compressive strength of 1,500 pounds per square inch (10 304 kPa).
UNIFORM BUILDING CODE STANDARD 21-17
TEST METHOD FOR COMPRRESSIVE STRENGTH OF MASONRY PRISMS


See Sections 2102.2, Item 6.4; 2105.3.2; and 2105.3.3, Uniform Building Code

SECTION 21.1701 — SCOPE

This standard covers procedures for masonry prism construction, testing and procedures for determining the compressive strength of masonry.

SECTION 21.1702 — CONSTRUCTION OF PRISMS

Prisms shall be constructed on a flat, level base. Masonry units used in the prism shall be representative of the units used in the corresponding construction. Each prism shall be built in an opened moisture-tight bag which is large enough to enclose and seal the completed prism. The orientation of units, where top and bottom cross sections vary due to taper of the cells, or where the architectural surface of either side of the unit varies, shall be the same orientation as used in the corresponding construction. Prisms shall be a single wythe in thickness and laid up in stack bond (see Figure 21-17-1).

The length of masonry prisms may be reduced by saw cutting; however, prisms composed of regular shaped hollow units shall have at least one complete cell with one full-width cross web on either end. Prisms composed of irregular-shaped units shall be cut to obtain a symmetrical cross section as possible. The minimum length of saw-cut prisms shall be 4 inches (102 mm).

Masonry prisms shall be laid in a full mortar bed (mortar bed both webs and face shells). Mortar shall be representative of that used in the corresponding construction. Mortar joint thickness, the tooling of joints and the method of positioning and aligning units shall be representative of the corresponding construction.

Prisms shall be a minimum of two units in height, but the total height shall not be less than 1.3 times the least actual thickness or more than 5.0 times the least actual thickness. Immediately following the construction of the prism, the moisture-tight bag shall be drawn around the prism and sealed.

Where the corresponding construction is to be solid grouted, prisms shall be solid grouted. Grout shall be representative of that used in the corresponding construction. Grout shall be placed not less than one day nor more than two days following the construction of the prism. Grout consolidation shall be representative of that used in the construction. Additional grout shall be placed in the prism after reconsolidation and settlement due to water loss, but prior to the grout setting. Excess grout shall be screeded off level with the top of the prism. Where open-end units are used, additional masonry units shall be used as forms to confine the grout during placement. Masonry unit forms shall be sufficiently braced to prevent displacement during grouting. Immediately following the grouting operation, the moisture-tight bag shall be drawn around the prism and resealed.

Where the corresponding construction is to be partially grouted, two sets of prisms shall be constructed; one set shall be grouted solid and the other set shall not be grouted.

Where the corresponding construction is of multiwythe composite masonry, masonry prisms representative of each wythe shall be built and tested separately.
Prisms shall be left undisturbed for at least two days after construction.

SECTION 21.1703 — TRANSPORTING MASONRY PRISMS
Prior to transporting each prism, strap or clamp the prism together to prevent damage during handling and transportation. Secure prism to prevent jarring, bouncing or falling over during transporting.

SECTION 21.1704 — CURING
Prisms shall remain sealed in the moisture-tight bag until two days prior to testing; the moisture-tight bag shall then be removed and curing continued in laboratory air maintained at a temperature of 75°F ± 15°F (24°C ± 8°C). Prisms shall be tested at 28 days after constructing the prism or at test age designated.

SECTION 21.1705 — PREPARATION FOR TESTING

21.1705.1 Capping the Prism. Cap top and bottom of the prism prior to testing with sulfur-filled capping or with high-strength gypsum plaster capping (such as "Hydrostone" or "Hyprocal White"). Sulfur-filled capping material shall be 40 to 60 percent by weight sulfur, the remainder being ground fireclay or other suitable inert material passing a No. 100 (150 μm) sieve, with or without a plasticizer. Spread the capping material over a level surface which is plane within 0.003 inch (0.076 mm) in 16 inches (406 mm). Bring the surface to be capped into contact with the capping paste; firmly press down the specimen, holding it so that its axis is at right angles to the capping surfaces. The average thickness of the cap shall not exceed 1/8 inch (3.2 mm). Allow caps to age at least two hours before testing.

21.1705.2 Measurement of the Prism. Measure the length and thickness of the prism to the nearest 0.01 inch (0.25 mm) by averaging three measurements taken at the center and quarter points of the height of the specimen. Measure the height of the prism, including caps, to the nearest 0.1 inch (2.54 mm).

SECTION 21.1706 — TEST PROCEDURE

21.1706.1 Test Apparatus. The test machine shall have an accuracy of plus or minus 1.0 percent over the load range. The upper bearing shall be spherically seated, hardened metal block firmly attached at the center of the upper head of the machine. The center of the sphere shall lie at the center of the surface held in its spherical seat, but shall be free to turn in any direction, and its perimeter shall have at least 1/4-inch (6.4 mm) clearance from the head to allow for specimens whose bearing surfaces are not exactly parallel. The diameter of the bearing surface shall be at least 5 inches (127 mm). A hardened metal bearing block may be used beneath the specimen to minimize wear of the lower platen of the machine. The bearing block surfaces intended for contact with the specimen shall have a hardness not less than 60 HRC (620 HB). These surfaces shall not depart from plane surfaces by more than 0.001 inch (0.0254 mm) in any 6-inch (153 mm) dimension. When the bearing area of the spherical bearing block is not sufficient to cover the area of the specimen, a steel plate with surfaces machined to true planes within plus or minus 0.001 inch (0.0254 mm) in any 6-inch (153 mm) dimension, and with a thickness equal to at least the distance from the edge of the spherical bearings to the most distant corner, shall be placed between the spherical bearing block and the capped specimen.

21.1706.2 Installing the Prism in the Test Machine. Wipe clean the bearing faces of the upper and lower platens or bearing blocks and of the test specimen and place the test specimen on the lower platen or bearing block. Align both centroidal axes of the specimen with the center of thrust of the test machine. As the spherically seated block is brought to bear on the specimen, rotate its movable portion gently by hand so that uniform seating is obtained.
21.1706.3 Loading. Apply the load, up one half of the expected minimum load, at any convenient rate, after which adjust the controls of the machine so that the remaining load is applied at a uniform rate in not less than one or more than two minutes.

21.1706.4 Observations. Describe the mode of failure as fully as possible or illustrate crack patterns, spalling, etc., on a sketch, or both. Note whether failure occurred on one side or one end of the prism prior to failure of the opposing side or end of the prism.

SECTION 21.1707 — CALCULATIONS

Calculations of test results shall be as follows:

21.1707.1 Net cross-sectional area. Determine the net cross-sectional area [square inches (mm²)] of solid grouted prisms by multiplying the average measured width dimension [inches (mm)] by the average measured length dimension [inches (mm)]. The net cross-sectional area of ungrouted prisms shall be taken as the net cross-sectional area of masonry units determined from a representative sample of units.

21.1707.2 Masonry prism strength. Determine the compressive strength of each prism [psi (kPa)] by dividing the maximum compressive load sustained [pounds (N)] by the net cross-sectional area of the prism [square inches (mm² × 1,000,000)].

21.1707.3 Compressive strength of masonry. The compressive strength of masonry [psi (kPa)] for each set of prisms shall be the lesser of the average strength of the prisms in the set, or 1.25 times the least prism strength multiplied by the prism height-to-thickness correction factor from Table 21-17-A. Where a set of grouted and nongrouted prisms are tested, the compressive strength of masonry shall be determined for the grouted set and for the nongrouted set separately. Where a set of prisms is tested for each wythe of a multiwythe wall, the compressive strength of masonry shall be determined for each wythe separately.

<table>
<thead>
<tr>
<th>TABLE 21-17-A</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Prisms h/lp</td>
<td>1.30</td>
</tr>
<tr>
<td>Correction factor</td>
<td>0.75</td>
</tr>
</tbody>
</table>

1h/lp—ratio of prism height to least actual lateral dimension of prism.

SECTION 21.1708 — MASONRY PRISM TEST REPORT

The test report shall include the following:

1. Name of testing laboratory and name of professional engineer responsible for the tests.

2. Designation of each prism tested and description of prism, including width, height and length dimensions, mortar type, grout and masonry unit used in the construction.

3. Age of prism at time of test.

4. Maximum compressive load sustained by each prism, net cross-sectional area of each prism and net area compressive strength of each prism.

5. Test observations for each prism in accordance with Section 21.1706.

6. Compressive strength of masonry for each set of prisms.

3-646
UNIFORM BUILDING CODE STANDARD 21-18
METHOD OF SAMPLING AND TESTING GROUT


See Section 2102.2, Item 9; and Table 21-B, Uniform Building Code

SECTION 21.1801 — SCOPE
This method covers procedures for both field and laboratory sampling and compression testing of grout used in masonry construction.

SECTION 21.1802 — APPARATUS
21.1802.1 Maximum-Minimum Thermometer.
21.1802.2 Straightedge. A steel straightedge not less than 6 inches (152.4 mm) long and not less than $\frac{1}{16}$ inch (1.6 mm) in thickness.
21.1802.3 Tamping Rod. A nonabsorbent smooth rod, either round or square in cross section nominally $\frac{3}{4}$ inch (15.9 mm) in dimension with ends rounded to hemispherical tips of the same diameter. The rod shall be a minimum length of 12 inches (304.8 mm).
21.1802.4 Wooden Blocks. Wooden squares with side dimensions equal to one-half the desired grout specimen height, within a tolerance of 5 percent, and of sufficient quantity or thickness to yield the desired grout specimen height, as shown in Figures 21-18-1 and 21-18-2.

Wooden blocks shall be soaked in limewater for 24 hours, sealed with varnish or wax, or covered with an impermeable material prior to use.

SECTION 21.1803 — SAMPLING
21.1803.1 Size of Sample. Grout samples to be used for slump and compressive strength tests shall be a minimum of $\frac{1}{2}$ ft. $^3$ (0.014 m$^3$).
21.1803.2 Field Sample. Take grout samples as the grout is being placed into the wall. Field samples may be taken at any time except for the first and last 10 percent of the batch volume.

SECTION 21.1804 — TEST SPECIMEN AND SAMPLE
21.1804.1 Each grout specimen shall be a square prism, nominally 3 inches (76.2 mm) or larger on the sides and twice as high as its width. Dimensional tolerances shall be within 5 percent of the nominal width selected.
21.1804.2 Three specimens constitute one sample.

SECTION 21.1805 — PROCEDURE
21.1805.1 Select a level location where the molds can remain undisturbed for 48 hours.
21.1805.2 Mold Construction.
21.1805.2.1 The mold space should simulate the grout location in the wall. If the grout is placed between two different types of masonry units, both types should be used to construct the mold.
21.1805.2.2 Form a square prism space, nominally 3 inches (76.2 mm) or larger on each side and twice as high as its width, by stacking masonry units of the same type and moisture condition as those being used in the construction. Place wooden blocks, cut to proper size and of the proper thickness or quantity, at the bottom of the space to achieve the necessary height of specimen. Tolerance on space and specimen dimensions shall be within 5 percent of the specimen width. See Figures 21-18-1 and 21-18-2.

21.1805.2.3 Line the masonry surfaces that will be in contact with the grout specimen with a permeable material, such as paper towel, to prevent bond to the masonry units.

21.1805.3 Measure and record the slump of the grout.

21.1805.4 Fill the mold with grout in two layers. Rod each layer 15 times with the tamping rod penetrating 1/2 inch (12.7 mm) into the lower layer. Distribute the strokes uniformly over the cross section of the mold.

21.1805.5 Level the top surface of the specimen with a straightedge and cover immediately with a damp absorbent material such as cloth or paper towel. Keep the top surface of the sample damp by wetting the absorbent material and do not disturb the specimen for 48 hours.

21.1805.6 Protect the sample from freezing and variations in temperature. Store an indicating maximum-minimum thermometer with the sample and record the maximum and minimum temperatures experienced prior to the time the specimens are placed in the moist room.

21.1805.7 Remove the masonry units after 48 hours. Transport field specimens to the laboratory, keeping the specimens damp and in a protective container.

21.1805.8 Store in a moist room conforming to nationally recognized standards.

21.1805.9 Cap the specimens in accordance with the applicable requirements of U.B.C. Standard 21-17.

21.1805.10 Measure and record the width of each face at midheight. Measure and record the height of each face at midpoint. Measure and record the amount out of plumb at midwidth of each face.

21.1805.11 Test the specimens in a damp condition in accordance with applicable requirements of U.B.C. Standard 21-17.

SECTION 21.1806 — CALCULATIONS

The report shall include the following:

1. Mix design.
2. Slump of the grout.
3. Type and number of units used to form mold for specimens.
4. Description of the specimens—dimensions, amount out of plumb—in percent.
5. Curing history, including maximum and minimum temperatures and age of specimen, when transported to laboratory and when tested.
7. Description of failure.
FIGURE 21-18-1
Grout Mold [Units 6 inches (152.4 mm) or Less In Height, 2\(1/2\) -inch-high (57.2 mm) Brick Shown]

FIGURE 21-18-2
Grout Mold [Units Greater than 6 inches (152.4 mm) In Height, 8-inch-high (203.2 mm) Concrete Masonry Unit Shown]
UNIFORM BUILDING CODE STANDARD 21-19
GROUT FOR MASONRY


See Section 2102.2, Item 8, Uniform Building Code

SECTION 21.1901 — SCOPE
This standard covers grout for use in the construction of reinforced and nonreinforced masonry structures.

SECTION 21.1902 — MATERIALS
Materials used as ingredients in grout shall conform to the following:

21.1902.1 Cementitious Materials. Cementitious materials shall conform to one of the following standards:

B. Blended Cement—Type IS, IS(MS) or IP of U.B.C. Standard 19-1.

21.1902.2 Water. Water shall be clean and potable.

21.1902.3 Admixtures. Additives and admixtures to grout shall not be used unless approved by the building official.

21.1902.4 Antifreeze Compounds. No antifreeze liquids, chloride salts or other substances shall be used in grout.

21.1902.5 Storage of Materials. Cementitious materials and aggregates shall be stored in such a manner as to prevent deterioration or intrusion of foreign material or moisture. Any material that has become unsuitable for good construction shall not be used.

SECTION 21.1903 — MEASUREMENT OF MATERIALS
The method of measuring materials for the grout used in construction shall be such that the specified proportions of the grout materials can be controlled and accurately maintained.

SECTION 21.1904 — GROUT
Grout shall consist of cementitious material and aggregate that have been mixed thoroughly for a minimum of five minutes in a mechanical mixer with sufficient water to bring the mixture to the desired consistency. The grout proportions and any additives shall be based on laboratory or field experience considering the grout ingredients and the masonry units to be used, or the grout shall be proportioned within the limits given in Table 21-B of this code, or the grout shall have a minimum compressive strength when tested in accordance with U.B.C. Standard 21-18 equal to its specified strength, but not less than 2,000 psi (13 800 kPa).

EXCEPTION: Dry mixes for grout which are blended in the factory and mixed at the jobsite shall be mixed in mechanical mixers until workable, but not to exceed 10 minutes.
UNIFORM BUILDING CODE STANDARD 21-20
STANDARD TEST METHOD FOR FLEXURAL
BOND STRENGTH OF MORTAR CEMENT

Test Standard of the International Conference of Building Officials
See Section 2102.2, Item 8, Uniform Building Code, and
U.B.C. Standard 21-14, Table 21-14-A

SECTION 21.2001 — SCOPE
This method covers the laboratory evaluation of the flexural bond strength of a standardized mortar and a standardized masonry unit.

SECTION 21.2002 — APPARATUS
The test apparatus consists of a metal frame designed to support a prism as shown in Figures 21-20-1 and 21-20-2. The prism support system shall be adjustable to support prisms ranging in height from two to seven masonry units. The upper clamping bracket that is clamped to the top masonry unit of the prism shall not come into contact with the lower clamping bracket during the test. An alignment jig, mortar template, and drop hammer as shown in Figures 21-20-3, 21-20-4 and 21-20-5 are used in the fabrication of prism specimens for testing.

SECTION 21.2003 — MATERIALS
21.2003.1 Masonry units used shall be standard masonry units selected for the purpose of determining the flexural bond strength properties of mortar cement mortars. The standard unit shall be in accordance with the following requirements:

1. Dimensions of units shall be 3 5/8 inches (92 mm) wide by 2 1/4 inches (57 mm) high by 7 5/8 inches (194 mm) long within a tolerance of plus or minus 1/8 inch (3.2 mm) and shall be 100 percent solid.

2. The unit material shall be concrete masonry manufactured with the following material proportions by volume:
   One part portland cement to eight parts aggregate

3. Aggregate used in the manufacture of the unit shall be as follows:

   | Gradation                         | 2.6 to 2.7 
   |-----------------------------------|------------
   | Bulk Specific Gravity Percent Retained by Weight |
   | 3/8-inch (9.5 mm) sieve            | 0          |
   | No. 4 (4.75 mm) sieve              | 0 to 5     |
   | No. 8 (2.36 mm) sieve              | 20 to 30   |
   | No. 16 (1.18 mm) sieve             | 15 to 25   |
   | No. 30 (600 μm) sieve              | 5 to 15    |
   | No. 50 (300 μm) sieve              | 5 to 10    |
   | No. 100 (150 μm) sieve             | 5 to 10    |
   | Pan                               | 5 to 10    |

4. Density of the unit shall be 125 to 135 pounds per cubic foot (2000 to 2160 kg/m³).

5. Unit shall be cured in a 100 percent relative humidity environment at 140°F ± 10°F (60°C ± 5.6°C) at atmospheric pressure for 10 to 20 hours. Additional curing, under covered atmospheric conditions, shall continue for at least 28 days. Unit shall be loose stacked in the cube (separated by a 1/4-inch (6.4 mm) gap) to allow air to circulate during drying.

6. At the time of fabricating the prisms, units shall have a moisture content in the range of 25 percent to 35 percent.
7. Upon delivery units shall be stored in the laboratory at normal temperature and humidity. Units shall not be wetted or surface treated prior to or during prism fabrication.

21.2003.2 Mortar. Mortar shall be prepared in accordance with the following:

1. Mortar proportions shall be in accordance with Table 21-20-A. The aggregate shall consist of a blend of one-half graded Ottawa sand and one-half Standard 20-30 Ottawa sand.

2. Mortar materials shall be mixed in a drum-type batch mixer for five minutes.

3. Determine mortar flow in accordance with applicable standards and adjust water until a flow of 125 ± 5 is achieved.

4. Determine mortar density, air content and initial cone penetration immediately after mixing the mortar in accordance with applicable standards. Mortar shall not be used when cone penetration is less than 80 percent of the initial cone penetration value.

SECTION 21.2004 — TEST SPECIMENS

21.2004.1 Number. Test specimens shall consist of one set of six prisms constructed with the mortar cement mortar. Each prism shall be six units in height.

21.2004.2 Prism Construction. (1) Each prism shall be built in an opened moisture-tight bag which is large enough to enclose and seal the completed prism. Set the first unit on a 1/2-inch (13 mm) plywood pallet in an alignment jig as shown in Figure 21-20-3. (2) Place the mortar template shown in Figure 21-20-4 on the unit such that the mortar bed depth prior to compaction is 1/2 inch (13 mm). Place mortar in template and strike off excess mortar with straight edge. (3) Remove template and immediately place the next unit on the mortar bed in contact with the three alignment bolts for that course using a bulls-eye level to assure uniform initial contact of the unit surface and bed mortar. Carefully position drop hammer apparatus shown in Figure 21-20-5 on top of unit and drop its 4-pound (1.81 kg) weight, round end down, once from a height of 1.5 inches (38 mm). (4) Repeat (2) and (3) until the prisms are complete. (5) Joints shall be cut flush after the prism is completely built. Joints shall not be tooled. (6) One hour, ± 15 minutes after completion of construction, place two masonry units of the type used to construct the prism upon the top course. (7) Identify all prisms using a water-resistant marker. (8) Draw and seal the moisture-tight bag around the prism. (9) All prisms should be cured for 28 days. Two days prior to testing remove the moisture-tight bag and continue curing in the laboratory air, maintained at a temperature of 75°F. ± 15°F. (23.9°C. ± 8.3°C.), with a relative humidity between 30 to 70 percent.

SECTION 21.2005 — TEST PROCEDURE

Place the prism vertically in the support frame as shown in Figure 21-20-1 and clamp firmly into a locked position using the lower clamping bracket. Orient the prism so that the face of the joint intended to be subjected to flexural tension is on the same side of the specimen as the clamping screws. The prism shall be positioned at the required elevation that results in a single unit projecting above the lower clamping bracket. A soft bearing material (for example, polystyrene) at least 1/2-inch (13 mm) thick shall be placed between the bottom of the prism and the adjustable prism base support.

Attach the upper clamping bracket to the top unit as shown in Figure 21-20-1. Tighten each clamping bolt using a torque not greater than 20 inch-pounds (2.26 N•m).

Apply the load at a uniform rate so that the total load is applied in not less than one minute or more than three minutes. Measure load to an accuracy of ± 2 percent with maximum error of five pounds (22.2 N).

SECTION 21.2006 — CALCULATIONS

Calculate the modulus of rupture of each mortar joint as follows:
21-20

$\frac{f_r}{bd^2} = \frac{6(PL + P_1 L_1)}{bd^2} \quad \text{For SI:} \quad \frac{f_r}{1000bd^2} = \frac{6(PL + P_1 L_1)}{1000bd^2}$

WHERE:

- $b =$ average width of cross section of failure surface, inches (mm).
- $d =$ average thickness of cross section of failure surface, inches (mm).
- $f_r =$ modulus of rupture, psi (kPa).
- $L =$ distance from center of prism to loading point, inches (mm).
- $L_1 =$ distance from center of prism to centroid of loading arm, inches (mm).
- $P =$ maximum applied load, pounds (N).
- $P_1 =$ weight of loading arm, pounds (N).

The flexural bond strength of mortar shall be determined as the average modulus of rupture of 30 joints minus 1.28 times the standard deviation of the sample which yields a value that will equal or exceed a mortar joint's modulus of rupture nine out of 10 times.

SECTION 21.2007 — REPORT

The report shall include the manufacturer of the mortar cement being evaluated, the source of manufacture, type of mortar cement, date of testing, laboratory name and laboratory personnel.

Report mortar density, air content, flow and cone penetration test data. Report the following data for the mortar cement mortar being evaluated:

<table>
<thead>
<tr>
<th>PRISM NO.</th>
<th>PRISM WEIGHT (lbs.) (kg)</th>
<th>JOINT NO.</th>
<th>TEST LOAD (lbs.) (N)</th>
<th>MOMENT (in.-lbs.) (N•m)</th>
<th>MODULUS OF RUPTURE</th>
<th>$f_r$ (psi) (kPa)</th>
<th>Mean, std. dev. (psi) (kPa)</th>
<th>COV %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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</tbody>
</table>

1Also, report the standard deviation for all six prisms (30 joints).

Report the flexural bond strength (determined in accordance with Section 21.2006) of the mortar cement mortar.

| TABLE 21-20-A—MORTAR PROPORTIONS BY VOLUME FOR EVALUATING FLEXURAL BOND |
|--------------------------------|----------------|----------------------|
| MORTAR | MORTAR CEMENT TYPE | PROPORTIONS |
| Type N | N | 1 | 3 |
| Type S | S | 1 | 3 |
| Type M | M | 1 | 3 |

3-654
FIGURE 21-20-1—BOND WRENCH TEST APPARATUS
FIGURE 21-20-2—DETAIL DRAWINGS OF BOND WRENCH

(Continued)
FIGURE 21-20-2—DETAIL DRAWINGS OF BOND WRENCH—(Continued)

PRISM BASE SUPPORT

(1" = 25.4 mm)

FIGURE 21-20-3—BOND WRENCH JIG WITH PALLET
FIGURE 21-20-4—FIRST BRICK WITH MORTAR TEMPLATE

11/2" Ø x 0'-8" (38 mm Ø x 203 mm), 4#, Rounded one end

19/16" Ø ID x 0'-6\(\frac{1}{2}\)" (39.7 mm Ø x 166 mm)

9\(\frac{1}{2}\)" x 7\(\frac{1}{2}\)" x 3\(\frac{1}{4}\)" (242 x 191 x 19 mm)
PLYWOOD

FIGURE 21-20-5—DROP HAMMER AND GUIDE
UNIFORM BUILDING CODE STANDARD 22-1
MATERIAL SPECIFICATIONS FOR STRUCTURAL STEEL


See Sections 1808.6.1, 1808.7 and 2202, Uniform Building Code, and Section 402.2, Uniform Sign Code

SECTION 22.101 — SCOPE
This standard covers steel and iron shapes, plates, sheet, strip, connectors and bars for use in the construction of buildings and for general structural purposes.

SECTION 22.102 — MATERIAL REQUIREMENTS
The material shall conform to the requirements as to the tensile properties set forth in Table 22-1-A.
<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>GRADE</th>
<th>SPECIFICATION TITLE</th>
<th>SIZE AND PRODUCT LIMITATIONS</th>
<th>TENSILE STRENGTH (ksi)</th>
<th>YIELD POINT (ksi)</th>
<th>REFERENCED ELSEWHERE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A27-61a</td>
<td>60-30</td>
<td>Mild- to medium-strength carbon steel castings</td>
<td>× 25.4 for mm</td>
<td>60</td>
<td>30</td>
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<td>65-35</td>
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<tr>
<td>A36-81a</td>
<td>58-80</td>
<td>Structural steel</td>
<td></td>
<td></td>
<td></td>
<td>U.B.C. Chapter 22, Divisions III and V</td>
</tr>
<tr>
<td>A48-76</td>
<td>Class No.</td>
<td>Gray iron castings</td>
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<tr>
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<td>20 A, B, C and S</td>
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<tr>
<td>A53-82</td>
<td>Type F</td>
<td>Steel pipe, black and hot-dipped, zine-coated, welded and seamless</td>
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<tr>
<td>A (Types E and S)</td>
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<td>B (Types E and S)</td>
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<tr>
<td>A148-81</td>
<td>80-40</td>
<td>High-strength steel casting for structural purposes</td>
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<td>120-95</td>
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<td>150-125</td>
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<td>175-145</td>
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<td>175</td>
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<tr>
<td>A242-81</td>
<td>3/4&quot; thick and under</td>
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<td>70</td>
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<td></td>
<td>Over 3/4&quot; to 11/2&quot;, inclusive</td>
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<td>67</td>
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<tr>
<td></td>
<td>Over 11/2&quot; to 4&quot; thick</td>
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<td>63</td>
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<tr>
<td>A252-82</td>
<td>1</td>
<td>Welded and seamless steel pipe piles</td>
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<td>Structural steel</td>
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<td>66</td>
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TABLE 22-1-A—TENSILE REQUIREMENTS
<table>
<thead>
<tr>
<th>A283-81</th>
<th>A B C D</th>
<th>Low and intermediate strength carbon steel plates shapes and bars</th>
<th>45-55</th>
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<tr>
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<td>50-60</td>
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<td>60-72</td>
<td>33</td>
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<tr>
<td>A307-82a</td>
<td>A and B</td>
<td>Bolts Bolts with cast-iron flanges</td>
<td>60 (min)</td>
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<tr>
<td></td>
<td>B</td>
<td></td>
<td>100 (max)</td>
<td>—</td>
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<tr>
<td>A325-83c</td>
<td></td>
<td>High-strength bolts for structural steel joints</td>
<td>$\frac{1}{8}''$ to $1''$ diameter, inclusive</td>
<td>105</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$1\frac{1}{8}''$ to $1\frac{1}{2}''$ diameter, inclusive</td>
<td>120</td>
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<tr>
<td>A366-72</td>
<td></td>
<td>Carbon steel cold-rolled sheet, commercial quality</td>
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<tr>
<td>(79)</td>
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<tr>
<td>A446-76</td>
<td>A B C D</td>
<td>Steel sheet zinc-coated (galvanized) by hot-dip process structural quality</td>
<td>45</td>
<td>33</td>
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<td>(81)</td>
<td>E</td>
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<td>52</td>
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<tr>
<td>A449-83a</td>
<td></td>
<td>Quenched and tempered steel bolts and studs</td>
<td>$\frac{1}{8}''$ to $1''$, inclusive</td>
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<td></td>
<td></td>
<td>Over $1''$ to $1\frac{1}{2}''$, inclusive</td>
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<td></td>
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<td>Over $1\frac{1}{2}''$ to $3''$, inclusive</td>
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<td>Quenched and tempered alloy steel bolts for structural steel connections</td>
<td>$\frac{1}{2}''$ to $1\frac{1}{2}''$, inclusive</td>
<td>150 (min)</td>
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<td>170 (max)</td>
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<td>A B C</td>
<td>Cold-formed welded and seamless carbon steel structural tubing in rounds and shapes</td>
<td>Rounds</td>
<td>45</td>
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<tr>
<td></td>
<td>B</td>
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<td>58</td>
<td>42</td>
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<td>C</td>
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<td>62</td>
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UNIFORM BUILDING CODE STANDARD 23-1
CLASSIFICATION, DEFINITION AND METHODS OF GRADING
FOR ALL SPECIES OF LUMBER

Based on U.S. Department of Commerce, American Softwood Lumber Standard
PS 20-70 and National Grading Rule for Dimension Lumber of the
National Grading Rule Committee


SECTION 23.101 — SCOPE

This standard sets forth general grading rules for all species of lumber referred to in Tables
grading rules referred to in approved recognized standards. Allowable stresses for species or grades
this code shall be established based on approved principles for conversion of wood strength values
to safe working stresses.

SECTION 23.102 — DEFINITIONS

The standard commercial names, or their commonly accepted trade names, for lumber cut from the
principal species of softwoods, as shown in Appendix A of this standard, shall be used in the
formula­tion of lumber grading rules.

The limitations of any grade of lumber described in certified grading rules shall be expressed
within the terms of the definitions in Appendix B of this standard.

The interpretation of terms used describing the factors influencing strength shall be within the
meaning of the terms and definitions of Section 23.108 and Appendix B of this standard.

SECTION 23.103 — CLASSIFICATION

23.103.1 Use Classification. Softwood lumber shall be classified as follows:

23.103.1.1 Yard lumber. Lumber of those grades, sizes and patterns which are generally intended
for ordinary construction and general building purposes.

23.103.1.2 Structural lumber. Lumber that is 2 inches (51 mm) or more in thickness and width
for use where working stresses are required.

23.103.1.3 Factory and shop lumber. Lumber that is produced or selected primarily for remanu-
facturing purposes.

23.103.2 Manufacturing Classifications. Softwood lumber shall be classified according to
extent of manufacture as follows:

23.103.2.1 Rough lumber. Lumber which has not been dressed (surfaced) but which has been
sawed, edged and trimmed at least to the extent of showing saw marks or equivalent in the wood
on the four longitudinal surfaces of each piece for its overall length.

23.103.2.2 Dressed (surfaced) lumber. Lumber that has been dressed by a planing machine
(for purpose of attaining smoothness of surface and uniformity of size) on one side (S1S), two
sides (S2S), one edge (S1E), two edges (S2E), or a combination of sides and edges (S1S1E,
S1S2E, S2S1E, S4S).
23.103.2.3 Worked lumber. Lumber which, in addition to being dressed, has been matched, shiplapped or patterned.

23.103.2.3.1 Matched lumber. Lumber that has been worked with a tongue on one edge of each piece and a groove on the opposite edge to provide a close tongue-and-groove joint by fitting two pieces together, when end matched, the tongue and groove are worked in the ends also.

23.103.2.3.2 Shiplapped lumber. Lumber that has been worked or rabbeted on both sides of each piece to provide a close-lapped joint by fitting two pieces together.

23.103.2.3.3 Patterned lumber. Lumber that is shaped to a pattern or to a molded form, in addition to being dressed, matched or shiplapped, or any combination of these workings.

23.103 Size Classification. Softwood lumber is classified according to size as follows:

23.103.3.1 Boards. Lumber less than 2 inches (51 mm) in nominal thickness and 2 inches (51 mm) or more in nominal width. Boards less than 6 inches (152 mm) may be classified as strips.

23.103.3.2 Dimension. Lumber from 2 inches (51 mm) to, but not including, 5 inches (127 mm) in nominal width. Dimension may be classified as framing, joists, planks, rafters, studs, small timbers, etc.

23.103.3.3 Timbers. Lumber 5 inches (127 mm) or more nominally in least dimension. Timber may be classified as beams, stringers, posts, caps, sills, girders, purlins, etc.

23.103.4 Rough-dry Size. The minimum rough-dry thickness of finish, common boards, and dimension of sizes 1 inches (25 mm) or more nominal thickness shall not be less than 1/8 inch (3.2 mm) thicker than the corresponding minimum finished dry thickness, except that 20 percent of a shipment may not be less than 3/32 inch (2.4 mm) thicker than the corresponding minimum finished dry thickness. The minimum rough-dry widths of finish, common strip boards, and dimension shall not be less than 1/8 inch (3.2 mm) wider than the corresponding minimum finished dry width.

23.103.5 Dressed Sizes. Dressed sizes of lumber shall equal or exceed the minimum sizes shown in Tables 23-1-A, 23-1-B, 23-1-C, 23-1-D and 23-1-E. See also Section 23.109.

NOTE: The actual sizes of all lumber dimensions referenced in this standard in terms of “nominal” sizes are set forth in Tables 23-1-A, 23-1-B, 23-1-D and 23-1-E. The use of nominal sizes in the language of the standard is for convenience and follows the practice of the industry. No inference should be drawn that the nominal sizes are actual sizes.

SECTION 23.104 — STANDARDS FOR GRADING RULES

23.104.1 General. To the extent to which differences in the characteristics of species, in the quality of logs, in conditions of manufacture, and in the uses to which the product is put will permit, in practical application, the basic provisions for the grading of lumber shall be uniform. Grading rules shall be sufficiently explicit to establish a maximum of 5 percent below grade as a reasonable variation between graders. If any grading rules indicate that a grade qualifies under two use classifications, the grade provisions shall satisfy the requirements for both classifications.

23.104.2 Yard Lumber.

23.104.2.1 Grade classifications. The grading of yard lumber shall be based on the uses for which the particular grade is designed, and shall be applied to each kind with reference to its size and length when graded, without consideration to further manufacture. On the basis of quality, yard lumber shall be classified Select, that is, lumber of good appearance and finishing qualities, or Common, that is, lumber which is suitable for general construction and utility purposes.

23.104.2.2 Grade characteristics. The method of determining the extent and limitations of the characteristics permitted in the poorest pieces admissible in each grade of yard lumber shall be
stated in an approved rule, except in the lowest grade of each classification. A grade shall be representative, however, and shall not comprise only low-line pieces.

23.104.2.3 Grade sizes. The dressed thicknesses and widths of yard lumber as specified in Section 23.103.2 shall be considered as minimum standards for the corresponding nominal sizes as shown. Lumber of standard size, rough or dressed, may be described by its nominal dimension, provided net sizes are also shown.

23.104.2.4 Grading faces. Timbers and dimension shall be graded from all four faces. All other yard lumber and yard boards may be graded from the face or best side only.

23.104.3 Structural Lumber.

23.104.3.1 Development of working stress and MOE values. Working stress and modulus of elasticity (MOE) values contained in grading rules shall be developed in accordance with approved standards and other technically sound criteria.

23.104.3.2 Mechanical grading. The grading of structural lumber by mechanical means is recognized as an acceptable method of grading, but all such grading equipment and methods are subject to approval.

23.104.3.3 Grading faces. Timbers and dimension shall be graded from all four faces.

23.104.4 General Grade Provisions.

23.104.4.1 Grade characteristics. Characteristics permitted and limitations for rough lumber shall be the same as those prescribed in grading rules for dressed lumber of like kind and grade and, in addition, such others as will disappear in standard dressing shall be allowed. If characteristics other than those described in grading rules are encountered, they shall be appraised in relation to the characteristics permitted or limitations prescribed for the grade under consideration and shall be allowed if regarded as equivalent or less damaging in effect on the strength, appearance or other utility value of the piece. The size of characteristics and limitations in any grade or species shall not exceed that permitted in the respective grading rules.

23.104.4.2 Special provisions. When heartwood, sapwood, grain classifications and other optional provisions are specified, and the lumber conforms to the requirements of such special provisions as well as of the regular grade designated, it may be regarded as of standard quality.

23.104.4.3 Mixed grades. Mixed grades other than the two highest established grades for each species shall not be included in grading rules.

23.104.4.4 Nonstandard grades. When nonstandard grades, sizes or workings are specified or when particular provisions of a standard grade are waived or changed, inspection shall be made accordingly, but all of the other provisions of the standard grading rules shall apply.

23.104.5 Seasoning. The grading rules shall include clear definitions for dry lumber, under 5-inch (127 mm) nominal thickness, which shall be based on 19 percent or lower maximum moisture content. The grade marking of green or dry lumber of any item shall be in accordance with approved recognized standards.

23.104.5.1 Moisture content determinations. Moisture content determinations shall be made with electric meters of an approved type, and the procedures to be used in making such determinations shall be in accordance with a nationally recognized method.

23.104.5.2 Dry size requirements. The grading rules shall require all lumber under 5-inch (127 mm) nominal thickness, sold as dry, to be 19 percent or less in moisture content at the time of dressing, and to not be less than dry dressed thickness and width at 19 percent moisture content as specified in this standard, or at such lower maximum moisture content as may be applicable to the lumber at the time of dressing. The minimum dressed dry sizes shall be as shown in Tables 23-1-A, 23-1-B, 3-666.
23.104.5.3 Green size requirements. The green sizes specifically stated in the rules shall not be less than the green sizes shown in Tables 23-1-C, 23-1-D and 23-1-E.

23.104.4 Size differentials. When the grading rules permit lumber under 5-inch (127 mm) nominal thickness to be dressed green, the rules shall require the lumber to be dressed to sizes specifically stated in the rules, which sizes shall provide differentials both in thickness and width, as set forth in Tables 23-1-A, 23-1-B, 23-1-C, 23-1-D and 23-1-E.

23.104.5 Grade marking. When grading rules provide for grade marking of lumber under 5-inch (127 mm) nominal thickness, the rules shall contain a provision for standardized marking of such lumber so as to indicate whether the lumber was green or dry at time of dressing.

SECTION 23.105 — STRUCTURAL LUMBER CLASSIFICATION

23.105.1 Size and Use Categories. The effects of knots, deviations of grain, shakes and checks on the strength of a member vary with the loading to which the piece is subjected. Also, the effect of seasoning varies with the size of the member. Structural lumber is therefore often classified according to its size and use.

23.105.2 Dimension Lumber.

23.105.2.1 Lumber which is 2 inches to 4 inches (51 mm to 102 mm) thick and 2 inches to 4 inches (51 mm to 102 mm) wide classified Structural Light Framing, Light Framing, Appearance Framing and Stud. There are four grades in this category.

23.105.2.2 Lumber which is 2 inches to 4 inches thick (51 mm to 102 mm), 5 inches (127 mm) and wider, classified for use as Structural Joist and Planks and Appearance Framing. There are four grades in this category. (See Section 23.107.)

23.105.2.3 Machine stress-rated lumber 2 inches (51 mm) and less in thickness and 2 inches (51 mm) and wider that has been evaluated by mechanical stress-rating equipment to determine the modulus of elasticity and is visually graded to limit certain characteristics and imperfections.

23.105.3 Beams and Stringers. Timbers of rectangular cross section 5 inches by 8 inches (127 mm by 203 mm) and up, graded for strength in bending when loaded on the narrow face.

23.105.4 Posts and Timbers. Timbers of square or nearly square cross section, 5 inches by 5 inches (127 mm by 127 mm) and larger, graded primarily to provide high compression values for use as posts or columns but adapted to miscellaneous uses in which bending strength is not especially important.

23.105.5 Decking and Wall and Roof Planks. Pieces 2 inches to 4 inches (51 mm to 102 mm) thick and 4 inches to 8 inches (102 mm to 203 mm) wide, graded for strength in bending when loaded on the wide face.

23.105.6 Structural Boards. Lumber of 1-inch (25 mm) thickness used in lightweight trusses or other structural elements, and 2 inches (51 mm) net or thinner and 3 inches (76 mm) and wider used in glued-laminated structural members where the principal stresses are in axial compression or tension. Boards for common purposes such as sheathing, finish or boxes are not included.

SECTION 23.106 — GENERAL REQUIREMENTS FOR STRESS GRADES

23.106.1 General Quality of Lumber. Only sound wood, free from any form of decay, shall be permitted unless otherwise specified. Unsound knots and limited amounts of decay in its early stages are permitted in some of the lower stress-rated grades.
In stress grading, all four faces and the ends shall be considered.

23.106.2 Slope of Grain. Slope of grain resulting from either diagonal sawing or from spiral or twisted grain in the tree is measured by the angle between the direction of the fibers and the edge of the piece. The angle is expressed as a slope.

When both diagonal and spiral grain are present, the combined slope of grain is taken as the effective slope.

Slope of grain is measured and limited at the zone in the length of a structural timber that shows the greatest slope. It shall be measured over a distance sufficiently great to define the general slope, disregarding such short local deviations as those around knots except as indicated in this section.

In 1-inch (25 mm) boards, or similar small sizes of lumber, a general slope of grain anywhere in the length shall not pass completely through the thickness of the piece in a longitudinal distance in inches less than the number expressing the specified permissible slope. Where such a slope varies across the width of the board, its average may be taken.

Local deviations must be considered in small sizes, and if a local deviation occurs in a piece less than 4 inches (102 mm) nominal in width or on the narrow face of a piece less than 2 inches (51 mm) nominal in thickness, and is not associated with a permissible knot in the piece, the measurement of slope shall include the local deviation.

23.106.3 Knots.

23.106.3.1 General. Cluster knots are prohibited in stress grades. Two or more knots closely spaced, with the fibers deflected around each knot individually, are not a cluster.

Holes associated with knots are measured and limited in the same way as knots.

A knot on the wide face of a bending or tension member is considered to be at the edge of the wide face if the center of the knot lies within two thirds of the knot diameter from the edge.

23.106.3.2 Knots in joists and planks. Knots in joists and planks may be measured by displacement method, in which the proportion of the cross section of the knot to the cross section of the piece is multiplied by actual face width to establish the equivalent knot size.

Alternatively, knots in joists and planks may be measured on the surface of the piece. Methods of measuring knots by this alternative are given in the following paragraphs.

The size of a knot on a narrow face of a joist or plank is its width between lines enclosing the knot and parallel to the edges of the piece (see Figure 23-1-1). A narrow-face knot that appears also in the wide face of a side-cut joist (but does not contain the intersection of those faces) is measured and graded on the wide face.

The size of a knot on a wide face is the average of its largest and smallest dimensions (see Figure 23-1-1) unless otherwise specified.

Any knot that contains the intersection of two faces, including a knot extending entirely across the width of a face in a side-cut joist, is a corner knot. A corner knot is measured on its end between lines parallel to the edges of the piece and is graded with respect to the face on which it is measured (see Figure 23-1-1). A corner knot in a joist containing the pith is measured either by its width on the narrow face between lines parallel to the edge, or by its smallest diameter on the wide face, whichever is more restrictive (see Figure 23-1-1). If a corner knot appears also on an opposite face, its limitation there as well as on the corner is necessary.

The sum of the sizes of all knots in any 6 inches (152 mm) of length of piece shall not exceed twice the size of the largest permitted knot. Two or more knots of maximum or near maximum permissible size shall not be allowed in the same 6 inches (152 mm) of length on a face. Any combination of knots that will make the piece unfit for its intended use shall not be admitted.

In the grading and measurement of knots in 3-inch by 4-inch (76 mm by 102 mm) and 4-inch by 4-inch (102 mm by 102 mm) sizes, each of the four faces is graded as a narrow face. For sizes 3-inch
by 3-inch (76 mm by 76 mm) and smaller, all knots shall be limited as if they were wide-face edge knots in the face on which they appear.

The size of knots on wide faces may be increased proportionately from the size permitted at the edge to the size permitted at the center line (see Figure 23-1-1).

23.106.3.3 Knots in beams and stringers. The size of a knot on a narrow face of a beam or stringer is its width between lines enclosing the knot and parallel to the edges of the piece (see Figure 23-1-3). When a knot on a narrow face of a side-cut piece extends into the adjacent one fourth of the width of a wide face, it is measured on the wide face.

The size of a knot on the wide face is measured by its smallest diameter (see Figure 23-1-3). An edge knot on the wide face is limited to the same size as a knot on the narrow face.

A corner knot in a beam or stringer containing the pith is measured either by its width on the narrow face between lines parallel to the edges or by its smallest diameter on the wide face, whichever is greater (see Figure 23-1-3). A corner knot in a side-cut piece is measured by whichever of these two is least.

The sum of the sizes of all knots within the middle one half of the length of a face, in a beam 20 feet (6096 mm) or less in length, when measured as specified for the face under consideration, shall not exceed four times the size of the largest knot allowed on that face. This restriction in a beam longer than 20 feet (6096 mm) shall apply to any 10 feet (3048 mm) of length within the middle one half of the length.

Where the grade is used for single-span bending applications only, the sizes of knots on narrow faces and at the edges of wide faces may be increased proportionately from the size permitted in the middle one third of the length to twice that size at the ends of the piece, except that the size of no knot shall exceed the size permitted at the center of the wide face. The size of knots on wide faces may be increased proportionately from the size permitted at the edge to the size permitted at the center line (see Figure 23-1-2).

Where the grade is to be used on continuous spans, the restrictions for knots in the middle one third of their lengths shall be applied to the middle two thirds of the length of pieces continuous on three supports, and to the full length of pieces continuous on four or more supports.

23.106.3.4 Knots in posts and timbers. The size of a knot on any face of a post or timber is taken as the diameter of a round knot, the lesser of the two diameters of an oval knot, or the greatest diameter perpendicular to the length of a spike knot (see Figure 23-1-4).

A corner knot is measured wherever the measurement will represent the true diameter of the branch causing the knot.

The sum of the sizes of all knots in any 6 inches (152 mm) of length of a post or timber shall not exceed twice the size of the largest permitted knot. Two or more knots of maximum or near maximum permissible size shall not be allowed in the same 6 inches (152 mm) of length on a face.

In compression members with greater width than thickness, the sizes of knots in both the narrow and the wide faces are allowed up to the size permitted in the wide face.

23.106.3.5 Knots in 1-inch (25 mm) boards. Measured the same as for joists and planks.

23.106.4 Shakes, Checks and Splits. Shakes are measured at the ends of the piece. The size of a shake is the distance between lines enclosing the shake and parallel to the wide face of the piece.

Splits and checks are treated as "equivalent shakes." The size of a side check is its average depth of penetration into the piece, measured from and perpendicular to the surface of the wide face on which it appears. The size of an end split or end check is one third of its average length measured along the length of the piece, except as noted below.

In single-span bending members, shakes, checks and splits are restricted only for a distance from each end equal to three times the width of the wide face, and within the critical zone, only in the...
middle one half of the wide face. For multiple-span bending members, shakes, checks and splits are restricted throughout the length in the middle one half of the wide face.

Where a combination of two checks in opposite faces, a check and a split, a check and a shake, or a split and a shake may later become a single horizontal shear plane, the sum of the sizes in the combination is restricted to the allowable size of shakes. Where such a combination is not additive in this way, only the largest single characteristic is considered.

23.106.5 Wane. Wane is permissible in all grades of bending members as far as strength properties are concerned, but “free from wane” may be specified when required by appearance or bearing, or other factors of use.

23.106.6 Specific Gravity Selection. Lumber may be selected as dense by grain characteristics for Douglas fir and southern pine. To be classified dense the wood shall average on one end or the other of each piece not less than six annual rings per inch (per 25 mm) and one third or more summerwood (the darker, harder portion of the annual ring) measured on a representative radial line. Pieces that average not less than four annual rings per inch (per 25 mm) shall be accepted as dense if they average one half or more summerwood. The contrast in color between springwood and summerwood in either case shall be distinct.

To ensure a representative radial line, measurement shall be made over a continuous length of 3 inches (76 mm) or as nearly 3 inches (76 mm) as is available. The length shall be centrally located in side-cut pieces. In pieces containing the pith, the measurement may exclude an inner portion of the radius amounting to approximately one fourth of the least dimension of the piece.

Dense material of any species may be selected by methods other than described above, provided that such methods are approved.

Lumber may be selected as close grain for Douglas fir from the coast region, redwood and southern pine. To be classified as close grain the wood shall average on one end or the other of each piece not less than six or more than 30 annual rings per inch (per 25 mm), measured on a representative radial line. To ensure a representative radial line, measurement shall be made as in the second paragraph of this subsection. Pieces averaging at least five, or more than 30, rings per inch (per 25 mm) shall be accepted as close grained if the measurement shows one third or more summerwood. Visually selected close-grained redwood shall average in each piece not less than eight or more than 40 annual rings per inch (per 25 mm).

Close-grained wood of any species may be selected by methods other than described above, provided that such methods are approved.

Medium-grained wood shall average on one end or the other of each piece not less than four annual rings per inch, measured on a representative radial line.

SECTION 23.107 — GRADING RULES FOR DIMENSION LUMBER

23.107.1 Scope. This section applies to dimension lumber referred to in Table 25-A of this code. Dimension lumber covered in this section is structural lumber as classified in Section 23.105.2.

23.107.2 General. The major characteristics encountered in grading of softwood lumber shall be as specified in Section 23.104. Minor characteristics unique to a single species which are not listed in the grade descriptions shall be assessed in comparison with the most similar characteristic listed in the grades and permitted or limited in the same fashion as the listed characteristic. All grade descriptions set forth the limiting characteristics that may occur in lumber in each grade. All or nearly all of the permissible characteristics of the grade shall not be present in maximum size or number in any one piece. Any piece with an unusual combination of characteristics which seriously affects normal serviceability is excluded from the grade.

Knots, checks, shakes and slope of grain shall be measured in accordance with the provisions of Section 23.106, except that no increase in slope of grain or size of knots shall be permitted outside
the middle one third of length. Except as otherwise provided herein, knots appearing on narrow faces shall be limited to the same displacement as knots specified at edges of wide faces. The limitations on knot sizes and other characteristics governing strength shall not be exceeded. Compression wood is prohibited in all grades if present in readily identifiable and damaging form based on ordinary visual inspection.

Dimension lumber is classified into two width categories and four use categories. Dimension lumber up to 4 inches (102 mm) wide is classified as “Structural Light Framing,” “Light Framing” and “Studs.” Dimension lumber 5 inches (127 mm) and wider is classified as “Studs” and “Structural Joists and Planks.”

**STRUCTURAL LIGHT FRAMING**

2 to 4 Inches (51 to 102 mm) Thick, 2 to 4 Inches (51 to 102 mm) Wide

<table>
<thead>
<tr>
<th>Grade Name (and Abbreviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select Structural (Sel Str)</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
</tbody>
</table>

**LIGHT FRAMING**

2 to 4 Inches (51 to 102 mm) Thick, 2 to 4 Inches (51 to 102 mm) Wide

<table>
<thead>
<tr>
<th>Grade Name (and Abbreviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction (Const)</td>
</tr>
<tr>
<td>Standard (Stand)</td>
</tr>
<tr>
<td>Utility (Util)</td>
</tr>
</tbody>
</table>

**STUDS**

2 to 4 Inches (51 to 102 mm) Thick, 2 Inches (51 mm) and Wider

<table>
<thead>
<tr>
<th>Grade Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stud</td>
</tr>
</tbody>
</table>

**STRUCTURAL JOISTS AND PLANKS**

2 to 4 Inches (51 to 102 mm) Thick, 5 Inches (127 mm) and Wider

<table>
<thead>
<tr>
<th>Grade Name (and Abbreviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select Structural (Sel Str)</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
</tbody>
</table>

23.107.3 Structural Light Framing.

**23.107.3.1 Select structural.** Two inches to 4 inches (51 mm to 102 mm) thick, 2 inches to 4 inches (51 mm to 102 mm) wide.

Characteristics permitted and limiting provisions shall be:

Checks—Surface seasoning checks, not limited. Through checks at ends are limited as splits.

Grain, for redwood—Close grain. For redwood open grain—Open grain. For Douglas fir dense—Dense. For Douglas fir, larch and southern pine—Medium.

Knots—Sound, firm, encased and pith knots, if tight and well spaced, are permitted in sizes not to exceed the following, or equivalent, displacement:
23.107.3.2 No. 1. Two inches to 4 inches (51 mm to 102 mm) thick, 2 inches to 4 inches (51 mm to 102 mm) wide:

Characteristics permitted and limiting provisions shall be:

Checks—Surface seasoning checks, not limited. Through checks at ends are limited as splits.

Grain, for redwood—Close grain. For redwood open grain—Open grain. For Douglas fir and southern pine dense—Dense. For Douglas fir, larch and southern pine—Medium.

Knots—Sound, firm, encased and pith knots, if tight and well spaced, are permitted in sizes not to exceed the following, or equivalent, displacement:

<table>
<thead>
<tr>
<th>NOM. WIDTH</th>
<th>AT EDGE WIDE FACE (&lt; 25.4 for mm)</th>
<th>CENTER LINE WIDE FACE</th>
<th>UNSOUND OR LOOSE KNOTS AND HOLES (ANY CAUSE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2&quot;</td>
<td>4/6&quot;</td>
<td>4/12&quot;</td>
<td>One hole or equivalent smaller per 3 linear feet (914 mm)</td>
</tr>
<tr>
<td>3&quot;</td>
<td>4/3&quot;</td>
<td>1/2&quot;</td>
<td></td>
</tr>
<tr>
<td>4&quot;x1</td>
<td>1&quot;</td>
<td>1/2&quot;</td>
<td></td>
</tr>
</tbody>
</table>

1In 3 x 4 (76 x 102 mm) and 4 x 4 (102 x 102 mm) sizes, a 1/16-inch (3.8 mm) knot is permitted anywhere on the 4-inch (102 mm) face.

Manufacture—Standard “E.”

Pitch and pitch streaks—Not limited.

Pockets, pitch or bark—Not limited.

Shake—On ends, limited to one half the thickness. Away from ends, several heart shakes up to 2 feet (610 mm) long, none through.
Skips—Hit-and-miss skips in 10 percent of pieces.
Slope of grain—1 in 10.
Splits—Equal in length to width of the piece.
Stain—Stained sapwood. Firm heart stain or firm red heart.
Wane—One fourth the thickness, one fourth the width; 5 percent of the pieces may have wane up to one half the thickness and one third the width for one fourth the length.
Warp—One half of medium.
Heartwood, in redwood "No. 1 Heart Structural"—All heartwood.

23.107.3.3 No. 2. Two inches to 4 inches (51 mm to 102 mm) thick, 2 inches to 4 inches (51 mm to 102 mm) wide:

Characteristics permitted and limiting provisions shall be:
Checks—Seasoning checks not limited. Through checks at ends are limited as splits.
Grain, for redwood close grain—Close grain. For redwood open grain—Open grain. For Douglas fir and southern pine dense—Dense. For Douglas fir and larch—Medium.
Knots—Well-spaced knots of any quality are permitted in sizes not to exceed the following or equivalent displacement:

<table>
<thead>
<tr>
<th>NOM. WIDTH</th>
<th>AT EDGE WIDE FACE</th>
<th>CENTER LINE WIDE FACE</th>
<th>HOLES (ANY CAUSE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2&quot;</td>
<td>5/8&quot;</td>
<td>5/8&quot;</td>
<td>5/8&quot;</td>
</tr>
<tr>
<td>3&quot;</td>
<td>7/8&quot;</td>
<td>7/8&quot;</td>
<td>7/8&quot;</td>
</tr>
<tr>
<td>4&quot;&quot;</td>
<td>1 1/4&quot;</td>
<td>2&quot;</td>
<td>1 1/4&quot;</td>
</tr>
</tbody>
</table>

1In 3 x 4 (76 x 102 mm) and 4 x 4 (102 x 102 mm) sizes, a 2-inch (51 mm) knot is permitted anywhere on the 4-inch (102 mm) face.

Manufacture—Standard "F."
Pitch and pitch streaks—Not limited.
Pockets, pitch or bark—Not limited.
Shake—On ends limited to one half the thickness. Away from ends, through heart shakes up to 2 feet (610 mm) long, well separated. If not through, single shakes may be 3 feet (914 mm) long or up to one fourth the length, whichever is greater.
Skips—Hit and miss; and, in addition, 5 percent of the pieces may be hit-or-miss or heavy skip not longer than 2 feet (610 mm).
Slope of grain—1 in 8.
Splits—Equal in length to one and one-half times the width of the piece.
Stain—Stained sapwood. Firm heart stain or firm red heart. Not limited.
Unsound wood—Not permitted in thicknesses over 2 inches (51 mm); but in 2-inch (51 mm) thickness, heart center streaks not over one third of the width or thickness, or small spots or streaks of firm honeycomb or speck equal to one sixth the width are permitted.
Wane—One third the thickness, one third the width; 5 percent of the pieces may have wane up to two thirds the thickness and one half the width for one fourth the length.
Warp—Light.
White speck—Firm, one third the face or equivalent.
Heartwood, in redwood “No. 2 Heart Structural”—All heartwood.

23.107.3.4 No. 3. Two inches to 4 inches (51 mm to 102 mm) thick, 2 inches to 4 inches (51 mm to 102 mm) wide:

Characteristics permitted and limiting provisions shall be:

Checks—Seasoning checks not limited. Through checks at ends are limited as splits.

Grain, for redwood—Close grain. For redwood open grain—Open grain. For southern pine dense—Dense.

Knots—Not restricted as to quality and are permitted in the following sizes or their equivalent displacement:

<table>
<thead>
<tr>
<th>NOM. WIDTH</th>
<th>AT EDGE FACE</th>
<th>CENTER LINE FACE</th>
<th>HOLES (ANY CAUSE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2&quot;</td>
<td>3/4&quot;</td>
<td>3/4&quot;</td>
<td>3/4&quot;</td>
</tr>
<tr>
<td>3&quot;</td>
<td>1 1/4&quot;</td>
<td>1 1/4&quot;</td>
<td>1 1/4&quot;</td>
</tr>
<tr>
<td>4&quot;</td>
<td>1 1/4&quot;</td>
<td>2 1/2&quot;</td>
<td>1 3/4&quot;</td>
</tr>
</tbody>
</table>

\[1\text{In 3 x 4 (76 mm x 102 mm) and 4 x 4 (102 mm x 102 mm) sizes, a 2 1/2-inch (64 mm) knot is permitted anywhere on the 4-inch (102 mm) face.}\]

Manufacture—Standard “F.”

Pitch and pitch streaks—Not limited.

Pockets, pitch or bark—Not limited.

Shake—Surface shakes permitted. If through at edges or ends, limited as splits. Elsewhere through shakes one third the length. Several such scattered along the length.

Skips—Hit or miss; in addition, 10 percent of pieces may have heavy skip.

Slope of grain—1 in 4.

Splits—Equal to one sixth the length of the piece.

Stain—Stained wood. Not limited.

Unsound wood—In spots or streaks limited to one third the cross section at any point along the length. Must not destroy nailing edge.

Wane—One half the thickness, one half the width. Five percent of the pieces may have up to seven eighths the thickness and three fourths the width for one fourth the length.

Warp—Medium.

White speck and honeycomb—Firm.

Heartwood, in redwood “No. 3 Heart Structural”—All heartwood.

23.107.4 Light Framing.

23.107.4.1 Construction. Two inches to 4 inches (51 mm to 102 mm) thick, 2 inches to 4 inches (51 mm to 102 mm) wide.

Characteristics permitted and limiting provisions are:

Checks—Surface seasoning checks not limited. Through checks at ends are limited as splits.

Knots—Sound, firm, encased and pith knots must be tight and are permitted in the following sizes or their equivalent displacement:
Knots spiked entirely across the wide face are limited to a displacement of approximately one fourth the cross section.

Manufacture—Standard "E."

Pitch and pitch streaks—Not limited.

Pockets, pitch or bark—Not limited.

Shake—Several heart shakes up to 2 feet (610 mm) long, similar to seasoning checks, none through.

Skips—Hit and miss on 10 percent of the pieces.

Slope of grain—1 in 6.

Splits—Equal in length to the width of the piece.

Stain—Stained sapwood. Firm heart stain or firm red heart.

Wane—One fourth the thickness, one fourth the width. Five percent of the pieces may have wane up to one half the thickness and one third the width for one fourth the length.

Warp—One half of medium.

**23.107.4.2 Standard.** Two inches to 4 inches (51 mm to 102 mm) thick, 2 inches to 4 inches (51 mm to 102 mm) wide.

Characteristics permitted and limiting provisions are:

Checks—Seasoning checks not limited. Through checks at ends are limited as splits.

Knots—Not restricted as to quality and are permitted in the following sizes or their equivalent displacement:

<table>
<thead>
<tr>
<th>NOM. WIDTH</th>
<th>ANYWHERE ON WIDE FACE (≤ 25.4 mm)</th>
<th>HOLEs</th>
</tr>
</thead>
<tbody>
<tr>
<td>2&quot;</td>
<td>3/4&quot;</td>
<td>5/8&quot;</td>
</tr>
<tr>
<td>3&quot;</td>
<td>1 1/4&quot;</td>
<td>3/4&quot;</td>
</tr>
<tr>
<td>4&quot;</td>
<td>1 1/2&quot;</td>
<td>1&quot;</td>
</tr>
</tbody>
</table>

Knots spiked entirely across the wide face are limited to a displacement of approximately one-third the cross section.

Manufacture—Standard "F."

Pitch and pitch streaks—Not limited.

Pockets, pitch or bark—Not limited.

Shake—on ends limited to one half the thickness. Away from ends through heart shakes up to 2 feet (610 mm) long, well separated. If not through, single shakes may be 3 feet (914 mm) long or up to one fourth the length, whichever is greater.

Skips—Hit and miss. In addition, 5 percent of pieces may be hit or miss, or heavy skip not longer than 2 feet (610 mm).

Slope of grain—1 in 4.
Splits—Equal in length to one and one-half times the width of the piece.

Stain—Stained sapwood. Firm heart stain or firm red heart. Not limited.

Unsound wood—Heart center streaks not over one third the thickness or width, or small spots or streaks of firm honeycomb or speck equal to one sixth the width are permitted.

Wane—One third the thickness, one third the width. Five percent of pieces may have wane up to two thirds the thickness and one half the width for one fourth the length.

Warp—Light.

White speck—Firm, one third the face or equivalent.

23.107.4.3 Utility. Two inches to 4 inches (51 mm to 102 mm) thick, 2 inches to 4 inches (51 mm to 102 mm) wide.

Characteristics permitted and limiting provisions are:

Checks—Seasoning checks not limited. Through checks at ends are limited as splits.

Knots—Not restricted as to quality and are permitted in the following sizes or their equivalent displacement:

<table>
<thead>
<tr>
<th>NOM. WIDTH</th>
<th>ANYWHERE ON WIDE FACE</th>
<th>HOLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2”</td>
<td>1 1/4”</td>
<td>1”</td>
</tr>
<tr>
<td>3”</td>
<td>2”</td>
<td>1 1/4”</td>
</tr>
<tr>
<td>4”</td>
<td>2 1/2”</td>
<td>1 1/2”</td>
</tr>
</tbody>
</table>

Knots spiked entirely across the wide face are limited to a displacement of approximately one half the cross section.

Manufacture—Standard “F.”

Pitch and pitch streaks—Not limited.

Pockets, pitch or bark—Not limited.

Shake—Surface shakes permitted. If through at edges or ends, limited as splits. Elsewhere through shakes one third the length. Several such scattered along the length.

Skips—Hit or miss. In addition, 10 percent of the pieces may have heavy skips.

Slope of grain—1 in 4.

Splits—Equal to one sixth of the length of the piece.

Stain—Stained wood, not limited.

Unsound wood—In spots or streaks limited to one third the cross section at any point along the length. Must not destroy nailing edge.

Wane—One half the thickness, one half the width. Five percent of the pieces may have wane up to seven eighths the thickness and three fourths the width for one fourth the length.

Warp—Medium.

White speck and honeycomb—Firm.

23.107.5 Studs. Two inches to 4 inches (51 mm to 102 mm) thick, 2 inches to 6 inches (51 mm to 152 mm) wide, 10 feet (3048 mm) and shorter. Characteristics permitted and limiting provisions are:

Checks—Seasoning checks not limited. Through checks at ends are limited as splits.

Knots—Not limited as to quality, but are well spaced and are permitted in the following sizes or their equivalent displacement:

3–676
<table>
<thead>
<tr>
<th>NOM. WIDTH</th>
<th>AT EDGE WIDE FACE</th>
<th>CENTER LINE WIDE FACE</th>
<th>HOLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2&quot;</td>
<td>3/16&quot;</td>
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<tr>
<td>6&quot;</td>
<td>2 1/16&quot;</td>
<td>33/32&quot;</td>
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</tbody>
</table>

1In 3 x 4 (76 x 102 mm) and 4 x 4 (102 x 102 mm), knot size shown for center line of wide face is permitted anywhere on 4-inch (102 mm) face.

Manufacture—Standard “F.”

Pitch and pitch streaks—Not limited.

Pockets, pitch or bark—Not limited.

Shake—If through at ends, limited as splits. Elsewhere through shakes one third the length.

Skips—Hit or miss on any face. In addition, 10 percent of the pieces may have heavy skips on wide faces only.

Slope of grain—1 in 4.

Splits—Equal in length to twice the width of the piece.

Stain—Stained sapwood. Firm heart stain or firm red heart.

Unsound wood—In spots or streaks limited to one third the cross section at any point along the length. Must not destroy nailing edge.

Wane—one half the width and one third the thickness without length limit, or equivalent, more for 2 feet (610 mm) if not exceeding three fourths the width and one half the thickness.

Warp—one half of medium.

White speck and honeycomb—Firm.

23.107.6 Structural Joists and Planks. Two inches to 4 inches (51 mm to 102 mm) thick, 5 inches (127 mm) and wider.

23.107.6.1 Select structural. Characteristics permitted and limiting provisions shall be:

Checks—Surface seasoning checks, not limited. Through checks at ends are limited as splits.

Grain, for redwood select structural—Close grain. For redwood select structural open grain—Open grain. For Douglas fir and southern pine dense—Dense. For Douglas fir, larch and southern pine—Medium.

Knots—Sound, firm, encased and pith knots, if tight and well spaced, are permitted in sizes not to exceed the following or equivalent displacement:

<table>
<thead>
<tr>
<th>NOM. WIDTH</th>
<th>AT EDGE WIDE FACE</th>
<th>CENTER LINE WIDE FACE</th>
<th>UNSOUND OR LOOSE KNOTS AND HOLES (ANY CAUSE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5&quot;</td>
<td>1&quot;</td>
<td>1 1/16&quot;</td>
<td>7/16&quot;</td>
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<tr>
<td>6&quot;</td>
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<td>1 7/16&quot;</td>
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<td>1 1/4&quot;</td>
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<td>12&quot;</td>
<td>2 1/16&quot;</td>
<td>3&quot;</td>
<td>1 1/4&quot;</td>
</tr>
<tr>
<td>14&quot;</td>
<td>2 3/8&quot;</td>
<td>3 1/4&quot;</td>
<td>1 1/4&quot;</td>
</tr>
</tbody>
</table>
Manufacture—Standard “E.”
Pitch and pitch streaks—Not limited.
Pockets, pitch or bark—Not limited.
Shake—On ends, limited to one half the thickness. Away from ends, several heart shakes up to 2 feet (610 mm) long, none through.
Skips—Hit and miss in 10 percent of pieces.
Slope of grain—1 in 12.
Splits—Equal in length to the width of the piece.
Stain—Stained sapwood. Firm heart stain or firm red heart limited to 10 percent of the piece.
Wane—One fourth the thickness, one fourth the width. Five percent of the pieces may have wane up to one half the thickness and one third the width for one fourth the length.
Warp—One half of medium.
Heartwood, in redwood “Select Heart Structural”—All heartwood.

23.107.6.2 No. 1. Characteristics permitted and limiting provisions shall be:
Checks—Surface seasoning checks, not limited. Through checks at ends are limited as splits.
Grain, for redwood—Close grain. For redwood open grain—Open grain. For Douglas fir and southern pine dense—Dense. For Douglas fir larch and southern pine—Medium.
Knots—Sound, firm, encased and pith knots, if tight and well spaced, are permitted in sizes not to exceed the following or equivalent displacement:

<table>
<thead>
<tr>
<th>NOM. WIDTH</th>
<th>AT EDGE WIDE FACE</th>
<th>CENTER LINE WIDE FACE</th>
<th>UNSOUND OR LOOSE KNOTS AND HOLES (ANY CAUSE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(x 25.4 for mm)</td>
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<tr>
<td>5”</td>
<td>1 1/4”</td>
<td>1 7/8”</td>
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<td>6”</td>
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<td>2 1/4”</td>
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<td>8”</td>
<td>2”</td>
<td>2 3/4”</td>
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<td>10”</td>
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<td>12”</td>
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<td>3 3/4”</td>
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<td>14”</td>
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<td>1 1/2”</td>
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</tbody>
</table>

One hole or equivalent smaller per 3 linear feet (914 mm)

Manufacture—Standard “E.”
Pitch and pitch streaks—Not limited.
Pockets, pitch or bark—Not limited.
Shake—On ends limited to one half the thickness. Away from ends, several heart shakes up to 2 feet (610 mm) long, none through.
Skips—Hit-and-miss skips in 10 percent of pieces.
Slope of grain—1 in 10.
Splits—Equal in length to width of the piece.
Stain—Stained sapwood. Firm heart stain or firm red heart.
Wane—One fourth the thickness, one fourth the width. Five percent of the pieces may have wane up to one half the thickness and one third the width for one fourth the length.
Warp—One half of medium.
Heartwood, for redwood “No. 1 Heart Structural”—All heartwood.
23.107.6.3 No. 2. Characteristics permitted and limiting provisions shall be:

Checks—Seasoning checks not limited. Through checks at ends are limited as splits.

Grain, for redwood—Close grain. For redwood open grain—Open grain. For Douglas fir and southern pine dense—Dense. For Douglas fir and larch—Medium.

Knots—Well-spaced knots of any quality are permitted in sizes not to exceed the following or equivalent displacement:

<table>
<thead>
<tr>
<th>NOM. WIDTH</th>
<th>AT EDGE WIDE FACE</th>
<th>CENTER LINE WIDE FACE</th>
<th>HOLES (ANY CAUSE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5&quot;</td>
<td>1\frac{1}{8}&quot;</td>
<td>2\frac{3}{8}&quot;</td>
<td>1\frac{3}{8}&quot;</td>
</tr>
<tr>
<td>6&quot;</td>
<td>1\frac{1}{8}&quot;</td>
<td>2\frac{7}{8}&quot;</td>
<td>1\frac{1}{2}&quot;</td>
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<tr>
<td>8&quot;</td>
<td>2\frac{1}{2}&quot;</td>
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<tr>
<td>10&quot;</td>
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<td>4\frac{1}{4}&quot;</td>
<td>2\frac{1}{2}&quot;</td>
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<tr>
<td>12&quot;</td>
<td>3\frac{3}{4}&quot;</td>
<td>4\frac{1}{4}&quot;</td>
<td>3&quot;</td>
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<tr>
<td>14&quot;</td>
<td>4\frac{1}{8}&quot;</td>
<td>5\frac{1}{4}&quot;</td>
<td>3\frac{1}{2}&quot;</td>
</tr>
</tbody>
</table>

Manufacture—Standard “F.”

Pitch and pitch streaks—Not limited.

Pockets, pitch or bark—Not limited.

Shake—On ends, limited to one half the thickness. Away from ends through heart shakes up to 2 feet (610 mm) long, well separated. If not through, single shakes may be 3 feet (914 mm) long or up to one fourth the length, whichever is greater.

Skips—Hit and miss and, in addition, 5 percent of the pieces may be hit or miss or heavy skip not longer than 2 feet (610 mm).

Slope of grain—1 in 8.

Splits—Equal in length to one and one half times the width of the piece.

Stain—Stained sapwood. Firm heart stain or firm red heart not limited.

Unsound wood—Not permitted in thicknesses over 2 inches (51 mm) but in 2-inch (51 mm) thickness, heart center streaks not over one third the width or thickness, or small spots or streaks of firm honeycomb or speck equal to one sixth the width are permitted.

Wane—One third the thickness, one third the width. Five percent of the pieces may have wane up to two thirds the thickness and one half the width for one fourth the length.

Warp—Light.

White speck—Firm, one third the face or equivalent.

Heartwood, for redwood “No. 2 Heart Structural”—All heartwood.

23.107.6.4 No. 3. Characteristics permitted and limiting provisions shall be:

Checks—Seasoning checks not limited. Through checks at ends are limited as splits.

Grain, for redwood—Close grain. For redwood open grain—Open grain. For southern pine dense—Dense.

Knots—Well-spaced knots of any quality are permitted in the following sizes or their equivalent displacement:
### 23.107.7 Mechanically Stress-rated Lumber

Each piece of mechanically stress-rated lumber shall be tested and marked to indicate the modulus of elasticity and shall comply with the following visual grading requirements:

**Checks**—Seasoning checks not limited. Through checks at ends limited as splits.

**Shake**—On ends, limited to one half the thickness. Away from ends, through heart shakes up to 2 feet (610 mm) long, well separated. If not through, single shakes may be 3 feet (914 mm) or up to one fourth the length, whichever is greater.

**Skips**—Hit and miss and, in addition, 5 percent of the pieces may be hit-or-miss or heavy skip not longer than 2 feet (610 mm).

**Splits**—Equal in length to one and one-half times the width of the piece.

**Wane**—One third the thickness, one third the width; 5 percent of pieces may have wane up to two thirds the thickness and one half the width for one fourth the length.

**Warp**—Light.

In addition to the visual limitations listed, knots, knotholes, burls, distorted grain or decay, partially or wholly at edges of wide faces, must not occupy more of the net cross section than:

\[
F_b (\text{psi}) \quad F_b (\text{N/mm}^2)
\]

<table>
<thead>
<tr>
<th>$1/2$ for 900 and lower</th>
<th>0.5 for 6.21 and lower</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1/3$ for 950 to and including 1,450</td>
<td>0.33 for 6.55 to and including 10.00</td>
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<tr>
<td>$1/4$ for 1,500 to 2,050</td>
<td>0.25 for 10.34 to 14.13</td>
</tr>
<tr>
<td>$1/6$ for 2,100 and over</td>
<td>0.17 for 14.48 and over</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>NOM. WIDTH</th>
<th>AT EDGE WIDE FACE</th>
<th>CENTER LINE WIDE FACE</th>
<th>HOLES (ANY CAUSE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5&quot;</td>
<td>2 1/4&quot;</td>
<td>3&quot;</td>
<td>1 7/8&quot;</td>
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<td>6&quot;</td>
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One hole or equivalent smaller per 1 linear foot (305 mm)
Machine stress-rated lumber is lumber that has been evaluated by mechanical stress-rating equipment. Machine stress-rated lumber is distinguished from visually stress-graded lumber in that each piece is nondestructively tested and marked to indicate the modulus of elasticity. Machine stress-rated lumber is also required to meet certain visual requirements as developed by the respective rules-writing agency.

A grade stamp on machine stress-rated lumber indicates the stress-rating system used meets requirements of the grading agency’s certification and quality-control procedures. The grade stamp will show the agency trademark, the mill name or number, will include the phrase “Machine Rated” or “MSR,” the species identification, and the “E” rating for the grade. The “E” rating is the rated modulus of elasticity in millions of pounds per square inch (N/mm²).

SECTION 23.108 — DEFINITIONS APPLICABLE TO GRADING RULES

Terms, words and phrases used in Section 23.107 shall be construed as follows and as defined in Appendix B.

1. BIRD’S-EYE. A small central spot with the wood fibers arranged around it in the form of an ellipse, so as to give the appearance of an eye. Bird’s-eye, unless open or checked, is not considered a defect.

2. BURL. A distortion of grain, usually caused by abnormal growth due to injury of the tree. The effect of burls is assessed in relation to knots.

3. CHECKS. A separation of the wood normally occurring across or through the rings of annual growth and usually as a result of seasoning.
   3.1 A surface check occurs only on one surface of a piece.
   3.2 A through check extends from one surface of a piece to the opposite or adjoining surface.
   3.3 Small checks are not over 1/32 inch (0.8 mm) wide and not over 4 inches (102 mm) long.
   3.4 Medium checks are not over 1/32 inch (0.8 mm) wide and not over 10 inches (254 mm) long.
   3.5 Large checks are larger than medium.
   3.6 A roller check is a crack in the wood structure caused by a piece of cupped lumber being flattened in passing between the machine rollers.
      A light roller check is a perceptible opening not over 2 feet (610 mm) long.
      A medium roller check is a perceptible opening over 2 feet (610 mm) long but not exceeding 4 feet (1219 mm) in length.
      A heavy roller check is over 4 feet (1219 mm) in length.

4. COMPRESSION WOOD. Abnormal wood that forms on the underside of leaning and crooked coniferous trees. It is characterized, aside from its distinguishing color, by being hard and brittle and by its relatively lifeless appearance. It is not permitted in readily identifiable and damaging form in stress grades or where specifically limited.

5. DECAY. A disintegration of the wood substance due to action of wood-destroying fungi, and is also known as dote, rot and unsound wood.
   5.1 Heart center decay is a localized decay developing in the living tree along the pith in some species.
   5.2 White specks are small white pits or spots in wood caused by the fungus “Fomes pini.” It develops in the living tree and does not develop further in wood in service.
   5.3 Honeycomb is similar to white speck but the pockets are larger.
   5.4 Peck is channeled or pitted areas or pockets as sometimes found in cedar and cypress.
6. **DISPLACEMENT**. is the amount of clear wood displaced by a knot and considered in its relation to the amount it reduces the strength of the cross section of the piece of lumber under consideration.

7. **EDGE**. There are three meanings for edge: the narrow face of rectangular-shaped pieces; or the corner of a piece at the intersection of two longitudinal faces; or, usually in stress grades, that part of the wide face nearest the corner of the piece.

7.1 Eased edges means slightly rounded surfacing on pieces of lumber to remove sharp corners. Lumber 4 inches (102 mm) or less in thickness is frequently shipped with eased edges unless otherwise specified. Lumber of 1-inch (25 mm) and 2-inch (51 mm) thickness may be rounded to a radius of no more than 1/16 inch (1.6 mm) and 1/8 inch (3.2 mm), respectively.

7.2 Square edged means free from wane without eased edges.

7.3 Free of wane means without wane but may have eased edges. (See WANE definition.)

7.4 Square corners means without eased edges but may permit wane allowance.

8. **GRAIN**. The stratification of fibers in wood composed of summerwood and springwood (see Appendix B).

8.1 Dense. In Douglas fir and southern pine tree species of longleaf, slash, shortleaf and loblolly, an average of approximately six or more annual rings per inch (per 25 mm) on either end of a piece and one third or more summerwood. Rings are to be measured on a representative radial line and the contrasting color between summerwood and springwood must be distinctive; also, Douglas fir pieces averaging less than six annual rings but not less than four annual rings per inch (per 25 mm) and southern pine of specified species averaging not less than four annual rings per inch (per 25 mm). Such averaging must be one half or more summerwood.

8.2 Medium grain. In applicable grades, an average of approximately four annual rings per inch (per 25 mm) measured on a representative radial line on either end of a piece. In Douglas fir, larch and southern pine tree species of longleaf, slash, shortleaf and loblolly, an average of approximately four or more annual rings per inch (per 25 mm) measured on a representative radial line; also, in Douglas fir and larch, pieces averaging less than four rings per inch (per 25 mm) and one third or more summerwood.

8.3 Close grain. In applicable species, an average of approximately six but not more than approximately 30 annual rings per inch (per 25 mm) on either end of a piece measured on a representative radial line. In Douglas fir and larch, pieces averaging five rings or more than 30 rings per inch (per 25 mm) are accepted as close grain if averaging one third or more summerwood. In southern pine, longleaf species, pieces shall average on either end not less than six annual rings per inch (per 25 mm) and one third or more summerwood measured on a representative radial line.

In redwood, an average ring count of not less than eight rings per inch (per 25 mm).

8.4 Open grain. In all species, pieces with an unrestricted rate of growth as to rings per inch (per 25 mm).

8.5 Slope of grain is the deviation of the line of fibers from a straight line parallel to the sides of the piece.

8.6 Vertical grain (VG) (Edge grain EG) (Rift grain) lumber is a piece sawn at approximately right angles to the annual growth rings so that the rings form an angle of 45 degrees or more with the surface of the piece.

8.7 Flat grain (FG) (Slash grain SG) lumber is a piece or pieces sawn approximately parallel to the annual growth rings so that all or some of the rings form an angle of less than 45 degrees with the surface of the piece.

8.8 Mixed grain (MG) lumber may be either or both vertical and flat grain.
8.9 Spiral grain is a deviation in the slope of rain caused when the fibers in a tree take a spiral course around the trunk of the tree instead of the normal vertical course.

8.10 Diagonal grain is a deviation in the slope of grain caused by sawing at an angle with the bark of the tree.

EXCEPTION: In redwood, grain is considered vertical when the rings of annual growth form an angle of 45 degrees or more with the surface of the piece. Any lumber that will not qualify as vertical grain is flat grain.

9. HEART. The portion of the tree contained within the sapwood. It is sometimes used to mean the pith.

9.1 Boxed heart means with the pith enclosed in the piece.

9.2 Heart center is the pith or center core of the log.

9.3 Free of heart centers (FOHC) means without pith (side cut). When a piece has been sawn so as to eliminate the pith (heart center), an occasional piece showing pith on the surface for not more than one fourth the length may be accepted.

10. HOLES. Holes may extend partially or entirely through a piece and may be from any cause. Holes that extend only partially through the piece may also be designated as surface pits. Unless otherwise specified, holes are measured the same as knots. Holes are classified by size as follows:

A pinhole is not over $\frac{1}{16}$ inch (1.6 mm) in diameter.

A medium (small) hole is not over $\frac{1}{4}$ inch (6.4 mm) in diameter.

A large hole is not over 1 inch (25 mm) in diameter.

A very large hole is over 1 inch (25 mm) in diameter.

11. KNOTS. A portion of a branch or limb that has become incorporated in a piece of lumber. In lumber, knots are classified as to form, size, quality and occurrence. A red knot is one that results from a live branch growth in the tree and is intergrown with the surrounding wood. A black knot is one that results from a dead branch which the wood growth of the tree has surrounded.

A round knot is a knot cut at right angles to the length of the knot (limb).

An oval knot is a knot cut at slightly more than right angles to the length of the knot (limb).

A spike knot is a knot cut either lengthwise of the knot or diagonally across it.

A pin knot is not over $\frac{1}{2}$ inch (13 mm).

A small knot is not over $\frac{3}{4}$ inch (19 mm).

A medium knot is not over 1$\frac{1}{2}$ inches (38 mm).

A large knot is over 1$\frac{1}{2}$ inches (38 mm).

A sound knot contains no decay. It may be red or black.

A pith knot is sound in all respects except it contains a pith hole not over $\frac{1}{4}$ inch (6.4 mm) in diameter.

A hollow knot is an apparently sound knot in all respects except it contains a hole over $\frac{1}{4}$ inch (6.4 mm) in diameter, and a through opening in a hollow knot may be of a size equal to other holes permitted.

An unsound knot contains decay.

A firm knot is solid across its face but contains incipient decay.

A tight knot is so fixed by growth, shape or position that it retains its place in the piece. It may be red or black.

An intergrown knot is one whose growth rings are partially or completely intergrown on one or more faces with the growth rings of the surrounding wood.
A watertight knot has its growth rings completely intergrown with those of the surrounding wood on one surface and is sound on that surface.

An encased knot is one which is not intergrown with the growth rings of the surrounding wood.

A loose or "not firmly fixed" knot is one not held tightly in place by growth, shape or position.

A fixed knot will retain its place in dry lumber under ordinary conditions but can be moved under pressure though not easily pushed out.

A knot cluster is two or more knots grouped together as a unit with the fibers of the wood deflected around the entire unit.

A star-check knot has radial checks.

Well-scattered knots are not in clusters and each knot is separated from any other by a distance at least equal to the diameter of the smaller of the two.

"Well-spaced" knots means that the sum of the sizes of all knots in any 6 inches (152 mm) of length of a piece must not exceed twice the size of the largest knot permitted. More than one knot of maximum permissible size must not be in the same 6 inches (152 mm) of length and the combination of knots must not be serious.

12. MANUFACTURING IMPERFECTIONS. Means all imperfections or blemishes which are the result of manufacturing, such as the following:

12.1 Chipped grain is a barely perceptible irregularity in the surface of a piece caused when particles of wood are chipped or broken below the line of cut. It is too small to be classed as torn grain and as usually found is not considered unless in excess of 25 percent of the surface involved.

12.2 Torn grain is an irregularity in the surface of a piece where wood has been torn or broken out by surfacing. Torn grain is described as follows:

Very light torn grain—not over \( \frac{1}{64} \) inch (0.4 mm) deep.

Light torn grain—not over \( \frac{1}{32} \) inch (0.8 mm) deep.

Medium torn grain—not over \( \frac{1}{16} \) inch (1.6 mm) deep.

Heavy torn grain—not over \( \frac{1}{8} \) inch (3.2 mm) deep.

Very heavy torn grain—over \( \frac{1}{8} \) inch (3.2 mm) deep.

12.3 Raised grain is an unevenness between springwood and summerwood on the surface of dressed lumber. Slight raised grain is an unevenness somewhat less than \( \frac{1}{64} \) inch (0.4 mm).

Very light raised grain is not over \( \frac{1}{64} \) inch (0.4 mm).

Light raised grain is not over \( \frac{1}{32} \) inch (0.8 mm).

Medium raised grain is not over \( \frac{1}{16} \) inch (1.6 mm).

Heavy raised grain is not over \( \frac{1}{8} \) inch (3.2 mm).

12.4 Loosened grain is a grain separation or loosening between springwood and summerwood without displacement.

Very light loosened grain is not over \( \frac{1}{64} \)-inch (0.4 mm) separation.

Light loosened grain is not over \( \frac{1}{32} \)-inch (0.8 mm) separation.

Medium loosened grain is not over \( \frac{1}{16} \)-inch (1.6 mm) separation.

Heavy loosened grain is not over \( \frac{1}{8} \)-inch (3.2 mm) separation.

Very heavy loosened grain is over \( \frac{1}{8} \)-inch (3.2 mm) separation.

12.5 Skips are areas on a piece that failed to surface clean. Skips are described as follows with equivalent areas being permissible:
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Very light skip is not over $\frac{1}{64}$ inch (0.4 mm) deep.
Light skip is not over $\frac{1}{32}$ inch (0.8 mm) deep.
Medium skip is not over $\frac{1}{16}$ inch (1.6 mm) deep.
Heavy skip is not over $\frac{1}{8}$ inch (3.2 mm) deep.

12.6 "Hit and miss" is a series of skips not over $\frac{1}{16}$ inch (1.6 mm) deep with surfaced area between.

12.7 Hit or miss means completely surfaced or partly surfaced or entirely rough. Scantness may be $\frac{1}{16}$ inch (1.6 mm).

12.8 Mismatch is an uneven fit in worked lumber when adjoining pieces do not meet tightly at all points of contact or when the surfaces of adjoining pieces are not in the same plane.

Slight mismatch is a barely evident trace of mismatch.
Very light mismatch is not over $\frac{1}{64}$ inch (0.4 mm).
Light mismatch is not over $\frac{1}{32}$ inch (0.8 mm).
Medium mismatch is not over $\frac{1}{16}$ inch (1.6 mm).
Heavy mismatch is not over $\frac{1}{8}$ inch (3.2 mm).

12.9 Machine burn is a darkening of the wood due to overheating by machine knives or rolls when pieces are stopped in machine.

12.10 Machine bite is a depressed cut of the machine knives at the end of the piece.

Very light machine bite is not over $\frac{1}{64}$ inch (0.4 mm) deep.
Light machine bite is not over $\frac{1}{32}$ inch (0.8 mm) deep.
Medium machine bite is not over $\frac{1}{16}$ inch (1.6 mm) deep.
Heavy machine bite is not over $\frac{1}{8}$ inch (3.2 mm) deep.

Very heavy machine bite is over $\frac{1}{8}$ inch (3.2 mm) deep.

12.11 Machine gouge is a groove cut by the machine below the desired line.

Slight machine gouge is less than $\frac{1}{64}$ inch (0.4 mm) deep.
Very light machine gouge is not over $\frac{1}{64}$ inch (0.4 mm) deep.
Light machine gouge is not over $\frac{1}{32}$ inch (0.8 mm) deep.
Medium machine gouge is not over $\frac{1}{16}$ inch (1.6 mm) deep.
Heavy machine gouge is not over $\frac{1}{8}$ inch (3.2 mm) deep.

12.12 A machine offset is an abrupt dressing variation in the edge surface which usually occurs near the end of the piece and without reducing the width or without changing the plane of the wide surface.

Very light machine offset is a variation not over $\frac{1}{64}$ inch (0.4 mm).
Light machine offset is a variation not over $\frac{1}{32}$ inch (0.8 mm).
Medium machine offset is a variation not over $\frac{1}{16}$ inch (1.6 mm).
Heavy machine offset is a variation not over $\frac{1}{8}$ inch (3.2 mm).

Very heavy machine offset is a variation over $\frac{1}{8}$ inch (3.2 mm).

12.13 Chip marks are shallow depressions or indentations on or in the surface of dressed lumber caused by shavings or chips getting embedded in the surface during dressing.

Slight chip marks are less than $\frac{1}{64}$ inch (0.4 mm) deep.
Very light chip marks are not over $\frac{1}{64}$ inch (0.4 mm) deep.
Light chip marks are not over $\frac{1}{32}$ inch (0.8 mm) deep.
Medium chip marks are not over $\frac{1}{16}$ inch (1.6 mm) deep.
Heavy chip marks are not over $\frac{1}{8}$ inch (3.2 mm) deep.

12.14 Knife marks are the imprints or markings of the machine knives on the surface of dressed lumber.
Very slight knife marks are visible only from a favorable angle and are perfectly smooth to the touch.
Slight knife marks are readily visible but evidence no unevenness to the touch.

12.15 Wavy dressing involves more uneven dressing than knife marks.
Very slight wavy dressing evidences unevenness that is barely perceptible to the touch.
Slight wavy dressing evidences perceptible unevenness that is somewhat less than $\frac{1}{64}$ inch (0.4 mm) deep.

13. CLASSIFICATIONS OF MANUFACTURING IMPERFECTIONS.

13.1 Standard “A” Manufacture admits: Very light torn grain; occasional slight chip marks; very slight knife marks.

13.2 Standard “B” Manufacture admits: Very light torn grain; very light raised grain; very light loosened grain; slight chip marks; average of one slight chip mark per lineal foot (305 mm) but not more than two in any lineal foot (305 mm); slight knife marks; very slight mismatch.

13.3 Standard “C” Manufacture admits: Medium torn grain; light raised grain; light loosened grain; very light machine bite; very light machine gouge; very light machine offset; light chip marks if well scattered; occasional medium chip marks; very slight knife marks; very slight mismatch.

13.4 Standard “D” Manufacture admits: Heavy torn grain; medium raised grain; very heavy loosened grain; light machine bite; light machine gouge; light machine offset; medium chip marks; slight knife marks; very light mismatch.

13.5 Standard “E” Manufacture admits: Torn grain; raised grain; very heavy loosened grain; medium machine bite; machine gouge; medium machine offset; chip marks; knife marks; light wavy dressing; light mismatch.

13.6 Standard “F” Manufacture admits: Very heavy torn grain; raised grain; very heavy loosened grain; heavy machine bite; machine gouge; heavy machine offset; chip marks; knife marks; medium wavy dressing; medium mismatch.

14. MOISTURE CONTENT. The weight of the water in wood expressed as a percentage of the weight of the oven-dry wood.

14.1 Surfaced green “S-GRN”—Lumber which at the time of surfacing had a moisture content in excess of 19 percent.

14.2 Surfaced dry “S-DRY” “KD,” or “KD 19”—Lumber which at the time of surfacing had a moisture content of 19 percent or less.

14.3 Moisture content of 15 percent “MC 15” or “KD 15”—Lumber which is kiln or air dried and which at the time of surfacing had a moisture content of 15 percent or less.
EXCEPTION: Occasional pieces may have a moisture content greater than that specified above.

15. OCCASIONAL PIECES. Means not more than 10 percent of the pieces in a parcel or shipment.

16. PITCH STREAK. Is a well-defined accumulation of pitch in the wood cells in a more or less regular streak. Pitch streaks are described approximately as follows, with equivalent areas being permissible:

   16.1 Very small pitch streak is \(\frac{3}{8}\) inch (9.5 mm) in width and 15 inches (381 mm) in length.
   16.2 Small pitch streak is one twelfth the width and one sixth the length of the piece.
   16.3 Medium pitch streak is one sixth the width and one third the length of the piece.
   16.4 A large pitch streak is not over one fourth the width by one half the length of the surface.
   16.5 A very large pitch streak is over one fourth the width by one half the length of the surface.
   16.6 A pitch seam is a shake or check which contains pitch.

17. PITH. Pith is the small soft core in the structural center of a log.

   17.1 Very small pith is not over \(\frac{1}{8}\) inch (3.2 mm) wide and occupies on face surface not over \(\frac{1}{4}\) square inch \((161 \text{ mm}^2)\) \(\frac{1}{8}\) inch wide by 2 inches long (3.2 mm wide by 51 mm long), or \(\frac{1}{16}\) inch by 4 inches (1.6 mm by 102 mm).
   17.2 Small pith occupies not over \(\frac{3}{4}\) square inch \((484 \text{ mm}^2)\) \(\frac{1}{8}\) inch by 3 inches (3.2 mm by 76 mm), \(\frac{3}{16}\) inch by 4 inches (4.8 mm by 102 mm), \(\frac{1}{8}\) inch by 6 inches (3.2 mm by 152 mm), or \(\frac{1}{16}\) inch by 12 inches (1.6 mm by 305 mm).
   17.3 Free of pith means that pith on or within the body of the piece is prohibited.

18. POCKET. A well-defined opening between the rings of annual growth which develops during the growth of the tree. It usually contains pitch or bark.

Pockets are described approximately as follows with equivalent areas being permissible:

   18.1 Very small pocket is \(\frac{1}{16}\) inch (1.6 mm) in width and 3 inches (76 mm) in length, or \(\frac{1}{8}\) inch (3.2 mm) in width and 2 inches (51 mm) in length.
   18.2 Small pocket is \(\frac{1}{16}\) inch (1.6 mm) in width and 6 inches (152 mm) in length, or \(\frac{1}{8}\) inch (3.2 mm) in width and 4 inches (102 mm) in length, or \(\frac{1}{4}\) inch (6.4 mm) in width and 2 inches (51 mm) in length.
   18.3 Medium pocket is \(\frac{1}{16}\) inch (1.6 mm) in width and 12 inches (305 mm) in length, or \(\frac{1}{8}\) inch (3.2 mm) in width and 8 inches (203 mm) in length, or \(\frac{3}{8}\) inch (9.5 mm) in width and 4 inches (102 mm) in length.
   18.4 A large pocket is not over 4 square inches \((2581 \text{ mm}^2)\) in area.
   18.5 A very large pocket is over 4 square inches \((2581 \text{ mm}^2)\) in area.

19. PLUGS AND FILLERS. Wood plugs and fillers are inserted into pieces of lumber to improve their appearance and usefulness. Quality of the inserts and workmanship must be in keeping with the quality of the grade. In dimension and other lumber graded for strength, inserts are limited to the same size and location as knots.

20. SAPWOOD. Outer layers of growth between the bark and the heartwood which contain the sap. In redwood, the layers of the cream-colored wood between the bark and heartwood.

   20.1 Bright sapwood shows no stain and is not limited in any grade except as specifically provided.
   20.2 Sapwood restrictions waived means that any restrictions in a rule on the amount of sapwood permitted in pieces graded under that rule are not to apply.
   20.3 Bright sapwood no defect (BSND) means that bright sapwood is permitted in each piece in any amount.
20.4 Bright sapwood, unless specifically restricted, is not limited in any grade. It is not limited if treated with anti-stain solution, kiln dried or air dried.

21. **SAW-SIZED.** Lumber sawn to size but permitting in 20 percent of the pieces a manufacturing tolerance of 1/32 inch (0.8 mm) under; in addition, an oversize tolerance of 1/8 inch (3.2 mm) is permitted.

Sized dimension lumber is uniformly manufactured to the net surfaced sizes and may be rough, surfaced or partially surfaced on one or more faces. When opposing faces are rough, a variation over size of 1/32 inch (0.8 mm) is permitted in No. 2 and better and Standard and better and, in addition, a variation of 1/16 inch (0.8 mm) undersize in 20 percent of the pieces is permitted. In Stud, Utility and No. 3, a variation of 1/8 inch (4.2 mm) over or under is acceptable in 20 percent of the pieces. When grade-stamped, sized dimension lumber must be identified as sized (SZD).

22. **SHAKE.** A lengthwise separation of the wood which usually occurs between or through the rings of annual growth.

22.1 A light shake is not over 1/32 inch (0.8 mm) wide.

22.2 A medium shake is not over 1/16 inch (3.2 mm) wide.

22.3 A surface shake occurs on only one surface of a piece. A fine shake is one with a barely perceptible opening.

22.4 A through shake extends from one surface of a piece to the opposite or to an adjoining surface.

22.5 A pith shake (or heart shake or heart check) extends through the growth rings from or through the pith toward the surface of a piece. and can be distinguished from a season check by the fact that its greatest width is nearest the pith whereas the greatest width of a season check in a pith-centered piece is farthest from the pith.

22.6 A ring shake occurs between the growth rings to partially or wholly encircle the pith.

23. **SPLITS.** A separation of the wood due to the tearing apart of the wood cells.

23.1 A very short split is equal in length to one half the width of the piece.

23.2 A short split is equal in length to the width of the piece and in no case exceeds one sixth the length.

23.3 A medium split is equal in length to twice the width of the piece and in no case exceeds one sixth the length.

23.4 A long split is longer than a medium split.

24. **STRESS GRADES.** Lumber grades having assigned working stress and modulus of elasticity values in accordance with accepted basic principles of strength grading.

25. **TRIMMING.** The act of crosscutting a piece to a given length.

26. **WANE DIP.** A dip extending across a surface to occupy full surface for a part of length.

26.1 A very short wane dip occupies full surface for not over 4 inches (102 mm) of length.

26.2 A short wane dip occupies full surface for not over 16 inches (406 mm) of length.

27. **WARP.** Any deviation from a true or plane surface, including bow, crook, cup and twist or any combination thereof. Warp restrictions are based on the average form of warp as it occurs normally, and any variation from this average form, such as short kinks, shall be appraised according to its equivalent effect. Pieces containing two or more forms shall be appraised according to the combined effect in determining the amount permissible. In these rules warp is classified as very light, light, medium and heavy, and applied to each width and length as set forth in the various grades in accordance with the following provisions and tables:

27.1 Bow is a deviation flatwise from a straight line drawn from end to end of a piece. It is measured at the point of greatest distance from the straight line. The amount permitted according
to the grade is as follows: If under 2 inches (51 mm) thick, three times as much as crook permitted for 2-inch (51 mm) faces. If 2 inches (51 mm) thick and under 3 inches (76 mm), twice as much as crook permitted for 2-inch (51 mm) faces. If 3 inches (76 mm) thick and over, the same as the amount of crook permitted for that thickness.

27.2 Crook is a deviation edgewise from a straight line drawn from end to end of a piece. It is measured at the point of greatest distance from the straight line. For amount permitted, see Table 23-1-F.

27.3 Cup is a deviation in the face of a piece from a straight line drawn from edge to edge of a piece. It is measured at the point of greatest distance from the straight line. The amount of cup shall not exceed the following:

<table>
<thead>
<tr>
<th>FACE WIDTH</th>
<th>2&quot; and 3&quot;</th>
<th>4&quot;</th>
<th>5&quot; and 6&quot;</th>
<th>8&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>10&quot;</td>
<td>1/32&quot;</td>
<td>1/32&quot;</td>
<td>1/32&quot;</td>
<td>1/16&quot;</td>
</tr>
<tr>
<td>12&quot;</td>
<td>1/16&quot;</td>
<td>1/16&quot;</td>
<td>1/8&quot;</td>
<td>3/16&quot;</td>
</tr>
<tr>
<td>14&quot; AND WIDER</td>
<td>Proportionately more</td>
<td>Proportionately more</td>
<td>Proportionately more</td>
<td></td>
</tr>
</tbody>
</table>

27.4 Twist is a deviation flatwise, or a combination of flatwise and edgewise, in the form of a curl or spiral, and the amount is the distance an edge of a piece at one end is raised above a flat surface against which both edges at the opposite end are resting snugly. For amount permitted, see Table 23-1-G.

SECTION 23.109 — GRADE MARKING (STAMPING)

23.109.1 The Grade Mark (Stamp). Lumber which is grade marked under this standard shall comply with the following:

1. The grade mark shall signify that the lumber conforms to the size, grade and seasoning provisions of the rules under which it is graded. When green lumber thinner than 5-inch (127 mm) nominal is graded and grade marked under the applicable grading rules, it shall comply with the green size requirements of such rules. If lumber is dressed to a size below minimum requirements or below the minimum sizes set forth in the applicable grading rules, the mark shall show size, and if thinner than 5-inch (127 mm) nominal, in addition, shall state whether the lumber was dry or green when dressed. If lumber is dressed to less than the standard thickness of 1-inch (25 mm) nominal, the mark shall show the dressed thickness and whether the lumber was green or dry when dressed.

2. The grade mark shall include an approved, easily distinguishable mark or insignia of the grading agency which has been approved by an accreditation body which complies with the requirements of U.S. Department of Commerce PS 20-70, or equivalent.

3. All pieces of a given grade shall be grade marked.

4. Mixed grades other than the two highest recognized grades for each grading rule category for each species shall not be grade marked with a combination grade designation; if grade marking is required, each piece shall be marked as of its actual grade.

5. The grade mark for structural lumber, except machine graded lumber, shall include an identification or designation of the commercial name of the species from which the lumber was produced. The identification of species will not be required when the agency symbol also indicates the species.
from which the lumber was produced. Where grading rules contain provisions for the grouping of species, each individual species included in a group shall be identified in the rules and the grade mark will include the designation assigned to the group.

6. A certified agency may provide further regulations for the use of its grade mark, provided the basic provisions of this section are observed.

23.109.2 Delegation of Grading Authority. Permission to grade mark may be delegated by any approved agency that participates in an accreditation program, such as the American Lumber Standards Committee, that operates a mill supervisory service.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>THICKNESSES</th>
<th>FACE WIDTHS</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Nominal</td>
<td>Minimum Dressed</td>
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<td></td>
<td>(inches)</td>
<td>(inches)</td>
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<td></td>
<td>× 25.4 for mm</td>
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<tr>
<td>Flooring¹</td>
<td>3/8</td>
<td>5/16</td>
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<td></td>
<td>1/2</td>
<td>7/16</td>
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<td>9/16</td>
<td>9/16</td>
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<tr>
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<td>1</td>
<td>3/4</td>
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<td></td>
<td>1 1/4</td>
<td>1</td>
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<tr>
<td>Partition¹</td>
<td>1 1/2</td>
<td>1 1/4</td>
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<td>1</td>
<td>2 1/4</td>
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<tr>
<td></td>
<td>2 1/4</td>
<td>2 1/32</td>
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<td></td>
<td>2 1/4</td>
<td>2 1/32</td>
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</tbody>
</table>

¹In tongued-and-grooved flooring 7/16-inch (11 mm), and 9/16-inch (14 mm) dressed thicknesses, the tongue or lap shall be 3/16 inch (4.8 mm) wide, with the overall widths 5/16-inch (4.8 mm) wider than the face widths shown. In all other worked lumber of dressed thicknesses of 3/8 inch to 1 1/4 inches (16 mm to 32 mm), the tongue shall be 1 1/4 inch (6.4 mm) wide or wider and the overall widths shall not be less than the dressed face widths shown in the above table plus the width of the tongue or lap.
TABLE 23-1-B—NOMINAL AND MINIMUM-DRESSED DRY SIZES OF SIDING AT 19 PERCENT MAXIMUM-MOISTURE CONTENT

(The thicknesses apply to all widths and all widths to all thicknesses.)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>Thicknesses</th>
<th>Face Widths</th>
<th>Nominal</th>
<th>Minimum Dressed</th>
<th>Nominal</th>
<th>Minimum Dressed</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nominal</td>
<td>Inches</td>
<td>Inches</td>
<td>Inches</td>
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<tr>
<td>Bevel siding</td>
<td>1/2</td>
<td>7/16 butt, 3/16 tip</td>
<td>4</td>
<td>3 1/2</td>
<td>4</td>
<td>3 1/2</td>
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<tr>
<td></td>
<td>9/16</td>
<td>15/32 butt, 3/16 tip</td>
<td>5</td>
<td>4 1/2</td>
<td>5</td>
<td>4 1/2</td>
</tr>
<tr>
<td></td>
<td>5/8</td>
<td>9/16 butt, 3/16 tip</td>
<td>6</td>
<td>5 1/2</td>
<td>6</td>
<td>5 1/2</td>
</tr>
<tr>
<td></td>
<td>3/4</td>
<td>11/32 butt, 3/16 tip</td>
<td>8</td>
<td>7 1/4</td>
<td>8</td>
<td>7 1/4</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>3/16 butt, 3/16 tip</td>
<td>10</td>
<td>9 1/4</td>
<td>10</td>
<td>9 1/4</td>
</tr>
<tr>
<td></td>
<td>3/4</td>
<td>11/32 butt, 3/16 tip</td>
<td>12</td>
<td>11 1/16</td>
<td>12</td>
<td>11 1/16</td>
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<tr>
<td>Rustic and drop siding</td>
<td>3/8</td>
<td>9/16</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
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<tr>
<td>[shiplapped, 3/8-in. (9.5 mm) lap]</td>
<td></td>
<td>23/32</td>
<td>5</td>
<td>4</td>
<td>5</td>
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<td>1</td>
<td>23/32</td>
<td>6</td>
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<tr>
<td>Rustic and drop siding</td>
<td>5/8</td>
<td>9/16</td>
<td>4</td>
<td>2 7/8</td>
<td>4</td>
<td>2 7/8</td>
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<tr>
<td>[shiplapped, 1/2-in. (13 mm) lap]</td>
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<td>23/32</td>
<td>5</td>
<td>3 1/8</td>
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<td>1</td>
<td>23/32</td>
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<td>4 1/8</td>
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<td>Rustic and drop siding</td>
<td>5/8</td>
<td>9/16</td>
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<td>(dressed and matched)</td>
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<td>23/32</td>
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</tbody>
</table>
# TABLE 23-1-C—NOMINAL AND MINIMUM-DRESSED SIZES OF BOARDS, DIMENSION, AND TIMBERS

(The thicknesses apply to all widths and all widths to all thicknesses.)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>THICKNESSES</th>
<th>FACE WIDTHS</th>
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<tbody>
<tr>
<td></td>
<td>Minimum Dressed Nominal</td>
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<td>Dry (inches)</td>
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</tbody>
</table>

1 Boards less than the minimum thickness for 1-inch (25 mm) nominal but 1/4 inch (16 mm) or greater thickness dry [1/16 inch (17 mm) green] may be regarded as American Standard Lumber, but such boards shall be marked to show the size and condition of seasoning at the time of dressing. They shall also be distinguished from 1-inch (25 mm) boards on invoices and certificates.
TABLE 23-1-D—NOMINAL AND MINIMUM-DRESSED SIZES OF  
[2 INCH (51 mm) AND UNDER] SHIPLAP, CENTERMATCH, AND D & M

(The thicknesses apply to all widths and all widths to all thicknesses.)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>THICKNESSES</th>
<th>FACE WIDTHS</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Minimum Dressed</td>
<td>Minimum Dressed</td>
</tr>
<tr>
<td></td>
<td>Nominal (Inches)</td>
<td>Dry (Inches)</td>
</tr>
<tr>
<td></td>
<td>× 25.4 for mm</td>
<td></td>
</tr>
<tr>
<td>Shiplap, 3/8-inch (9.5 mm) lap</td>
<td>1</td>
<td>3/4</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>5/8</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>7/8</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>7/8</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>7/8</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>7/8</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>7/8</td>
</tr>
<tr>
<td>Shiplap, 1/2-inch (13 mm) lap</td>
<td>1</td>
<td>3/8</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>8</td>
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<td>7 1/4</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>7 1/4</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>7 1/4</td>
</tr>
<tr>
<td>Centermatch, 1/4-inch (6.4 mm) tongue</td>
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<td>1 1/2</td>
</tr>
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<td></td>
<td>1 1/2</td>
<td>1 1/4</td>
</tr>
<tr>
<td></td>
<td>1 1/2</td>
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<td>1 1/2</td>
<td>1 1/4</td>
</tr>
<tr>
<td></td>
<td>1 1/2</td>
<td>1 1/4</td>
</tr>
<tr>
<td>2-inch (51 mm) D &amp; M, 3/8-inch (9.5 mm) tongue</td>
<td>2</td>
<td>1 1/2</td>
</tr>
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<td>10</td>
<td>7 1/4</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>7 1/4</td>
</tr>
<tr>
<td>2-inch (51 mm) shiplap, 1/2-inch (13 mm) tongue</td>
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<td>1 1/2</td>
</tr>
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<td>5</td>
</tr>
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<td></td>
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</tr>
<tr>
<td></td>
<td>12</td>
<td>7 1/4</td>
</tr>
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</table>
### TABLE 23-1-E—WORKED LUMBER SUCH AS FACTORY FLOORING, HEAVY ROOFING, DECKING, AND SHEET PILING

(The thicknesses apply to all widths and all widths to all thicknesses.)

(See note.)

<table>
<thead>
<tr>
<th>THICKNESSES&lt;sup&gt;1&lt;/sup&gt;</th>
<th>FACE WIDTHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal</td>
<td>Minimum Dressed (Inches)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TONGUED AND GROOVED</th>
<th>25.4 for mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td>Green</td>
</tr>
<tr>
<td>2 1/2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>2 1/2</td>
</tr>
<tr>
<td>3 1/2</td>
<td>3</td>
</tr>
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<td>4</td>
<td>3 1/2</td>
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<tr>
<td>4 1/2</td>
<td>4</td>
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</tbody>
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<table>
<thead>
<tr>
<th>SHIPLAP</th>
<th>25.4 for mm</th>
</tr>
</thead>
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<tr>
<td>Dry</td>
<td>Green</td>
</tr>
<tr>
<td>2 1/2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>2 1/2</td>
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<td>4</td>
<td>3 1/2</td>
</tr>
<tr>
<td>4 1/2</td>
<td>4</td>
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</tbody>
</table>

<table>
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<th>GROOVED FOR SPLINES</th>
<th>25.4 for mm</th>
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</thead>
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<td>Green</td>
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<td>3 1/2</td>
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<tr>
<td>4 1/2</td>
<td>4</td>
</tr>
</tbody>
</table>

**NOTE:** In worked lumber of nominal thicknesses of 2 inches (51 mm) and over, the tongue shall be 3/16 inch (9.5 mm) wide in tongued-and-grooved lumber and the lap 1/2 inch (13 mm) wide in shiplapped lumber, with the overall widths 3/16 inch (9.5 mm) and 1/2 inch (13 mm) wider, respectively, than the face widths shown. Double tongued-and-grooved decking may be manufactured with a 3/16-inch (7.9 mm) tongue.

<sup>1</sup>See Table 23-1-C for information on 2-inch (51 mm) dimension.

3-694
<table>
<thead>
<tr>
<th>LENGTH IN FEET</th>
<th>DESCRIPTION</th>
<th>WIDTH OF PIECE x 25.4 for mm</th>
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<td></td>
<td></td>
<td>2&quot;</td>
</tr>
<tr>
<td>4 and 6</td>
<td>Very light</td>
<td>1/16</td>
</tr>
<tr>
<td></td>
<td>Light</td>
<td>1/8</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>3/64</td>
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<td>1/2</td>
</tr>
<tr>
<td>8</td>
<td>Very light</td>
<td>1/8</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>1/2</td>
</tr>
<tr>
<td></td>
<td>Light</td>
<td>1/2</td>
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3–695
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<th>Length in Feet</th>
<th>Description</th>
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<th>3&quot;, 4&quot;</th>
<th>5&quot;, 6&quot;</th>
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<td>1/4</td>
<td>5/16</td>
<td>3/8</td>
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<tr>
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<td>1/8</td>
<td>3/8</td>
<td>1/2</td>
<td>5/8</td>
<td>3/4</td>
<td>3/4</td>
</tr>
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<td>Medium</td>
<td>3/16</td>
<td>1/2</td>
<td>3/4</td>
<td>1</td>
<td>11/4</td>
<td>11/2</td>
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<td></td>
<td>Heavy</td>
<td>1/4</td>
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<td>11/8</td>
<td>11/2</td>
<td>17/8</td>
<td>2</td>
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<tr>
<td>6</td>
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<td>3/32</td>
<td>3/16</td>
<td>5/16</td>
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<td>7/16</td>
<td>9/16</td>
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<tr>
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<td>Medium</td>
<td>9/32</td>
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<td>3/4</td>
<td>1</td>
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<td>3/4</td>
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<td>1</td>
<td>17/8</td>
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<td>5/8</td>
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<td>3/4</td>
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<td>1</td>
<td>17/8</td>
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<td>7/4</td>
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<td>3/4</td>
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<td>2 1/8</td>
<td>3</td>
<td>31/8</td>
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</tr>
<tr>
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<td>3/4</td>
<td>1</td>
<td>11/4</td>
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<td>1 1/2</td>
<td>2 1/4</td>
<td>3</td>
<td>31/8</td>
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<td>4</td>
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<td>11/16</td>
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<td>2 1/4</td>
<td>3</td>
<td>31/8</td>
<td>6</td>
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<td>20 and longer</td>
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<td>5/16</td>
<td>5/8</td>
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<td>3 1/4</td>
<td>5</td>
<td>61/4</td>
<td>7/2</td>
</tr>
</tbody>
</table>
Maximum Size of Knots Permitted in Various Parts of Joists and Planks, and Beams and Stringers:

A, maximum size on narrow face in middle third of length with a uniform increase to 2A but not to exceed B, at the ends.

B, maximum size at center of wide face.

C, maximum size at edge of wide face in middle third of length with a uniform increase to 2C but not to exceed B at the ends and a uniform increase to B at the center of the wide face. In beams and stringers, A and C are equal.

L, length.

W, width of side face.

T, width of narrow face.

**FIGURE 23-1-1**

Measurement of Knots in Joists and Planks

**FIGURE 23-1-2**

Measurement of Knots in Beams and Stringers

**FIGURE 23-1-3**

Measurement of Knots in Posts and Timbers or Other Compression Members

**FIGURE 23-1-4**

Measurement of Knots (see also Section 23.106)
APPENDIX A—NOMENCLATURE OF COMMERCIAL SOFTWOODS

The following commercial names for lumber cut from the principal species of softwoods should be used in grading rule description and in specifications.

<table>
<thead>
<tr>
<th>COMMERCIAL NAMES FOR LUMBER</th>
<th>OFFICIAL COMMON TREE NAMES</th>
<th>BOTANICAL NAMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alaska Cedar</td>
<td>Alaska cedar</td>
<td><em>Chamaecyparis nootkatensis.</em></td>
</tr>
<tr>
<td>Incense Cedar</td>
<td>incense cedar</td>
<td><em>Libocedrus decurrens.</em></td>
</tr>
<tr>
<td>Port Orford Cedar</td>
<td>Port Orford cedar</td>
<td><em>Chamaecyparis lawsoniana.</em></td>
</tr>
<tr>
<td>Eastern Red Cedar</td>
<td>eastern red cedar</td>
<td><em>Juniperus virginiana.</em></td>
</tr>
<tr>
<td>Western Red Cedar</td>
<td>western red cedar</td>
<td><em>Thuja plicata.</em></td>
</tr>
<tr>
<td>Northern White Cedar</td>
<td>northern white cedar</td>
<td><em>Thuja occidentalis.</em></td>
</tr>
<tr>
<td>Southern White Cedar</td>
<td>Atlantic white cedar</td>
<td><em>Chamaecyparis thyoides.</em></td>
</tr>
<tr>
<td>Balsam Fir</td>
<td>balsam fir</td>
<td><em>Abies balsamea.</em></td>
</tr>
<tr>
<td>Douglas Fir</td>
<td>Douglas fir</td>
<td><em>Pseudotsuga taxifolia.</em></td>
</tr>
<tr>
<td>Noble Fir</td>
<td>noble fir</td>
<td><em>Abies procera.</em></td>
</tr>
<tr>
<td>White Fir</td>
<td>alpine fir</td>
<td><em>Abies lasiocarpa.</em></td>
</tr>
<tr>
<td></td>
<td>California red fir</td>
<td><em>Abies magnifica.</em></td>
</tr>
<tr>
<td></td>
<td>grand fir</td>
<td><em>Abies grandis.</em></td>
</tr>
<tr>
<td></td>
<td>noble fir</td>
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<td><em>Abies concolor.</em></td>
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<td><em>Tsuga canadensis.</em></td>
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<td><em>Tsuga heterophylla.</em></td>
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<td><em>Tsuga heterophylla.</em></td>
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<td>alligator juniper</td>
<td><em>Juniperus deppeana.</em></td>
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<td><em>Juniperus scopolorum.</em></td>
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<td>Utah juniper</td>
<td><em>Juniperus osteosperma.</em></td>
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<td><em>Pinus palustris.</em></td>
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<td>slash pine</td>
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<td><em>Picea pungens.</em></td>
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<td>Pacific Yew</td>
<td>Pacific yew</td>
<td><em>Taxus brevifolia.</em></td>
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APPENDIX B

A Glossary of Lumber Terms

(See also Section 23.108)

A
AIR DRIED, seasoned by exposure to the atmosphere, in the open or under cover, without artificial heat.

ALL-HEART, of heartwood throughout; that is, free of sapwood.

ANNUAL RING, growth put on in a single year.

B
BARK POCKET, patch or bark partially or wholly enclosed in the wood. Classified as are pitch pockets.

BLEMISH, anything marring the appearance of lumber.

BOXED PITH, where the pith is enclosed within the four sides of the piece.

BRIGHT, unstained.

C
CHARACTERISTICS, distinguishing features which, by their extent and number, determine the quality of a piece of lumber.

CLEAR, free or practically free of all blemishes, characteristics, or defects.

COMPRESSION WOOD, abnormal wood that forms on the under side of leaning and crooked coniferous trees. It is characterized, aside from its distinguishing color, by being hard and brittle and by its relatively lifeless appearance.

CORNER, the intersection of two adjacent faces.

CROOK, see "warp."

CROSS BREAK, separation of the wood across the width.

CROSSCUTTING, cutting with a saw across the width.

CUP, see "warp."

CUTTING, resulting pieces after crosscutting and/or ripping.

D
DEGRADES, pieces which on reinspection prove of lower quality than the grade in which they were shipped.

DIAGONAL GRAIN, a deviation of the grain from a line parallel to the edges, which results from sawing a piece of lumber at an angle other than parallel with the bark.

DOUBLE END TRIMMED, trimmed reasonably square by a saw on both ends.

F
FIRM RED HEART, a stage of incipient decay characterized by a reddish color in the heartwood, which does not unfit the wood for the majority of yard purposes. (Not to be confused with natural red heartwood in some species.)

G
GROWTH RING, the growth put on in a single year.

GUM POCKET, an opening between growth rings which usually contains or has contained resin or bark, or both.

GUM SEAM, check or shake filled with gum.

GUM SPOT, accumulation of gumlike substance occurring as a small patch. May occur in conjunction with a birdpeck or other injury to the growing wood.

GUM STREAK, well-defined accumulation of gum in more or less regular streak. Classified as are pitch streaks.

H
HEART FACE, face side free of sapwood.

HEARTWOOD, inner core of the tree trunk comprising the annual rings containing non-living elements; usually darker in color than sapwood.

HONEYCOMB (DECAY), honeycomb is indicated by large pits in the wood.

K
KILN-DRIED, seasoned in a chamber by means of artificial heat.

KNOT, branch or limb embedded in the tree and cut through in the process of lumber manufacture; classified according to size, quality, and occurrence. To determine the size of a knot, average the maximum length and maximum width, unless otherwise specified.

LARGE KNOT, over 1 1/2 inches (38 mm) in diameter.

MEDIUM KNOT, over 3/4 inch (19 mm), but not over 1 1/2 inches (38 mm) in diameter.
PIN KNOT, not over 1/2 inch (13 mm) in diameter.

SMALL KNOT, over 1/2 inch (13 mm), but not over 1/4 inch (19 mm) in diameter.

PECK, channelled or pitted areas or pockets as sometimes found in cedar and cypress.

PITCH, accumulation of resin in the wood cells in a more or less irregular patch.

HEAVY PITCH, very evident presence of pitch showing by its color and consistency.

LIGHT PITCH, lightly evident presence of pitch.

MASSED PITCH, clearly defined accumulation of solid pitch in a body by itself.

MEDIUM PITCH, trace of pitch slightly more evident than light pitch.

PITCH POCKET, an opening between growth rings which usually contains or has contained resin or bark, or both.

CLOSED PITCH POCKET, does not show an opening on both sides of the piece.

LARGE PITCH POCKET, width or length exceeds the maximum permissible for medium pitch pocket.

MEDIUM PITCH POCKET, not over 1/8 inch (3.2 mm) in width and not over 8 inches (203 mm) in length; or not over 1/4 inch (9.5 mm) in width and not over 4 inches (102 mm) in length.

OPEN (THROUGH) PITCH POCKET, is cut across on both sides of the piece.

SMALL PITCH POCKET, not over 1/8 inch (3.2 mm) in width and not over 4 inches (102 mm) in length, or not over 1/4 inch (6.4 mm) in width and not over 2 inches (51 mm) in length.

VERY SMALL PITCH POCKET, not over 1/8 inch (3.2 mm) in width and not over 2 inches (51 mm) in length.

PITCH SEAM, shake or check filled with pitch.

PITH, small soft core in the structural center of a log.

BOXED PITH, where the pith is within the four faces of an end of a piece.

PITH FLECK, narrow streak resembling pith on the surface of a piece, usually brownish, up to several inches (1 inch = 25.4 mm) in length, resulting from burrowing of larvae in the growing tissue of the tree.

R

RAISED GRAIN, roughened condition of the surface of dressed lumber in which the hard summerwood is raised above the softer springwood, but not torn loose from it.

S

SAPWOOD, outer layers of growth in a tree, exclusive of bark, which contain living elements; usually lighter in color than heartwood.

SAW BUTTED, trimmed by a saw on both ends.

SEASONING, evaporation or extraction of moisture from green or partially dried wood.

SIDE CUT, where the pith is not enclosed within the four sides of the piece.

SLOPE OF GRAIN, cross grain or deviation of the fiber from a line parallel to the sides of the piece, and may consist of diagonal grain, spiral grain, or both.

MEDIUM CROSS GRAIN, slope of grain more than 1 inch (25 mm) in a length of 15 inches (203 mm), but not more than 1 inch (25 mm) in a length of 8 inches (203 mm).

SLIGHT CROSS GRAIN, slope of grain not more than 1 inch (25 mm) in a length of 15 inches (381 mm).

STEEP CROSS GRAIN, slope of grain more than 1 inch (25 mm) in a length of 8 inches (203 mm).

STRAIGHT GRAIN, slope of grain limited to 1 inch (25 mm) each 20 inches (508 mm) of length.

SMOKE-DRIED, seasoned by exposure to the heat and smoke of fire maintained beneath or within the stacks of lumber.

SOFTWOOD, one of the group of trees which have needle-like or scale-like leaves. The term has no specific reference to the softness of the wood.

SOUND, free of decay.

SPIRAL GRAIN, fibers that extend spirally about instead of vertically along the bole of a tree.

SPRINGWOOD, more or less open and porous tissue marking the inner part of each annual ring, formed early in the period of growth.

STAIN, discoloration on or in lumber other than its natural color.
HEAVY STAIN, difference in color so pronounced as practically to obscure the grain of the wood.

LIGHT STAIN, slight difference in color which will not materially impair the appearance of the piece if given a natural finish.

MEDIUM STAIN, pronounced difference in color which, although it does not obscure the grain of the wood, is customarily objectionable in a natural but not in a painted finish.

SUMMERWOOD, denser fibrous outer portion of each annual ring, usually without conspicuous pores, formed late in the growing period, not necessarily in summer.

UNSOUND, decayed.

VARIATION IN SAWING, a deviation from the line of cut. Slight variation is not over 1/16 inch scant in 1-inch (1.6 mm scant in 25 mm) lumber, 1/8 inch in 2-inch (3.2 mm in 51 mm), 3/16 inch in 3 inches to 7 inches (4.8 mm in 76 to 178 mm), and 1/4 inch in 8-inch (6.4 mm in 203 mm) and up.

WANE, this is bark or lack of wood from any cause on the edge or corner of a piece.

MEDIUM WANE, over 1/4 inch (6.4 mm), but not over 1/2 inch (13 mm) wide on the surface on which it appears, for one sixth of the length and one fourth of the thickness of the piece.

LARGE WANE, over 1/2 inch (13 mm) wide on the surface on which it appears, or over one sixth of the length and one fourth of the thickness of the piece, or both.

SLIGHT WANE, not over 1/4 inch (6.4 mm) wide on the surface on which it appears for one sixth of the length and one fourth of the thickness of the piece.

WARP, any variation from a true or plane surface, includes bow, crook, cup, or any combination thereof.

BOW, deviation flatwise from a straight line from end to end of a piece, measured at the point of greatest distance from the straight line.

CROOK, deviation edgewise from a straight line from end to end of a piece, measured at the point of greatest distance from the straight line; and classified as slight, small, medium and large. Based on a piece 4 inches (102 mm) wide and 16 feet (4880 mm) long, the distance for each degree of crook shall be: slight crook, 1 inch (25 mm); small crook, 1 1/2 inches (38 mm); medium crook, 3 inches (76 mm); and large crook, over 3 inches (76 mm). For wider pieces it shall be 1/8 inch (3.2 mm) less for each additional 2 inches (51 mm) of width. Shorter or longer pieces may have the same curvature.

CUP, deviation flatwise from a straight line across the width of a piece, measured at the point of greatest distance from the line; and classified as slight, medium and deep. Based on a piece 12 inches (305 mm) wide, the distance from each degree of cup shall be: slight cup, 1/4 inch (6.4 mm); medium cup, 3/8 inch (9.5 mm); and deep cup, 1/2 inch (13 mm). Narrower or wider pieces may have the same curvature.
UNIFORM BUILDING CODE STANDARD 23-2
CONSTRUCTION AND INDUSTRIAL PLYWOOD

Based on Product Standard PS 1-83 (for Construction and Industrial Plywood) of the United States Department of Commerce, and National Bureau of Standards Calculation of Diaphragm Action, an Engineering Standard of the International Conference of Building Officials


SECTION 23.201 — SCOPE

23.201.1 General. This standard covers construction and industrial plywood for both Exterior and Interior types. This standard also covers construction and industrial hardwood plywood of red and white lauan (Philippine mahogany), tanoak, red alder and western poplar.

23.201.2 Wood Species. Plywood produced under this standard considers four species classifications: Groups I, 2, 3 and 4. The species used for the face and back plies are at the option of the manufacturer. When face and back veneers are of the same species group, the panels shall be identified as being of that species group. The species covered in each group are set forth in Table 23-2-A. In addition, other softwood or hardwood species having an average specific gravity of 0.41 or more, based on green volume and oven dry weight, may be used for inner plies except as required for premium grades in Section 23.205.

SECTION 23.202 — DEFINITIONS

General definitions not included in the following section are to be interpreted as defined in U.B.C. Standard 23-1.

BACK is the side of a panel that is of lower veneer quality on any panel whose outer plies are of different veneer grades.

BORER HOLES are voids made by wood-boring insects, such as grubs or worms.

BROKEN GRAIN is a (leafing, shelling, grain separation) separation on veneer surface between annual rings.

CENTERS are inner plies whose grain direction runs parallel to that of the outer plies. May be of parallel laminated plies.

CHECK is a lengthwise separation of wood fibers, usually extending across the rings of annual growth caused chiefly by strains produced in seasoning.

CLASS I, CLASS II are terms used to identify different species group combinations of B-B concrete form panels. The standard provides for two classes, Class I and Class II, as described in Section 23.205.3.

CORE is sometimes referred to as a crossband.

CROSSBANDS are inner layers whose grain direction runs perpendicular to that of the outer plies. They may be of parallel laminated plies and are sometimes referred to as core.

CROSSBAND GAP and CENTER GAP are open joints extending through or partially through a panel, which results when crossband or center veneers are not tightly butted.

DEFECTS, OPEN, are irregularities such as splits, open joints, knotholes, or loose knots, that interrupt the smooth continuity of the veneer.

DELAMINATION is a visible separation between plies that would normally receive glue at their interface and be firmly contacted in the pressing operation. Wood characteristics, such as
checking, leafing, splitting and broken grain, are not to be construed as delamination. See corresponding definition for those terms.

1. For purposes of reinspection, areas coinciding with open knotholes, pitch pockets, splits and gaps and other voids or characteristics permitted in the panel grade are not considered in evaluating ply separation of Interior-type panels bonded with interior or intermediate glue.

2. In evaluating Interior panels bonded with exterior glue, delamination in any glueline shall not exceed 3 square inches (1935 mm$^2$) except where directly attributable to defects permitted in the grade as follows:

Delamination associated with:

2.1 Knots and knotholes—shall not exceed the size of the defect plus a surrounding band not wider than $\frac{3}{4}$ inch (19 mm).

2.2 All other forms of permissible defects—shall not exceed the size of the defect.

3. In evaluating Exterior-type panels for ply separation, the area coinciding with the grade characteristics noted in Item 1 are considered, and a panel is considered delaminated if visible ply separation at a single glueline in such area exceeds 3 square inches (1935 mm$^2$).

EDGE Splits are wedge-shaped openings in the inner plies caused by splitting of the veneer before pressing.

FACE is the better side of any panel whose outer plies are of different veneer grades; also either side of a panel where the grading rules draw no distinction between faces.

GROUP is the term used to classify species covered by this standard in an order that provides a basis for simplified marketing and efficient utilization. Species covered by the standard are classified as Groups 1, 2, 3 and 4. See Table 23-2-A for listing of species in individual groups.

HEARTWOOD is the nonactive core of a log generally distinguishable from the outer portion (sapwood) by its darker color.

INNER PLIES are other than exposed face and back plies in a panel construction.

JOINTED INNER PLIES are crossband and center veneer that have had edges machinesquared to permit tightest possible layup.

KNOT is a natural characteristic of wood that occurs where a branch base is embedded in the trunk of a tree. Generally the size of a knot is distinguishable by (1) a difference in color of limbwood and surrounding trunkwood; (2) abrupt change in growth ring width between knot and bordering trunkwood; and (3) diameter of circular or oval shape described by points where checks on the face of a knot that extend radially from its center to its side experience abrupt change in direction.

KNOTHOLES are voids produced by the dropping of knots from the wood in which they are originally embedded.

LAP is a condition where the veneers are so placed that one piece overlaps the other.

LAYER is a single veneer ply or two or more plies laminated with grain direction parallel. Two or more plies laminated with grain direction parallel is a parallel laminated layer.

NOMINAL THICKNESS is full “designated” thickness. For example, $\frac{1}{10}$-inch (2.5 mm) nominal veneer is 0.10 inch (2.5 mm) thick. Nominal $\frac{1}{2}$-inch-thick (13 mm) panel is 0.50 inch (13 mm) thick. Also, commercial size designations are subject to acceptable tolerances.

PATCHES are insertions of sound wood or synthetic material in veneers or panels for replacing defects. “Boat” patches are oval shaped with sides tapering in each direction to a point or to a small rounded end. “Router” patches have parallel sides and rounded ends. “Sled” patches are rectangular with feathered ends.

PITCH POCKET is a well-defined opening between rings of annual growth, usually containing, or which has contained, pitch, either solid or liquid.
**PITCH STREAK** is a localized accumulation of resin in coniferous woods which permeates the cells forming resin soaks, patches or streaks.

**PLUGS** are sound wood of various shapes, including, among others, circular and dogbone, for replacing defective portions of veneer used to fill openings and provide a smooth, level, durable surface. Plugs usually are held in veneer by friction until veneers are bonded into plywood.

**PLY** is a single veneer lamina in a glued plywood panel. (See also “layer.”)

**PLYWOOD** is a flat panel, built up of sheets of veneer called plies, united under pressure by a bonding agent to create a panel with an adhesive bond between plies as strong as or stronger than the wood. Plywood is constructed of an odd number of layers with grain of adjacent layers perpendicular. Layers may consist of a single ply or two or more plies laminated with grain direction parallel. Outer layers and all odd-numbered layers generally have the grain direction oriented parallel to the long dimension of the panel. The odd number of layers with alternating grain direction equalizes strains, prevents splitting and minimizes dimensional change and warping of the panel.

**Interior type**—Plywood of this type is moisture resistant. It is intended for all interior applications as well as applications where it may be temporarily exposed to the elements. Table 23-2-D lists the grades within this type. Adhesive performance requirements are provided in Section 23.207.

**Intermediate glue (IMG) type**—Plywood of this type is bonded with adhesives that possess high-level bacteria, mold and moisture resistance. It is plywood suitable for protected construction and industrial uses where delays in providing protection may be expected. Adhesive performance requirements are provided in Section 23.207. (The grades of IMG-type plywood generally available are given in Table 23-2-D.)

**Exterior type**—Plywood of this type is produced with a C grade veneer or better throughout and is bonded with completely waterproof adhesives. It is a plywood that will retain its glue bond when repeatedly wetted and dried or otherwise subjected to the weather, and is therefore intended for permanent exterior exposure. Table 23-2-E lists the grades within this type. Adhesive performance requirements are provided in Section 23.207.

**Overlaid plywood** is Exterior-type plywood to which has been added a resin-treated fiber surfacing material on one or both sides. It is made in two standard categories, “High Density” and “Medium Density,” and a “Special” category, all of which refer to the surfacing materials. The overlay surfaces are permanently fused to the base panel under heat and pressure. Although designed for all types of moisture exposure and service, all overlaid plywood is made only in the Exterior type. This refers to the base panel and to the overlay itself.

**REPAIR** is any patch, plug or shim.

**SAPWOOD** is the living wood of lighter color occurring in the outer portion of a log. Sapwood is sometimes referred to as “sap.”

**SHIM** is a long narrow repair of wood or suitable synthetic not more than \(\frac{3}{16}\) inch (4.8 mm) wide.

**SHOP CUTTING PANELS** are panels which have been rejected as not conforming to grade requirements of standard grades in this standard. Identification of these panels shall be with a separate mark that makes no reference to this standard and contains the notation, “Shop Cutting Panel—All Other Marks Void.” Blistered panels are not considered as coming within the category covered by this stamp.

**SPAN RATING** is a set of numbers used in marking sheathing and combination subfloor underlayment (single floor) grades of plywood as described in Section 23.209.

**SPLIT** is lengthwise separation of wood fibers completely through the veneer caused chiefly by manufacturing process or handling.

**STREAKS** are synonymous with “pitch streaks.”
STRUCTURAL I, II are names used to identify panels that provide for greatest refinement of engineering properties which may be important in the use of plywood for structural components and other sophisticated engineered applications. Manufacturing requirements include special provisions for species, panel construction and veneer grade characteristics as described in Section 23.205.4.

TORN GRAIN. (See "broken grain.")

TOUCH-SANDING is a sizing operation consisting of a light surface sanding in a sander. Sanding skips to any degree are admissible.

VENeer. Thin sheets of wood of which plywood is made. Veneer is also referred to as plies in the glued panel.

WATERPROOF ADHESIVE is glue capable of bonding plywood in a manner to satisfy the exterior performance requirements given herein.

WHITE POCKET is a form of decay (Fomes pini) that attacks most conifers but has never been known to develop in wood in service. In plywood manufacture, routine drying of veneer effectively removes any possibility of decay surviving.

Heavy white pockets may contain a great number of pockets, in dense concentrations, running together and at times appearing continuous. Holes may extend through the veneer but wood between pockets appears firm. At any cross section extending across the width of the affected area, sufficient wood fiber shall be present to develop not less than 40 percent of the strength of clear veneer. Brown cubical and similar forms of decay which have caused the wood to crumble are prohibited.

Light white pockets are advanced beyond incipient or stain stage to the point where the pockets are present and plainly visible, mostly small and filled with white cellulose and generally distributed with no heavy concentrations. Pockets for the most part are separate and distinct with few to no holes through the veneer.

WOOD FAILURE (PERCENT) is the area of wood fiber remaining at the glueline following completion of the specified shear test. Determination is by means of visual examination and expressed as a percent of the 1-square-inch (645 mm²) test area. (See Section 23.214 for test.)

SECTION 23.203 — REQUIREMENTS

23.203.1 Workmanship. Unless otherwise specified, sanded plywood shall be surfaced on two sides. Faces and backs of panels shall be full width and full length except that C grade and D grade backs may be narrow on one edge or short on one end only, but by not more than 1/8 inch (3.2 mm) for half the panel length or width, respectively. Inner plies shall be full width and length except that one edge or end void not exceeding 1/8 inch (3.2 mm) in depth or 8 inches (203 mm) in length per panel will be acceptable. Crossband veneers not exceeding 1/8 inch (3.2 mm) in thickness may be lapped but by not more than 3/16 inch (4.8 mm) when adjacent to faces, or 1/2 inch (13 mm) when adjacent to backs, and provided such laps create no adjacent visible opening. Sanding defects resulting from crossband laps shall not be permitted in panel faces.

C or D grade veneers may be lapped by not more than 1/2 inch (13 mm), provided such laps create no adjacent visible opening. All plies of CD panels only shall be full length and full width except that no more than half the length of one edge nor half the width of one end may contain short or narrow plies. This is contingent on such plies not being short or narrow by more than 3/16 inch (4.8 mm), the aggregate area in the plane of the plies of such edge characteristics not exceeding 6 square inches (3871 mm²) in the entire panel, and such edge characteristics not occurring in more than one ply at any panel cross section.

In grades other than CD, backs may be narrow on one edge or short on one end only, but by not more than 1/8 inch (3.2 mm) for half the panel length or width, respectively; inner plies shall be full
width and length, except that one edge or end void not exceeding \( \frac{1}{8} \) inch (3.2 mm) in depth or 8 inches (203 mm) in length per panel will be acceptable.

Crossband gaps or center gaps, except as noted for plugged crossband and jointed crossband shall not exceed 1 inch (25 mm) in width for a depth of 8 inches (203 mm) (measured from panel edge) and the average of all gaps occurring in a panel shall not exceed \( \frac{1}{2} \) inch (13 mm). Every effort shall be made to produce closely butted core joints.

Where plugged inner plies are specified, inner plies shall be of C-Plugged veneer and gaps between adjacent pieces of inner plies shall not exceed \( \frac{1}{2} \) inch (13 mm). Where jointed inner plies are specified, gaps between pieces of inner plies shall not exceed \( \frac{3}{8} \) inch (9.5 mm), and the average of all gaps occurring in a panel shall not exceed \( \frac{3}{16} \) inch (4.8 mm).

Unless otherwise specified, plugged core (also referred to as solid core) shall be core and center construction of C-Plugged veneer, and gaps between adjacent pieces of core shall not exceed \( \frac{1}{2} \) inch (13 mm). When jointed core is specified, gaps between pieces of core shall not exceed \( \frac{3}{8} \) inch (9.5 mm), and the average of all gaps occurring in a panel shall not exceed \( \frac{3}{16} \) inch (4.8 mm).

Plywood shall be clean, well manufactured, and free from blisters, laps and other defects, except as expressly permitted herein. Panels shall have no continuous holes or through openings from face to back.

End butt joints may be used only under the following conditions:
1. Decorative grades as provided in Section 23.205.2.
2. Butt joints having a total aggregate width not exceeding the width of the panel may occur in the center ply of five-ply, five-layer panels. The butt joints must be perpendicular to the grain of the panel face and back plies. The use of butt-jointed centers is allowed in Interior sanded grades in thicknesses up to and including \( \frac{1}{2} \) inch (13 mm), and in C-D and C-D Plugged thicknesses up to and including \( \frac{3}{4} \) inch (19 mm). End butt joints shall not be used in Structural I or II panels. Panels with butt joints in center plies shall be marked “butt-jointed center.”

Plywood panels shall be constructed in the grades and veneer combinations as set forth in Tables 23-2-D and 23-2-E. All terms used herein shall be interpreted as described in Section 23.202. Constructions for all panels shall conform to the minimum number of plies and layers as set forth in Table 23-2-C. The proportion of wood with grain perpendicular to panel face grain shall not be less than 33 percent or more than 70 percent of the total panel thickness. The combined thickness of inner layers in panels having four or more plies shall not be less than 45 percent of the total panel thickness. For application of the above requirements, the panel thickness shall be the actual finished panel thickness and veneer thickness shall be the dry veneer thickness before layup. The grain of all layers shall be at right angles to the grain of adjacent layers and to the ends or edges of the panels.

The entire area of each contacting surface of the adjacent veneer plies including repairs shall be bonded with an adhesive in a manner to assure satisfactory compliance with the performance requirements for its type as set forth in the tests described in this standard. Where face or back plies consist of more than one piece of edge-joined veneer, gaps between adjacent pieces shall be graded as splits. Any adhesive or bonding system that causes degradation of the wood or latent failure of bond will not be permitted.

For the purpose of veneer repairing or edge joining, strings, ribbons or tapes up to \( \frac{3}{8} \)-inch (9.5 mm) maximum width can occur in a glueline and shall be considered as allowable localized defects in the evaluation of glueline test specimens. Wider strings, ribbons or tapes may be used for veneer repairing or joining if they are prequalified to show bonding equal to the required bonding for that panel. Glueline test specimens cut to include the strings, ribbons or tapes wider than \( \frac{3}{8} \) inch (9.5 mm) shall not be discarded because of the presence of these materials.

Veneer strips may be joined by string stitching, provided the punch for making holes prior to stitching has a dimension across the grain of 0.095 inch (2.4 mm) or less and the holes are spaced \( \frac{1}{2} \) inch (13 mm) center-to-center or greater. All veneer used for inner plies may be stitched. Stitched veneer used for outer plies is limited to panels with C or D grade faces or backs, except stitched C
Veneer may not be used for faces in decorative panels. Panels may have face or back plies stitched but not both.

Shims or strips of veneer shall not be used to repair panel edge voids. However, filling of permissible edge voids with approved synthetic fillers neatly applied will be admitted. Staples or pins of metal or synthetic material are prohibited. Face and back plies of exposed N, A and B veneer panels shall have the bark or tight surface out. Plies directly under surfaces of overlaid panels are not considered exposed veneers.

23.203.2 Tolerance. A tolerance of $+0.0 \text{ inch} - \frac{1}{16} \text{ inch}$ $(0.0625)$ $(+0.0 \text{ mm} - 1.6 \text{ mm})$ shall be allowed on the specified length and/or width. Sanded panels shall have a thickness tolerance of $\frac{1}{64} \text{ inch}$ $(0.0156)$ $(0.4 \text{ mm})$ of the specified panel thickness of $\frac{3}{4}$ inch $(19 \text{ mm})$ and less, and $\pm 3.0$ percent of the specified thickness for panels thicker than $\frac{3}{4}$ inch $(19 \text{ mm})$. Unsanded, touch-sanded, and overlaid panels shall fall within a plus or minus tolerance of $\frac{1}{32}$ inch $(0.0312)$ $(0.8 \text{ mm})$ of the specified panel thickness for all thicknesses through $\frac{13}{16}$ inch $(21 \text{ mm})$, and such panels greater than $\frac{13}{16}$ inch $(21 \text{ mm})$ shall have a thickness tolerance of $5$ percent over or under the specified thickness. Panel thickness shall be based on a moisture content of $9$ percent.

Panels shall be square within $\frac{1}{64}$ inch per lineal foot $(1.3 \text{ mm per m})$ for panels of 4-foot by 4-foot $(1219 \text{ mm by 1219 mm})$ size or larger. Panels less than 4 feet $(1219 \text{ mm})$ in length or width shall be square within $\frac{1}{16}$ inch $(1.6 \text{ mm})$ measured along the short dimension. All panels shall be sawn so that a straight line drawn from one corner to the adjacent corner shall fall within $\frac{1}{16}$ inch $(1.6 \text{ mm})$ of panel edge.

23.203.3 Moisture Content. Moisture content of panels at time of shipment shall not exceed $18$ percent of oven-dry weight as determined by the oven-dry test specified in Section 23.217.

SECTION 23.204 — VENEER

23.204.1 General. Except as noted, veneers shall be $\frac{1}{10}$ inch $(2.5 \text{ mm})$ or thicker in panels $\frac{3}{8}$ inch $(9.5 \text{ mm})$ rough (unsanded) thickness or over; $\frac{1}{12}$ inch $(2.1 \text{ mm})$ or thicker in panels of lesser thickness. In no case shall veneers used in face or back layers be thicker than $\frac{1}{4}$ inch $(6.4 \text{ mm})$, or veneers used in inner layers thicker than $\frac{5}{16}$ inch $(7.9 \text{ mm})$.

One-twelfth-inch $(2.1 \text{ mm})$ veneer may be used as crossbands in five-ply, five-layer, $\frac{1}{2}$-inch $(13 \text{ mm})$ panels and in parallel laminated layers.

One-sixteenth-inch $(1.6 \text{ mm})$ veneer may be used for any ply in five-ply Exterior-type panels less than $\frac{1}{2}$ inch $(13 \text{ mm})$ in thickness, as the center only in other five-ply panels, and may be included in a parallel laminated layer.

Face and back veneers must be $\frac{1}{8}$-inch $(3.2 \text{ mm})$ minimum thickness for $\frac{19}{32}$ inch and $\frac{5}{16}$ inch $(15.1 \text{ mm and 15.9 mm})$, three-, four- and five-ply, three-layer panels of C-D, C-D Plugged, C-C, C-C Plugged and Underlayment grades.

For further limitations on panel layup, refer to Table 23-2-C panel constructions and workmanship.

The average veneer thickness shall conform to the limitations given in this standard within a tolerance of $5$ percent of the specified nominal thickness measured dry before layup.

Parallel laminated outer layers may be used only in C-C, C-D, Structural I C-C and C-D, and Structural II C-C and C-D grades. Such layers shall consist of veneers $\frac{1}{10}$ inch $(2.5 \text{ mm})$ or thicker in any thickness combination not exceeding $\frac{1}{4}$-inch $(6.4 \text{ mm})$ total layer thickness. The face and back plies or exposed plies of outer layers shall conform to the species group and grade requirements for faces and backs, respectively, of the panel grade. The unexposed plies of outer layers, or sub-face and sub-back plies, shall conform to the species group and grade requirements for inner plies of the panel grade as specified in Sections 23.204.3 and 23.204.4.
The maximum split or gap in subfaces and subbacks shall be \( \frac{1}{4} \) inch (6.4 mm) under the faces of Structural IC-C and C-D and Structural II C-C and C-D panels, \( \frac{1}{2} \) inch (13 mm) under the faces of C-C and C-D grades, and \( \frac{1}{2} \) inch (13 mm) under D backs.

Parallel laminated inner layers in any grade shall consist of veneers \( \frac{1}{16} \) inch (1.6 mm) or thicker in any thickness combination not exceeding \( \frac{7}{16} \)-inch (11 mm) total layer thickness. Individual plies in such layers shall conform to the species group and grade requirements for inner plies of the panel grade.

The veneers used in each ply of each panel and the completed panel shall conform with the applicable veneer grade and with the construction and workmanship requirements given herein. Additionally, the type and frequency of the characteristics shall be further limited as set forth for the grades listed in Table 23-2-B.

23.204.2 Number of Plies. For a given thickness, the number of plies used in the panel makeup shall not be less than as provided in Table 23-2-C.

23.204.3 Species for Faces and Backs. For purposes of this standard, veneer species are classified into the four groups given in Table 23-2-A. The species of face and back plies may be from any group; however, when a face or back is made of more than one piece, the entire ply shall be of the same species. Panels, other than unsanded and touch-sanded panels, with span ratings which are produced with face and back veneers of the same species group shall be classified as being of that species group. Touch-sanded panels without span ratings that are manufactured with face and back plies of different species groups shall be identified by the larger numbered species group (i.e., Group 4 is larger numbered than Group 1). Sanded panels \( \frac{3}{16} \) inch (9.5 mm) or less in thickness and decorative panels of any thickness that are manufactured with face and back plies of different species groups shall be identified by the face species group number. Sanded panels greater than \( \frac{3}{16} \) inch (9.5 mm) that are manufactured with face and back plies of different species groups shall be identified by the larger numbered species group, except that sanded panels with C or D grade backs may be identified by the face species group number if backs are no more than one species group larger in number than the face and are \( \frac{1}{16} \) inch (3.2 mm) or thicker before sanding. The species classification group (except for unsanded and touch-sanded panels with span ratings) shall be set forth in the grade mark on each panel. See Section 23.209 for identification requirements for unsanded and touch-sanded panels with span ratings. Where intermixing between species groups occurs in the faces and backs of unsanded or touch-sanded panels with span ratings, provisions of Table 23-2-G shall be followed. (Douglas fir for the purpose ... and loblolly [Pinus taeda] pines.) Because black, white and Engelmann spruce cannot be separated in veneer form by gross structure or minute anatomy, these species shall be classed as Engelmann spruce unless procedures are established for identification prior to peeling.

23.204.4 Species for Inner Plies. Inner plies may be of any species or of any softwood species or any hardwood species having a published average specific gravity value of 0.41 or more, based on green volume and oven-dry weight, except as required for premium panels in Section 23.205.

23.204.5 Scarfed Veneers. Scarfed veneer may be used for any face, back or inner ply except as provided in Section 23.211. Scarfed joints shall not have a slope steeper than 1 in 8, but may be specified at less than 1 in 8. Veneer in the scarf area shall not contain defects which reduce its effective cross section by more than 20 percent. Veneer scarfed joints shall be glued with a waterproof adhesive.

23.204.6 Classification. All veneers used in the construction of the plywood panels shall conform to one of the following grade requirements of which N grade is the highest classification:

23.204.6.1 Grade N veneer. Grade N veneer (intended for natural finish) shall be smoothly cut 100 percent heartwood or 100 percent sapwood, free from knots, knotholes, pitch pockets, open splits, other open defects, and stain; limited to not more than two pieces in a 48-inch (1219 mm) width; not more than three pieces in wider panels; and well matched for color and grain.
Suitable synthetic fillers may be used to fill small cracks or checks not more than $\frac{1}{32}$ inch (0.8 mm) wide; small splits or openings up to $\frac{1}{16}$ inch (1.6 mm) wide if not exceeding 2 inches (51 mm) in length; and small chipped areas or openings not more than $\frac{1}{8}$ inch (3.2 mm) wide by $\frac{1}{4}$ inch (6.4 mm) long. Pitch streaks averaging not more than $\frac{3}{8}$ inch (9.5 mm) in width and blending with color of wood are permitted.

Repairs shall be neatly made and parallel to grain and are limited to a total of six in number in any 4-foot by 8-foot (1219 mm by 2438 mm) face, with proportional limits for other sizes. They shall also be well matched for color and grain.

Patches are limited to three "router" patches not exceeding 1 inch (25 mm) in width and 3$\frac{1}{2}$ inches (89 mm) in length.

No overlapping is permitted.

Wood shims not exceeding $\frac{3}{16}$ inch (4.8 mm) in width and 12 inches (305 mm) in length that occur only at the ends of the panel are permitted.

23.204.6.2 Grade A veneer. Grade A veneer (suitable for painting) shall be firm, smoothly cut and free from knots, pitch pockets, open splits and other open defects. It shall be well joined when of more than one piece.

Suitable synthetic fillers may be used to fill, in Exterior-type panels, small cracks or checks not more than $\frac{1}{32}$ inch (0.8 mm) wide; small splits or openings up to $\frac{1}{16}$ inch (1.6 mm) wide, if not exceeding 2 inches (51 mm) in length; and small chipped areas or openings not more than $\frac{1}{8}$ inch (3.2 mm) wide by $\frac{1}{4}$ inch (6.4 mm) long. In Interior-type panels: small cracks or checks not more than $\frac{3}{16}$ inch (4.8 mm) wide; openings or depressions up to $\frac{1}{2}$ inch (13 mm) wide by 2 inches (51 mm) long or equivalent area.

Pitch streaks averaging not more than $\frac{3}{8}$ inch (9.5 mm) in width, blending with color of wood, are permitted.

Sapwood and discolorations are also permitted.

Repairs shall be wood or of synthetic patching material neatly made and parallel to grain, limited to a total of 18 in number, excluding shims, in any 4-foot by 8-foot (1219 mm by 2438 mm) face and shall have proportional limits on other sizes.

Patches are limited to the boat, router and sled types. Radius of ends of boat patches shall not exceed $\frac{1}{8}$ inch (3.2 mm). Patches shall not exceed 2$\frac{1}{4}$ inches (57 mm) in width singly. Multiple patches consisting of not more than two patches, neither of which may exceed 7 inches (178 mm) in length if either is wider than 1 inch (25 mm) are permitted, except that there may be one multiple repair consisting of three die-cut veneer patches. Synthetic repairs shall not exceed 2$\frac{1}{4}$ inches (57 mm) in width. Shims are permitted except over or around patches or as multiple repairs.

23.204.6.3 Grade B veneer. Grade B veneer shall be solid and free from open defects and broken grain except as noted. Slightly rough grain and minor sanding and patching defects, including sander skips not exceeding 5 percent of panel area are permitted.

Suitable synthetic filler may be used to fill, in Exterior-type panels, small splits or openings up to $\frac{1}{16}$ inch (1.6 mm) wide if not exceeding 2 inches (51 mm) in length and small chipped areas or openings not more than $\frac{1}{8}$ inch (3.2 mm) wide by $\frac{1}{4}$ inch (6.4 mm) long. In Interior-type panels: small cracks or checks not more than $\frac{3}{16}$ inch (4.8 mm) wide; openings or depressions up to $\frac{1}{2}$ inch (13 mm) wide by 2 inches (51 mm) long or equivalent area.

Knots up to 1 inch (25 mm) measured across the grain if both sound and tight, pitch streaks averaging not more than 1 inch (25 mm) in width, and discolorations are permitted.

Splits not wider than $\frac{1}{12}$ inch (0.8 mm) and vertical holes not exceeding $\frac{1}{16}$ inch (1.6 mm) in diameter if not exceeding an average of one per square foot in number are permitted. Horizontal or surface tunnels limited to $\frac{1}{16}$ inch (1.6 mm) across, 1 inch (25 mm) in length, and 12 in number in a 4-foot by 8-foot (1219 mm by 2438 mm) panel or proportionately in panels of other dimensions are also permitted.
Repairs shall be neatly made of wood or synthetic patching material. Repairs permitted are patches ("boat," "router" and "sled") not exceeding 3 inches (76 mm) in width individually where occurring in multiple repairs, or 4 inches (102 mm) in width where occurring singly. Synthetic veneer repairs shall not exceed 4 inches (102 mm) in width. Synthetic panel repairs shall not exceed 2 1/4 inches (57 mm) in width. Shims are permitted. Synthetic shims shall completely fill kerfs or voids; shall present a smooth level surface; and shall not crack, shrink or lose their bond under Exterior-type plywood test exposures described in Sections 23.215.2 and 23.215.3. Performance of synthetic shims under normal conditions of service shall be comparable to that of wood shims.

Synthetic plugs not exceeding dimensions specified previously which present solid, level, hard surfaces and whose performances under normal conditions of service are comparable to that of wood plugs are permitted.

**23.204.6.4 Grade C veneer.** Grade C veneer permits sanding defects that will not impair the strength or serviceability of the panel, knots if tight and not more than 1 1/2 inches (38 mm) across the grain, and knotholes up to 1 inch (25 mm) measured across the grain. An occasional knothole more than 1 inch (25 mm) but not more than 1 1/2 inches (38 mm) measured across the grain, occurring in any section 12 inches (305 mm) along the grain in which the aggregate width of all knots and knotholes occurring wholly within the section does not exceed 6 inches (152 mm) in a 48-inch (1219 mm) width, and proportionately for other widths is also permitted.

Splits tapering to a point and limited to 1 1/2 inch (13 mm) by one-half panel length, 3/8 inch (9.5 mm) by any panel length are permitted, provided separation at one end does not exceed 1/16 inch (1.6 mm) where split runs full panel length, or 1/4 inch (6.4 mm) maximum width where located within 1 inch (25 mm) of parallel panel edge.

Voids due to missing wood on panel faces and backs not otherwise specified above shall not exceed the maximum width of knotholes permitted in the grade and the length of such voids shall not exceed 6 inches (152 mm).

Repairs shall be wood or synthetic material, neatly made. Wood veneer repairs shall be die cut, and wood panel repairs shall be router or sled type. Wood repairs shall not exceed 3 inches (76 mm) in width individually where occurring in multiple repairs, or 4 inches (102 mm) in width where occurring singly; plugs (circular or "dog bone") not exceeding 3 inches (76 mm) in width individually where occurring in multiple repairs or 4 inches (102 mm) in width where occurring singly; and shims including synthetic as provided for in B grade.

Synthetic veneer repairs shall not exceed 4 inches (102 mm) in width.

Synthetic panel repairs shall not exceed 2 1/4 inches (57 mm) in width.

Shims are permitted.

C-Plugged veneer (veneer used for faces of underlayment, C-D Plugged and C-C Plugged grades, and inner plies of overlaid panels and other products if specified) may contain knotholes, worm and borer holes, and other open defects not larger than 1/4 inch by 1/2 inch (6.4 mm by 13 mm), sound and tight knots up to 1/2 inches (38 mm) measured across the grain, splits up to 1/8 inch (3.2 mm) wide, broken grain, pitch pockets, if solid and tight, plugs, patches and shims. Synthetic repairs in veneer shall not exceed 4 inches (102 mm) in width. Synthetic panel repairs shall not exceed 2 1/4 inches (57 mm) in width. Where grades having C-Plugged face veneer are specified as fully sanded, sanding defects shall be the same as admitted under B grade. Sander skips to any degree shall be admissible in C-Plugged veneer.

**23.204.6.5 Grade D veneer.** Grade D veneer permits any number of plugs, patches, shims, worm or borer holes, sanding defects and other characteristics, provided they do not seriously impair the strength or serviceability of the panels. See also Section 23.203.

Tight knots are permitted in inner plies; and in D grade backs where limited to 2 1/2 inches (64 mm) measured across the grain.
In D grade backs, an occasional tight knot larger than 2½ inches (64 mm) but not larger than 3 inches (76 mm) measured across the grain, occurring in any section 12 inches (305 mm) along the grain in which the aggregate width of all knots and knotholes occurring wholly within the section does not exceed 10 inches (254 mm) in a 48-inch (1219 mm) width and proportionately for other widths is also permitted.

Knotholes up to 2½ inches (64 mm) across the grain, an occasional knothole larger than 2½ inches (64 mm) but not larger than 3-inch (76 mm) dimension occurring in any section 12 inches (305 mm) along the grain in which the aggregate width of all knots and knotholes occurring wholly within the section does not exceed 10 inches (254 mm) in a 48-inch (1219 mm) width, and proportionately for other widths; in sanded panels, knotholes not exceeding 2½ inches (64 mm) across the grain in veneer thicker than 1/8 inch (3.2 mm); and knotholes not exceeding 3½ inches (89 mm) across the grain are permitted in veneers at least two plies removed from the face and back plies of C-D and C-D Plugged grades having five or more plies.

Splits measured at a point 8 inches (203 mm) from their end shall not exceed 1 inch (25 mm) in width, tapering to not more than 1/16 inch (1.6 mm) where split runs full panel length; however, the maximum width within 8 inches (203 mm) of the end of the split shall not exceed the maximum width of knotholes permitted within the grade.

Splits on panel faces and backs shall not exceed ½ inch (6.4 mm) where located within 1 inch (25 mm) of parallel panel edge.

Voids due to missing wood on panel backs not otherwise specified above shall not exceed the maximum width of knotholes permitted in the grade and the length of such voids shall not exceed 6 inches (152 mm).

Any area 24 inches (610 mm) wide across the grain and 12 inches (305 mm) long, in which light or heavy white pocket occurs, shall not contain more than three of the following characteristics, in any combination: 6-inch (152 mm) width of heavy white pocket; 12-inch (305 mm) width of light white pocket. One knot or knothole, 1½ inches to 2½ inches (38 mm to 64 mm), or two knots or knotholes, 1 inch to 1½ inches (25 mm to 38 mm); knots or knotholes less than 1 inch (25 mm) shall not be considered. Size of any knot or knothole shall be measured in greatest dimension. Any repair in white pocket area shall be treated for grading purposes as a knothole.

23.204.6.6 Synthetic repairs. Synthetic fillers shall be limited to the repair of minor defects as specified in this standard. Synthetic fillers shall be of an approved type.

23.204.6.7 Synthetic shims, patches and plugs. These repairs shall completely fill kerfs or voids; shall present a smooth, level surface; and shall not crack, shrink, or lose their bond. Performance of synthetic shims, patches and plugs under normal conditions of service shall be comparable to that of wood repairs. The equivalency shall be established by testing and evaluation in accordance with approved procedures.

SECTION 23.205 — PREMIUM GRADES

23.205.1 Marine Plywood. Marine grade shall be of Exterior-type meeting applicable requirements of this standard, and of one of the following grades: A-A, A-B, B-B, High Density Overlay, or Medium Density Overlay, all as modified below for "Marine" plywood.

Only Douglas fir 1 and western larch veneer shall be used.

"A" faces shall be limited to a total of nine single repairs in a 4-foot by 8-foot (1219 mm by 2438 mm) sheet, or to a proportionate number in any other size as manufactured. "B" faces or backs where specified, and all inner plies, shall conform to "B" quality veneer requirements and shall be full length and width.

All patches shall be glued with an adhesive meeting Exterior-type performance requirements of this standard and, in addition, shall be set in the panel using a technique involving both heat and pressure.
When the inner ply veneers consist of two or more pieces of veneer, the edges shall be straight and square without lapping. Neither edge of a panel shall have any crossband gap or edge-split in excess of \( \frac{1}{8} \) inch (3.2 mm) wide. Crossband gaps and edge-splits per 8 feet (2438 mm) of crossband ply shall not exceed four in number. End splits and gaps on either end of a panel shall not exceed \( \frac{1}{8} \) inch (3.2 mm) in aggregate width. Filling of crossband gaps and edge-splits with crossband gaps and edge-split materials that serve to conceal the gaps or splits is prohibited.

23.205.2 Decorative Panels. Specialty panels with decorative face veneer treatments in the form of striations, grooving, embossing, brushing, etc., which, except for the special face treatment, meet all of the requirements of this standard, including veneer qualities, glue bond performance and workmanship, shall be considered as conforming to the standard.

An occasional butt joint up to 6 inches (152 mm) in width shall be permitted for decorative effect in veneer on one panel face only. Where butt joints occur, the aggregate width of all knots and knot-holes and two thirds the aggregate width of all repairs, including butt joints, shall not exceed 6 inches (152 mm) in any area 12 inches (305 mm) along the grain by 48 inches (1219 mm) wide or proportionately for other widths.

23.205.3 Exterior B-B (Concrete Form) Panels. A panel especially made for general concrete form use. Face veneers shall not be less than B grade and shall always be from the same species group. Inner plies shall not be less than C grade. (See Table 23-2-E for veneer grade limitations of High Density overlaid concrete form panels.) This grade of plywood is produced in two classes and panels of each class shall be identified accordingly. Panels shall be sanded two sides, edge-sealed and, unless otherwise specified, mill-oiled. Species shall be limited as follows and are applicable also to High Density overlaid exterior concrete form panels.

Class I—Faces of any Group 1 species, crossband of any Group 1 or Group 2 species, and centers of any Group 1, 2, 3 or 4 species.

Class II—Faces of any Group 1 or Group 2 species, and crossband and centers of any Group 1, 2, 3 or 4 species, or faces of Group 3 species of \( \frac{1}{8} \) inch (3.2 mm) minimum thickness before sanding, crossband of any Group 1, 2 or 3 species, and centers of any Group 1, 2, 3 or 4 species.

23.205.4 Structural Grade Panels. Panels especially designed for engineered applications such as structural components where design properties including tension, compression, shear, cross-panel flexural properties and nail bearing may be of significant importance. In addition to the special species, grade and glue bond requirements set forth in Table 23-2-F, all other provisions of this standard for the specific types and grades form a part of the specifications for Structural grade panels.

23.205.5 Special Exterior. A premium panel of Exterior type that may be produced of any specified species covered by this standard. It shall otherwise meet all of the requirements for Marine Exterior and be produced in one of the following grades: A-A, A-B, B-B, High Density Overlay, or Medium Density Overlay.

23.205.6 Underlayment, C-C Plugged. Face veneer shall be \( \frac{1}{10} \) inch (2.5 mm) or thicker before sanding. The veneer immediately adjacent to the face ply of C-C Plugged and Underlayment shall be C grade or better with no knotholes over 1 inch (25 mm) across the grain, except that (1) veneer immediately adjacent to the face ply of Underlayment may be D grade with open defects up to \( 2^{1/2} \) inches (64 mm) across the grain or (2) veneer immediately adjacent to the face ply of C-C Plugged may be C grade with open defects up to \( 1^{1/2} \) inches (38 mm) across the grain, provided the face veneer is Group 1 or Group 2 species of \( \frac{1}{8} \) inch (4.2 mm) minimum thickness before sanding. Also see requirements set forth in Table 23-2-B.

SECTION 23.206 — OVERLAYS

23.206.1 General. The standard grades of overlaid plywood are listed in Table 23-2-E.
23.206.2 High Density. The surfacing on the finished product shall be hard, smooth and of such character that further finishing by paint or varnish is not necessary. It shall consist of a cellulose-fiber sheet or sheets, containing not less than 45 percent resin solids based on a volatile-free weight of fiber and resin. The resin shall be a thermosetting phenol or melamine type. The total resin-impregnated materials for each face shall not be less than 0.012 inch (0.3 mm) thick before pressing and shall weigh not less than 60 pounds per 1,000 square feet (0.29 kg/m²), including both resin and fiber. The resin impregnation shall be sufficient to make a continuous bond without voids or blisters between the surfacing material and the plywood. The overlay face is usually produced in natural translucent color, but certain other colors may be used by manufacturers for identification.

Other resin-cellulose fiber overlay systems having a weight of not less than 60 pounds per 1,000 square feet (0.29 kg/m²) of single surface exclusive of glueline, and which possess performance capabilities of the above phenol system, may be identified as High Density Overlay. Determination of equivalent performance shall be based on approved tests.

23.206.3 Medium Density. The resin-treated facing on the finished product shall present a smooth, uniform surface intended for high-quality paint finishes. It shall consist of a cellulose-fiber sheet containing not less than 17 percent resin solids for a beater loaded sheet, or 22 percent for an impregnated sheet, both based on the volatile-free weight of resin and fiber exclusive of glueline. The resin shall be a thermosetting phenol or melamine type. The resin-treated material shall not weigh less than 58 pounds per 1,000 square feet (0.28 kg/m²) of single face including both resin and fiber but exclusive of glueline. After application, the material shall not measure less than 0.012 inch (0.3 mm) thick. Some evidence of the underlying grain may appear. The overlay face is produced in a natural color and certain other colors.

Other resin-cellulose fiber overlay systems having a weight of 58 pounds per 1,000 square feet (0.28 kg/m²) of single surface exclusive of glueline, and which possess performance capabilities of the above phenol system, may be identified as Medium Density Overlay. Determination of equivalent performance shall be based on approved test methods.

23.206.4 Special Overlays. Surfacing materials having special characteristics which do not fit the exact description of High Density or Medium Density types as outlined previously. These must meet the test requirements for overlaid plywood and have a durable surface material. Panels shall be identified as “Special Overlay.”

SECTION 23.207 — ADHESIVE BOND REQUIREMENTS

23.207.1 General. Lots represented by test panels shall be considered as meeting the requirements of this standard if all of the following minimum requirements are met.

23.207.2 Interior-type Bonded with Interior Glue (Underlayment, C-D Plugged and C-D). A panel shall be considered as meeting the requirements of the standard if three or more of the five test specimens pass. The material represented by the sampling shall be considered as meeting the requirements of this standard if 90 percent or more of the panels pass the test described in Section 23.213.

23.207.3 Interior-type Bonded with Exterior Glue (Structural C-D). When tested in accordance with Section 23.213, the average wood failure of all test specimens, regardless of the number of panels tested, shall not be less than 80 percent.

When more than one panel is tested:

1. At least 90 percent of the panels represented by the test pieces shall have 60 percent wood failure or better.
2. At least 95 percent of the panels represented by the test pieces shall have 30 percent wood failure or better.

These requirements are applicable separately and independently to the results obtained from the vacuum-pressure test and the boiling test. Specimens cut through localized defects permitted in the
grade shall be discarded. Test specimens showing delamination in excess of \( \frac{1}{8} \) inch (3.2 mm) deep and 1 inch (25 mm) long shall be rated as 0 percent wood failure.

23.207.4 All Other Grades of Interior-type Plywood. A panel shall be classed as failing if more than two of the five test specimens fail. The material represented by the sampling shall be considered as meeting the requirements of this standard if 85 percent or more of the panels pass, when tested in accordance with Section 23.213.

23.207.5 Mold Resistance. Underlayment, C-D Plugged, and Standard shall be made with an adhesive possessing a mold resistance equivalent to that created by adding, to plain protein glue, 5 pounds (2.27 kg) of pentachlorophenol or its sodium salt per 100 pounds (45.36 kg) of dry glue base.

IMG-type plywood shall be made with an adhesive possessing a high degree of resistance to attack by bacteria and mold organisms. Adhesives, in order to qualify for use in the manufacture of IMG-type panels, must meet the "bacteria test" requirements published by the American Plywood Association. This procedure is specifically designed for adhesive qualification and is not applicable to inspection and testing, as covered in Section 23.212.

23.207.6 Resistance to Elevated Temperature. Underlayment, C-D Plugged shall be made with an adhesive possessing resistance to temperatures up to 160°F (71°C) at least equal to that of plain protein glue. Urea resin glue shall not be used in these grades unless evidence is submitted indicating performance equivalent to plain protein glues.

23.207.7 Interior-type Bonded with Intermediate Glue (IMG-type). When tested in accordance with Section 23.214, IMG-type plywood shall be considered as meeting the requirements of the standard if all of the following minimum conditions are met:

1. The average wood failure of all test specimens, regardless of the number of panels tested, shall not be less than 45 percent.
2. When more than one panel is tested, at least 90 percent of the panels represented by the test pieces shall have 30 percent wood failure or better.

Specimens cut through localized defects permitted in the grade shall be discarded. Test specimens showing delamination in excess of \( \frac{1}{8} \) inch (3.2 mm) deep and 1 inch (25 mm) long shall be rated as 0 percent wood failure.

23.207.8 Exterior Type. When tested in accordance with Section 23.215, Exterior-type plywood shall be considered as meeting the requirements of this standard if all of the following minimum conditions are met:

1. The average wood failure of all test specimens, regardless of the number of panels tested, shall not be less than 85 percent.
2. When more than one panel is tested:
   2.1 At least 75 percent of the panels represented by the test pieces shall have 80 percent wood failure or better.
   2.2 At least 90 percent of the panels represented by the test pieces shall have 60 percent wood failure or better.
   2.3 At least 95 percent of the panels represented by the test pieces shall have 30 percent wood failure or better.

These requirements are applicable separately and independently to the results obtained from the vacuum-pressure test and the boiling test. Specimens cut through localized defects permitted in the grade shall be discarded. Test specimens showing delamination in excess of \( \frac{1}{8} \) inch (3.2 mm) deep and 1 inch (25 mm) long shall be rated as 0 percent wood failure.

Plywood shall be tested for heat durability as described in Section 23.215. Any delamination due to combustion shall be considered as failure, except when occurring at a localized defect permitted
in the grade. When testing overlaid plywood, blisters or bubbles in the surface caused by combustion shall not be considered delamination.

The bond between veneers of overlaid plywood as well as the bond between the overlay and the base panel shall meet the wood failure requirements described above for exterior. In evaluating specimens for separation of resin-treated face from the plywood, fiber failure shall be considered the same as wood failure.

SECTION 23.208 — GRADE MARKING

All plywood shall be grade marked in accordance with Section 2303 of this code. No reference shall be made to this standard in the certification or trademarking or grade marking of panels not conforming to all provisions of the standard. Each panel shall be identified with the mark of a qualified inspection and testing agency that shall designate the species group classification or span rating, glue bond type (Interior or Exterior), grade name or the grade of face and back veneers, and a symbol signifying conformance with the standard.

Panels not fully satisfying Exterior veneer requirements shall be identified as “Interior.” However, the additional notation “Exterior Glue” or “Intermediate” (IMG) may be used where applicable to supplement the designation of Interior grades bonded with Exterior glue or Intermediate glue. Any further reference to adhesive bond, including those which imply premium performance or special warranty by the manufacturer, as well as manufacturer’s proprietary designations, shall be separated from the grade marks or trademarks of the testing agency by not less than 6 inches (152 mm).

SECTION 23.209 — SPAN RATING FOR UNSANDED AND TOUCH-SANDED PANELS

Grade marking or trademarking of C-C, C-D, Structural C-C and Structural C-D, and of C-C Plugged and Underlayment to be used as combination subfloor underlayment (single floor) shall include a span rating for the thickness shown in Table 23-2-G. The numbers are presented as a fraction in the marking of sheathing grades of plywood, and as a single number for C-C Plugged and Underlayment. They describe the recommended maximum spans in inches (mm) under normal use conditions and correspond with commonly accepted criteria. For sheathing, the left-hand number refers to spacing of roof framing, and the right-hand number relates to spacing of the floor framing. The single number for Underlayment and C-C Plugged refers to spacing of the floor framing in single floor applications. The span rating number is related to species and thickness of the panel face and back veneers and panel thickness. It is established by either one of the following procedures:

1. By specification as detailed in Table 23-2-G.

2. By performance testing to satisfy the strength, stiffness and durability criteria as detailed in Section 23.210. Such performance testing is to be performed by a qualified testing agency.

Panels manufactured as C-C, C-D, Structural C-C and Structural C-D shall not be sanded, touch-sanded, surface textured or thickness sized by any mechanical means. However, sanded or touch-sanded panels which do not meet the grades for which they were intended may be reclassified and marked as C-C or C-D, provided the panels meet all applicable requirements for C-C or C-D and the finished face and back veneers after sanding each have a minimum net thickness equal to 90 percent of the applicable thickness in Table 23-2-G.

SECTION 23.210 — PERFORMANCE TESTING QUALIFICATION REQUIREMENTS

23.210.1 General. Acceptance of performance-tested plywood under this standard is based upon testing of panel strength, stiffness and durability. Panels selected for testing shall be of near-minimum grade and near-minimum thickness. All provisions of veneer grade and panel workmanship are applicable.


23.210.3.1 Concentrated loads. A minimum of 10 tests (specimens taken from at least five panels) shall be conducted for both concentrated static and impact loads according to Section 23.216. The tests shall be conducted for each exposure condition specified in Table 23-2-L or 23-2-N (wet, dry and/or wet/redry).

23.210.3.1.1 Deflection. At least 90 percent of tests shall deflect no more than the specified maximum.

23.210.3.1.2 Retest. If no more than two tests in a lot of 10 fail to meet the deflection requirements, another lot of 10 may be tested for that requirement. If no more than one test fails in this second round of testing, the requirements shall be considered satisfied.

23.210.3.1.3 Ultimate load. For each lot, 100 percent of tests shall support the specified minimum ultimate load.

23.210.3.1.4 Retest. If no more than one test in a lot of 10 fails to meet the minimum ultimate load requirement, another lot of 10 may be tested for that requirement. If all pass the retest, the requirements shall be considered satisfied.

23.210.3.2 Uniform loads. A minimum of 10 tests (specimens taken from at least five panels) shall be conducted for uniform load capacity according to Section 23.217. The tests shall be conducted for each exposure condition specified in Table 23-2-M or 23-2-O.

23.210.3.2.1 Deflection. The average deflection shall not be greater than that specified.

23.210.3.2.2 Retest. If the average deflection is greater than specified, but does not exceed the requirement by 20 percent, another lot of 10 may be tested for that requirement. If the average of the first and second lot taken together does not exceed that specified, the requirement shall be considered satisfied.

23.210.3.2.3 Ultimate load. For each lot, 100 percent of tests shall support the specified minimum ultimate load.

23.210.3.2.4 Retest. If no more than one test in a lot of 10 fails to meet the ultimate load requirement, another lot of 10 may be tested for that requirement. If all specimens pass this retest, the requirements shall be completely satisfied.

23.210.4 Bond Durability. Panels shall be classed as Exposure 1 or Exterior.

23.210.4.1 Exposure. Panels rated as Exposure 1 shall be so identified and shall satisfy the bond requirements for Interior panels bonded with exterior glue as specified in Section 23.207.3.

23.210.4.2 Exterior. Panels rated as Exterior shall be so identified and shall satisfy the bond requirements as specified in Section 23.207.8.

23.210.5 Product Evaluation. Upon satisfactory completion of the appropriate requirements of Sections 23.210.3 and 23.210.4, a manufacturing specification will be written based on product evaluation under this section. This specification is to be used for quality assurance purposes by the manufacturer and the manufacturer's qualified testing agency. Product evaluation will be made on the same lot supplied by the manufacturer for qualification testing. Control values established during product evaluation will be the basis for quality evaluation of future production. The mill specification shall contain the following information.

23.210.5.1 Panel construction. Panels shall be defined as to veneer species and construction.

23.210.5.2 Mechanical properties. Twenty tests (specimens taken from at least 10 panels) shall be evaluated for bending stiffness both along and across the major panel axis according to
the procedures of Section 23.218. The control value for each panel direction will be the sample mean and the minimum will be the lower value of a 90 percent confidence interval established on the mean.

Ten tests (specimens taken from at least 10 different panels) shall be tested for maximum bending moment both along and across the major panel axis according to the procedures of Section 23.218. The control value for each panel direction will be the minimum observed value, or the sample mean less 1.8 times the sample standard deviation, whichever is the higher value.


23.210.6.1 Quarterly reexamination. A product qualified by performance testing shall be subjected to quarterly reexamination by the manufacturer’s qualified testing agency. Panels shall be tested according to the procedures of Section 23.210.5.2.

23.210.6.2 Resampling. Failure to meet established control values shall result in an immediate intensive resampling of current production which will be tested for the failing property. This resampling shall consist of 20 panels.

23.210.6.3 Requalification. When results of the resampling fail to meet the applicable test requirements, a requalification for structural properties under Section 23.210.3 shall be required.

SECTION 23.211 — SCARF- AND FINGER-JOINTED PANELS

23.211.1 General. Neither panels with N faces nor the faces of such panels, unless longer than 10 feet (3048 mm), shall be scarfed or finger jointed except when specifically so ordered. Panels of other grades may be scarfed or finger jointed. Panels longer than 12 feet (3658 mm) are necessarily scarfed. Scarf joints shall not have a slope greater than 1 to 8, but may be specified as less than 1 to 8. Joints shall be glued with a waterproof adhesive and meet the test requirements specified in this section as applicable. In addition, the adhesive shall not show creep or flow characteristics greater than unjointed wood when subject to load under any conditions of temperature and moisture.

23.211.2 Strength Requirements (Interior, IMG and Exterior) Scarfed and Finger-jointed Panels. Panels shall be tested in accordance with Section 23.216.1. If the average ultimate stress of the three test specimens of any one panel is less than 4,000 psi (27.58 N/mm²) for panels of Group 1 species, or less than 2,800 psi (19.3 N/mm²) for panels of Group 2 or Group 3 species, or 2,400 psi (16.55 N/mm²) for panels of Group 4 species, then that panel fails. The jointed panels represented by the sampling are acceptable if not more than one of the panels fails.

23.211.3 Scarf- and Finger-joint Durability for Interior and IMG Panels. Panels shall be tested as outlined in Section 23.216.2. Test specimens showing continuous delamination in excess of 1/16 inch (1.6 mm) deep and 1/2 inch (13 mm) long at the joint glueline shall be considered as failing. More than one failing specimen in a panel shall constitute failure of that panel. The jointed panels represented by the sampling are acceptable if not more than one of the panels fails.

23.211.4 Scarf-joint Durability for Exterior and Interior Panel Bonded with Exterior and Intermediate Glue. Panels shall be tested in accordance with Section 23.219.3. The material represented by the sampling shall be evaluated in accordance with Sections 23.207.2 and 23.207.3.

23.211.5 Finger-joint Durability for Exterior-type Panels and Interior-type Panels Bonded with Exterior or Intermediate Glue. Panels shall be tested in accordance with Section 23.216. The joints shall meet the following minimum conditions:

23.211.5.1 The average wood failure rating of all specimens from each panel when tested in accordance with Section 23.216 shall not be less than 85 percent.

23.211.5.2 No single specimen from a panel (average of face and back gluelines) shall rate less than 60 percent wood failure.
23.211.5.3 No single face or back glueline in any specimen shall rate less than 30 percent wood failure.

SECTION 23.212 — INSPECTION AND TESTING

23.212.1 General. The tests specified in this section shall be used to determine the glue bond quality of plywood produced under this standard.

23.212.2 Inspections. All plywood designated as complying with this standard shall be subject to inspection prior to coating or finishing, except that concrete form material may have a priming coat of oil or other clear preparation before inspection. The above requirement does not apply to Interior-type plywood bonded with exterior glue or to Exterior-type plywood when tested for glue bond quality.

23.212.3 Plywood Panel Grade, Size and Thickness Reinspections. If reinspection establishes that an item is more than 5 percent below grade or out of dimensional tolerance according to the grade description, that item fails to pass the reinspection. The below-grade panels shall not be accepted. If reinspection establishes that a disputed item is 5 percent or less below grade or out of dimensional tolerance, it passes the reinspection. In addition to the above 5 percent grade and dimensional tolerance, a 5 percent tolerance shall apply separately to the inner-ply gap limitations, including the limitations applicable to the plugged crossband and jointed crossband, as specified in Section 23.203.

23.212.4 Plywood Glue Bond Quality Reinspections. Reinspection of the unused panels shall be carried out following the procedures specified in Sections 23.212, 23.213, 23.214 and 23.215. If the reinspection tests establish that the glue bond quality does not meet the requirements of Section 23.207, as applicable, the panels fail to pass the reinspection. If the glue bond quality requirements are met, panels pass the reinspection. Any delaminated Exterior-type or overlaid panels are not acceptable.

23.212.5 Sampling for Panel Grade, Size and Thickness Reinspections. Grade, size and thickness may include all panels of an item in dispute. However, when approved, a reduced basis for sampling consisting of at least 20 percent or 300 panels, whichever is smaller, shall be inspected for conformance to grade. For reduced sampling, the quantity of panels selected from each disputed item shall be prorated according to the number of panels. Panels found to be below grade or out of tolerance for size and thickness shall have improper grademarks obliterated and shall be remarked for appropriate classification with a special inspection mark registered by the qualified agency conducting the reinspection and applied by this agency’s authorized representative.

23.212.6 Sampling for Glue Bond Reinspections. For test purposes, 20 panels, or 5 percent of the panels, whichever is less, shall be selected at random from the item which is in dispute. The number of panels required shall be calculated by applying the “percent panels” to the lot size and converting part panels to whole panels by using a rounding procedure where 0.01 to 0.49 parts are considered to be the smaller whole number, while 0.50 to 0.99 parts are considered to be the larger whole number. These panels shall be selected from locations distributed as widely as practicable throughout the material being sampled. When an item, lot, or shipment involves panels with different adhesive bond requirements as provided for in Section 23.207, testing and evaluation shall apply separately to each category.

Sampling shall include no less than 20 panels of Interior-type Underlayment, C-D Plugged, and C-D. Sampling of Interior-type (including the different adhesive qualities) or Exterior-type shall be prorated on the basis of ratio of their volume to total volume (i.e., for shipments containing 50 percent Exterior, 10 Exterior panels shall be selected), but in no case shall less than 10 panels of each type or adhesive quality be selected. Shipments of Interior-type plywood bonded with exterior glue shall be sampled in the same manner as Exterior plywood.

23.212.7 Specimen Preparation. One piece shall be cut from each Interior panel selected and from that piece five test specimens shall be cut. Each specimen shall be 2 inches wide by 5 inches...
(51 mm wide by 127 mm) along the grain. From each Exterior panel selected, one piece shall be cut from the panel and from that piece 10 test specimens shall be cut as described in Section 23.215.1. Of the 10 specimens cut from each test piece, five shall be for vacuum pressure test, and five shall be for the boil test. From each overlaid panel selected, 10 specimens shall be cut as described for Exterior plywood. These shall be for testing the bond between veneers. A second set of 10 specimens shall be cut to test the bond between the overlay and the base panel as described in Section 23.215.1.

From five of the Exterior test panels and five of the overlaid test panels, $5 \frac{1}{2}$-inch by 8-inch (140 mm by 203 mm) specimens shall be cut and tested as described in Section 23.215.4.

**SECTION 23.213 — TEST FOR INTERIOR-TYPE PLYWOOD**

The test specimens prepared as described in Section 23.219.3 shall be placed in a pressure vessel and completely submerged in 110°F. (43.3°C.) water. A vacuum of 15 inches of mercury (50.7 kPa) shall be drawn, maintained for 30 minutes and released. Specimens shall then be allowed to soak in the same water at atmospheric pressure for four and one half hours with no additional heating. They shall be removed and dried for 15 hours at 150°F. (65.6°C.) in an oven with fan-forced air circulation of 45 to 50 air changes per minute. Specimens shall then be examined for delamination and evaluated in accordance with requirements given in the following paragraph.

Total continuous visible delamination of $\frac{1}{4}$ inch (6.4 mm) or more in depth and 2 inches (51 mm) in length along the edges of a 2-inch by 5-inch (51 mm by 127 mm) test specimen shall be considered as failure. Where required, this shall be determined by probing with a suitable feeler gage not greater than 0.013 inch (0.3 mm) in thickness. When delamination occurs by reason of a localized defect permitted in the grade, other than white pocket, that test specimen shall be discarded.

**SECTION 23.214 — TESTS FOR IMG-TYPE PLYWOOD**

23.214.1 Preparation of Test Specimens. Test specimens, taken as described in Section 23.219.3, shall be cut $3 \frac{1}{4}$ inches (83 mm) long and 1 inch (25 mm) wide, and kerfed one third of the length of the specimen from each end, as illustrated in Figure 23-2-1, so that a 1-inch (25 mm) square test area in the center results. Specimens shall be oriented so that the grain direction of the ply under test runs at a 90-degree angle to the length of the specimen. Kerfing shall extend two thirds of the way through the ply under test, and shall not penetrate the next glueline.

If the number of plies exceeds three, the cuts shall be made so as to test any two of the joints, but the additional plies need not be stripped except as demanded by the limitations of the width of the retaining jaws on the testing device. When desired, special jaws may be constructed to accommodate the thicker plywood. If the number of plies exceeds three, the choice of joints to be tested shall be left to the discretion of the approved inspection and testing agency, but at least one half of the tests shall include the innermost joints.

23.214.2 Vacuum Soak Test. The test specimens shall be placed in a pressure vessel and submerged in water 120°F. (48.9°C.). A vacuum of 15 inches of mercury (50.7 kPa) shall be drawn and maintained for 30 minutes. Following release of vacuum, specimens shall continue soaking for 15 hours at atmospheric pressure. The temperature of the water shall not drop below 75°F. (23.9°C.) at any time during the 15-hour soaking period. Specimens shall then be removed from the vessel and tested while wet by tension loading to failure in a shear testing machine operated at a maximum head travel of 16 inches per minute (406 mm per minute). Jaws of the machine shall securely grip the specimen so there is no slippage. The percentage of wood failure of the specimens shall be determined with specimens in a dry condition and evaluated as described in Section 23.207.7.
length of the specimen from each end, as illustrated in Figure 23-2-1, so that a 1-inch (25 mm) square test area in the center results. Specimens shall be oriented so that the grain direction of the ply under test runs at a 90-degree angle to the length of the specimen. Kerfing shall extend two thirds of the way through the ply under test, and shall not penetrate the next glueline. Overlaid plywood specimens, taken as described in Section 23.212.3 for testing of bond between veneers, shall be cut as described above for Exterior specimens. Overlaid specimens for testing the bond between the overlay and the base panel, shall be cut 1 inch (25 mm) wide and long enough for handling (3 inches [76 mm] is a convenient length) and kerfed just through the overlay 1 inch (25 mm) from the end, on each overlay face.

(a) Three-ply Specimen

(b) Five-ply Specimen

NOTE: Orient grain direction across specimens to test inner two joints.

FIGURE 23-2-1—SHEAR TEST SPECIMENS
(1 inch = 25.4 mm)

If the number of plies exceeds three, the cuts shall be made so as to test any two of the joints, but the additional plies need not be stripped except as demanded by the limitations of the width of the retaining jaws on the testing device. When desired, special jaws may be constructed to accommodate the thicker plywood. If the number of plies exceeds three, the choice of joints to be tested shall be left to the discretion of the approved inspection and testing agency, but at least one half of the tests shall include the innermost joints.

23.215.2 Vacuum-pressure Test. The test specimen shall be placed in a pressure vessel and submerged in cold tap water. A vacuum of 25 inches of mercury (84.4 kPa) shall be drawn and maintained for 30 minutes, followed immediately with application of 65-70 psi (448-483 kPa) of pressure for 30 minutes duration. Specimens shall then be removed from the vessel and tested while wet by tension loading to failure in a shear testing machine operated at a maximum head travel of 16 inches per minute (406 mm per minute). Jaws of the machine shall securely grip the specimens so there is no slippage. The percentage of wood failure of the specimens shall be determined with specimens in a dry condition and evaluated as described in Section 23.207.8.

The bond between veneers in overlaid plywood shall be tested in an identical manner and evaluated as described in Section 23.207.8. Specimens for testing the bond between the overlay and the base panel shall be subjected to the same test cycle described above. The bond between the overlay and the base panel shall be tested by inserting a sharp, thin blade of adequate stiffness into the corner of the 1-inch (25 mm) test area at the overlay-veneer interface, taking care not to cut into the overlay, and attempting to peel off the overlay. It may be necessary to reinsert the blade several times in order to remove the overlay from the 1-square-inch (645 mm²) area. The percentage of wood and/or fiber failure shall then be estimated with specimens in a dry condition and evaluated as

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described in Section 23.207.8. The value for each specimen shall be the average of the test areas on each face.

23.215.3 Boiling Test. Test specimens shall be boiled in water for four hours and then dried for 20 hours at a temperature of 145°F ± 5°F. (62.8°C ± 2.8°C.) with sufficient air circulation to lower moisture content of the specimens to a maximum of 8 percent, based on oven-dry weight. The specimens shall be boiled again for a period of four hours, cooled in water, and tested while wet by tension loading for failure in a shear testing machine operated at a maximum head travel of 16 inches per minute (406 mm per minute). Jaws of the machine shall securely grip the specimens so there is no slippage. The percentage of wood failure of the specimens shall be determined with specimens in a dry condition and evaluated as described in Section 23.207.8. The bond between veneers in overlaid plywood shall be tested and evaluated in an identical manner. Specimens to test the bond between the overlay and the base panels shall be subjected to the same test cycle described above. The bond between the overlay and the base panel shall be tested by inserting a sharp, thin blade of adequate stiffness into the comer of the 1-inch (25 mm) test area at the overlay-veneer interface, taking care not to cut into the overlay, and attempting to peel off the overlay. It may be necessary to reinsert the blade several times in order to remove the overlay from the 1-square-inch (645 mm²) area. The percentage of wood and/or fiber failure shall then be estimated with specimens in a dry condition and evaluated as described in Section 23.207.8. The value for each specimen shall be the average of the test areas on each face.

23.215.4 Heat Durability Test. Specimens cut as described in Section 23.212.3 shall be placed on a stand as illustrated in Figure 23-2-2. It shall then be subjected to a 1,472°F to 1,652°F. (800°C. to 900°C.) flame from a Bunsen-type burner for a period of 10 minutes or, in the case of a thin specimen, until a brown char area appears on the backside. The burner shall be equipped with a wing top to envelop the entire width of the specimen in flame. The top of the burner shall be 1 inch (25 mm) from the specimen face and the flame 1 1/2 inches (38 mm) high. The flame shall impinge on the face of the specimen 2 inches (51 mm) from the bottom end. After the test, the sample shall be removed from the stand and the gluelines examined for delamination by separating the charred plies with a sharp, chisel-like instrument. Specimens shall be evaluated in accordance with Section 23.207.8.

![Apparatus for Heat Durability Test](image)
SECTION 23.216 — TESTS FOR PERFORMANCE UNDER CONCENTRATED STATIC AND IMPACT LOADS

23.216.1 Preparation of Test Specimens. Samples shall be selected representative of the plywood product being evaluated. Length, \( L \), of panels shall conform to the maximum center-to-center support spacing, \( S \), anticipated in service, continuous over the minimum number of spans recommended for its use. See Figures 23-2-7 and 23-2-8. Width, \( W \), of individual pieces shall be 24 inches (610 mm) or greater for span ratings up to 24 inches (610 mm) on center and 48 inches (1219 mm) for greater span ratings.

23.216.2 Test Procedure.

23.216.2.1 Concentrated static. Specimens shall be loaded at locations shown in Figure 23-2-7 using a 3-inch-diameter (76 mm) loading disc, except a 1-inch-diameter (25 mm) loading disc shall be used to determine strength of single-layer floor panels in the dry or redried condition.

Stiffness shall be determined by measuring deflection in 50-pound (222 N) increments to 200 pounds (890 N). Strength shall be determined by loading to failure.

23.216.2.2 Concentrated impact. Specimens shall be loaded at locations shown in Figure 23-2-8 using an impact device 9 to 10 1/2 inches (229 to 267 mm) in diameter and weighing 30 pounds (13.6 kg), except that for span ratings greater than 24 inches (610 mm) on center, the impact device shall weigh 60 pounds (27.2 kg).

Strength shall be determined by impacting the specimen from the specified height at increments of 6 inches (152 mm). Deflection under a 200-pound (890 N) concentrated load, using a 3-inch-diameter (76 mm) disc, shall be measured before the test and after each impact. After the specified impact load has been reached, the concentrated load shall be applied to failure.

SECTION 23.217 — TEST FOR PERFORMANCE UNDER UNIFORM LOADS

23.217.1 Apparatus. A vacuum chamber is used consisting of a sealed box with the panel to be tested forming the top. See Figure 23-2-9. A 6-mil (0.15 mm) polyethylene sheet or equivalent is attached.
securely taped at the perimeter to seal the top surface. A vacuum pump reduces air pressure under the specimen such that load is measured.

23.217.2 Preparation of Test Specimens. Samples shall be selected representative of the plywood product being evaluated. The specimen length perpendicular to framing shall be equal to twice the maximum center-to-center support spacing, $S$, anticipated in service. See Figure 23-2.10. The specimen width is at least $23\frac{1}{2}$ inches (597 mm).

23.217.3 Test Procedure. The specimen is mounted in the vacuum box following anticipated joist spacing and recommended nail size and spacing and sealed. The panel is loaded to the specified level. Deflections are measured at locations shown in Figure 23-2.10 sufficient to develop the straight-line portion of the load-deflection curve, but in no case shall the number of data points be less than six.

SECTION 23.218 — TEST FOR PANEL BENDING

23.218.1 Apparatus. A testing machine shall be used capable of applying pure moments to opposite ends of the test panel through loading frames and measurement of moment and deformation.

23.218.2 Preparation of Test Specimens. Samples shall be selected representative of the plywood product being evaluated. Specimens shall measure 4 feet by 4 feet (1219 mm by 1219 mm).

23.218.3 Test Procedure. Separate specimens are subjected to pure moment along and across the major axis. Deformation or curvature is measured in a manner adequate to calculate bending stiffness. Test is carried on to failure to evaluate maximum moment.

SECTION 23.219 — SCARF- AND FINGER-JOINT TESTS

23.219.1 Strength. Three test specimens shall be cut at random along each joint from panels selected as directed in Section 23.219.3. Type, grade and species of the panels shall be recorded. The specimens shall be cut so as to include the joint and shall be prepared as illustrated in Figure 23-2.3. Insofar as possible, the joint test area shall contain no localized natural defects permitted within the grade. At the joint, the maximum thickness and width of plies parallel with the load shall be recorded. Each specimen shall then be placed in the tension grips of a testing machine and loaded continuously at a rate of cross-head travel of 0.030 to 0.040 inch per minute (0.76 to 1.02 mm per minute) until failure, and the ultimate load recorded. The ultimate stress in pounds per square inch shall be computed using the ultimate load and area of those plies whose grain is parallel with direction of load. Moisture content of specimens at the time of testing shall not exceed 16 percent.

23.219.2 Scarf-joint Durability of Interior-type Panels Bonded with Interior Glue. Ten test specimens shall be cut at random along each scarf joint from panels selected as directed in Section 23.219.3, and shall be prepared following the general procedure in the same subsection, but shall be cut so that the scarf joint occurring on one surface of the panel runs across the middle of five specimens and the joint occurring on the opposite surface runs across the middle of the other five specimens. The specimens shall be subjected to the same test procedure as outlined in Section 23.212.

23.219.3 Scarf-joint Durability of Exterior-type Panels and Interior-type Panels Bonded with Exterior or Intermediate Glue. Ten test specimens shall be cut at random along each joint from panels selected as directed in Section 23.219.3. The specimens shall be prepared following the general procedure described in Section 23.221.1, but, in addition, shall be cut so that the joints run through the test specimens as shown in Figure 23-2.4. For Exterior-type panels and Interior-type bonded with exterior glue, five specimens shall be subjected to the vacuum-pressure test described in Section 23.215.2, and five to the boiling test of Section 23.215.3. The panels shall be evaluated as described in Section 23.207.

For Interior-type panels bonded with intermediate glue (IMG), the 10 specimens shall be subjected to the vacuum soak test outlined in Section 23.214.2. The panels shall be evaluated as described in Section 23.207.
23.219.4 Finger-joint Durability of Interior-type Panels Bonded with Interior Glue. Five specimens shall be cut at random along the finger joint from each panel selected and shall be prepared following the general procedure in Section 23.211 so that the middle of the joint coincides with the middle of the five specimens. The specimens shall be subjected to the same test procedure as outlined in Section 23.219.

23.219.5 Finger-joint Durability of Exterior-type Panels and Interior-type Panels Bonded with Exterior or Intermediate-type Glue. Ten specimens shall be cut at random along the finger joint from each panel selected according to Section 23.211. These specimens shall be cut so as to include the joint and shall be prepared as illustrated in Figure 23-2-5.

For Exterior-type panels and Interior-type panels bonded with exterior glue, five of the specimens shall be subjected to the vacuum pressure test of Section 23.215.2 and five to the boiling test of Section 23.215.1.

For Interior-type panels bonded with intermediate glue, the 10 specimens shall be subjected to the vacuum soak test of Section 23.214.

Upon completion of the vacuum pressure and boil tests, or vacuum soak tests, as applicable, a wedge or chisel (see Figure 23-2-6) shall be inserted in locations shown in Figure 23-2-5 in such a manner as to pry apart the scarfed portions of the joint without directly contacting the glued area. Test specimens shall be dried and percent wood failure in the test area estimated and applied separately for both the boil and vacuum pressure treatments. The panels shall be evaluated as described in Section 23.207.

SECTION 23.220 — TEST FOR DETERMINATION OF MOISTURE CONTENT (OVEN-DRYING METHOD)

The moisture content of the plywood shall be determined as follows: a small test specimen shall be cut from each sample panel; the test specimen shall measure not less than 9 square inches (5806 mm$^2$) in area and shall weigh not less than 20 grams (approximately $3/4$ ounce). All loose splinters shall be removed from the specimen. The specimen shall be immediately weighed on a scale that is accurate to 0.5 percent, and the weight shall be recorded as original weight. The specimen shall then be dried in an oven at 212°F to 221°F (100°C to 105°C) until constant weight is attained. After drying, the specimen shall be reweighed immediately, and this weight shall be recorded as the oven-dry weight. The moisture content shall be calculated as follows:

SECTION 23.221 — PLYWOOD SECTION PROPERTIES

23.221.1 General. Section properties set forth in Tables 23-2-H and 23-2-I shall be used with all species and grades of plywood in this standard. The section properties shall be used in determining

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compliance with allowable stresses set forth in Table 23-1-B of this code. The properties have been adjusted to reflect “effective” section properties in each of two directions, assuming a homogenous material. As a result of these adjusted values, moment of inertia $I'$ shall be used only in stiffness calculations, with section modulus $S''$ used in bending stress calculations.

23.221.2 Veneer Lay-up. Section properties listed are adjusted to allow for variations in panel veneer constructions. Properties parallel to the face grain of the plywood are based on a panel construction giving minimum values in that direction. Properties perpendicular to the face grain are based on a different panel construction, giving minimum values in that direction. Properties for the two directions, however, cannot be added to achieve properties of the full panel.

\[ \frac{\text{Original weight} - \text{Oven-dry weight}}{\text{Oven-dry weight}} \times 100 = \text{Moisture content (percent)} \]

**SECTION 23.222 — CALCULATION OF DIAPHRAGM DEFLECTION**

Calculations for diaphragm deflection shall account for the usual bending and shear components as well as any other factors, such as nail deformation, which will contribute to the deflection.

The deflection ($\Delta$) of a blocked plywood diaphragm uniformly nailed throughout may be calculated by use of the following formula. If not uniformly nailed, the constant 0.188 (0.614) in the third term must be modified accordingly.

\[
\Delta = \frac{5vL^2}{8EAb} + \frac{vL}{4Gt} + 0.188L_n + \frac{\Sigma(\Delta_X)}{2b}
\]

For SI:

\[
\Delta = \frac{52vL^2}{EAb} + \frac{vL}{4Gt} + 0.614L_n + \frac{\Sigma(\Delta_X)}{2b}
\]

**WHERE:**

- $A$ = area of chord cross section, in square inches (mm²).
- $b$ = diaphragm width, in feet (mm).
- $E$ = elastic modulus of chords, in pounds per square inch (N/mm²).
- $e_n$ = nail deformation, in inches (mm) (see Table 23-2-K).
- $G$ = modulus of rigidity of plywood, in pounds per square inch (N/mm²) (see Table 23-2-J).
SECTION 23.223 — CALCULATION OF SHEAR WALL DEFLECTION

The deflection ($\Delta$) of a blocked shear wall uniformly nailed throughout may be calculated by use of the following formula:

$$\Delta = \frac{8vh^3}{EAb} + \frac{vh}{Gl} + 0.75 h\eta_n + d_a$$

For SI:

$$\Delta = \frac{2000vh^3}{3EAb} + \frac{vh}{Gl} + 2.46 h\eta_n + d_a$$

WHERE:

- $A$ = area of boundary element cross section in square inches (mm$^2$) (vertical member at shear wall boundary).
- $b$ = wall width, in feet (mm).
- $d_a$ = deflection due to anchorage details (rotation and slip at tie-down bolts).
- $E$ = elastic modulus of boundary element (vertical member at shear wall boundary), in pounds per square inch (N/mm).
- $\eta_n$ = nail deformation, in inches (mm) (see Table 23-2-K).
- $G$ = modulus of rigidity of plywood, in pounds per square inch (N/mm) (see Table 23-2-J).
- $h$ = wall height, in feet (mm).
- $t$ = effective thickness of plywood for shear, in inches (mm) (see Tables 23-2-H and 23-2-I).
- $v$ = maximum shear due to design loads at the top of the wall, in pounds per lineal foot (N/mm).
- $\Delta$ = the calculated deflection, in inches (mm).

SECTION 23.224 — ALLOWABLE STRESSES FOR SHEAR THROUGH THE THICKNESS

Shear-through-the-thickness stresses in Table 23-I-B of this code are based on the most common structural applications, as where plywood is mechanically fastened to framing. If the plywood is rigidly glued to full-length, continuous (unjointed) framing around all panel edges, increase allowable shear-through-the-thickness stresses by 33 percent. If the continuous framing is glued to only two edges parallel to the face grain, increase stresses by 19 percent. When continuous framing is only at edges perpendicular to the face grain, no increase in stresses shall be taken.

In lieu of the increase in shear-through-the-thickness stresses given above for continuous glued framing, a 33 percent increase may be taken when panels are regraded to limit core gap width and placement. Contiguous core gaps in adjacent plies within a layer shall be measured as a single gap from the outermost edge of one to the opposite edge of the other. Noncontiguous core gaps in any parallel ply of the panel shall be offset by at least 1 inch (25 mm), measured from innermost edges of the gaps. Gap width limitations are as follows:
1. For all three-layer panels (including three-ply and four-ply), core gaps shall not be wider than \( \frac{1}{4} \) inch (6.4 mm).

2. For panels with five or more layers, core gaps shall be limited to 1 inch (25 mm) in \( \frac{1}{2} \)-inch-thick (13 mm) panels and to \( \frac{1}{2} \) inch (13 mm) in thicker panels.
FIGURE 23-2-5—CLEAVAGE TEST, TYPICAL TEST SPECIMEN

FIGURE 23-2-6—WEDGE OR CHISEL FOR CLEAVAGE TEST
Figure 23.2.7—Concentrated Static Load Test Specimens
FRAMING (TYPICAL)

UNSUPPORTED EDGE (TYPICAL)

SHEATHING WITH FULL EDGE SUPPORT

UNSUPPORTED EDGE (TYPICAL)

SHEATHING WITH PARTIAL EDGE SUPPORT

SHEATHING WITHOUT EDGE SUPPORT

FRAMING MEMBERS, ENDS CLAMPED TO PREVENT ROTATION OR VERTICAL MOVEMENT DURING TESTING. (FRAMING SUPPORTED AT TEST LOCATIONS).

1 T & G, EDGE CLIPS OR SIMILAR
2 FRAMING MEMBER, BLOCKING OR EQUAL

FIGURE 23-2-8—IMPACT LOAD TEST SPECIMENS

3-729
S = center-to-center support spacing.

\[
d = 0.4215(S) \text{ for two span.}
\]

W = panel width, minimum = 23.5 inches (597 mm).

\( \Theta \) = location of deflection measurement.

**FIGURE 23-2-9—VACUUM CHAMBER TEST EQUIPMENT**

**FIGURE 23-2-10—UNIFORM LOAD TEST SPECIMENS**
<table>
<thead>
<tr>
<th>GROUP 1</th>
<th>GROUP 2</th>
<th>GROUP 3</th>
<th>GROUP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aptong&lt;sup&gt;1,2&lt;/sup&gt;</td>
<td>White lauan</td>
<td>Alder, red</td>
<td>Aspen</td>
</tr>
<tr>
<td>Beech, American</td>
<td>Maple, black</td>
<td>Birch, paper</td>
<td>Bigtooth</td>
</tr>
<tr>
<td>Birch</td>
<td>Mengkulang&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Cedar, Alaska</td>
<td>Quaking</td>
</tr>
<tr>
<td>Sweet Yellow</td>
<td>Meranti, red&lt;sup&gt;1,4&lt;/sup&gt;</td>
<td>Fir, subalpine</td>
<td>Caivo</td>
</tr>
<tr>
<td>Douglas fir&lt;sup&gt;1,3&lt;/sup&gt;</td>
<td>Mersawa&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Hemlock, eastern</td>
<td>Cedar</td>
</tr>
<tr>
<td>Keruing&lt;sup&gt;1,2&lt;/sup&gt;</td>
<td>Pine</td>
<td>Maple, bigleaf</td>
<td>Incense</td>
</tr>
<tr>
<td>Larch, western</td>
<td>Pond</td>
<td>Pine</td>
<td>Western red</td>
</tr>
<tr>
<td>Maple, sugar</td>
<td>Red</td>
<td>Jack</td>
<td>Cottonwood</td>
</tr>
<tr>
<td>Pine</td>
<td>Virginia</td>
<td>Lodgepole</td>
<td>Eastern</td>
</tr>
<tr>
<td>Caribbean</td>
<td>Western White</td>
<td>Ponderosa</td>
<td>Black (western poplar)</td>
</tr>
<tr>
<td>Ocote</td>
<td>Spruce</td>
<td>Spruce</td>
<td>Pine</td>
</tr>
<tr>
<td>Pine, southern</td>
<td>Black</td>
<td>Redwood</td>
<td>Eastern white</td>
</tr>
<tr>
<td>Lobolly</td>
<td>Red</td>
<td>Spruce</td>
<td>Sugar</td>
</tr>
<tr>
<td>Longleaf</td>
<td>Sitka</td>
<td>Engelmann</td>
<td></td>
</tr>
<tr>
<td>Shortleaf</td>
<td>Sweetgum</td>
<td>White</td>
<td></td>
</tr>
<tr>
<td>Slash</td>
<td>Tamarack</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tanoak</td>
<td>Yellow-poplar</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup> Each of these names represents a trade group of woods consisting of a number of closely related species.

<sup>2</sup> Species from the genus Dipterocarpus are marked collectively: Aptong if originating in the Philippines; Keruing if originating in Malaysia or Indonesia.

<sup>3</sup> Douglas fir from trees grown in the states of Washington, Oregon, California, Idaho, Montana, Wyoming, and the Canadian provinces of Alberta and British Columbia shall be classed as Douglas fir No. 1. Douglas fir from trees grown in the states of Nevada, Utah, Colorado, Arizona and New Mexico shall be classed as Douglas fir No. 2.

<sup>4</sup> Red meranti shall be limited to species having a specific gravity of 0.41 or more based on green volume and oven-dry weight.
<table>
<thead>
<tr>
<th>PANEL GRADE DESIGNATION</th>
<th>DESCRIPTION AND NUMBER OF CHARACTERISTICS PER PANEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-N, N-A</td>
<td>No crossband laps adjacent to faces and backs</td>
</tr>
<tr>
<td>N-B</td>
<td>No crossband laps adjacent to N faces</td>
</tr>
<tr>
<td></td>
<td>No more than 2 crossband laps adjacent to B grade side</td>
</tr>
<tr>
<td></td>
<td>Laps are limited to $\frac{3}{16}$ inch (4.8 mm)</td>
</tr>
<tr>
<td>N-D</td>
<td>No crossband laps adjacent to faces</td>
</tr>
<tr>
<td></td>
<td>No more than a total of 2 of any combination of the following:</td>
</tr>
<tr>
<td></td>
<td>- Knothole in D veneer over $2\frac{1}{2}$ inches (64 mm) but not over 3 inches (76 mm)</td>
</tr>
<tr>
<td></td>
<td>- Split in D veneer over $\frac{1}{2}$ inch (13 mm) (not over 1 inch [25 mm])</td>
</tr>
<tr>
<td></td>
<td>- Crossband lap adjacent to backs</td>
</tr>
<tr>
<td>Underlayment and C-C Plugged</td>
<td>No knotholes in veneer adjacent to face over 1 inch (25 mm) across the grain where C grade is required per Tables 23-2-D and 23-2-E</td>
</tr>
<tr>
<td></td>
<td>No knotholes in veneer adjacent to face over $2\frac{1}{2}$ inches (64 mm) where D grade is permitted or $1\frac{1}{2}$ inches (38 mm) where C grade is permitted per Section 23.205.6</td>
</tr>
<tr>
<td></td>
<td>No laps adjacent to face</td>
</tr>
<tr>
<td>Structural I and II C-D</td>
<td>No splits in faces over $\frac{1}{4}$ inch (6.4 mm)</td>
</tr>
<tr>
<td></td>
<td>No splits in backs over $\frac{1}{2}$ inch (13 mm)</td>
</tr>
<tr>
<td></td>
<td>No more than a total of 2 of any combination of the following:</td>
</tr>
<tr>
<td></td>
<td>- Knothole in C veneer over 1 inch (25 mm) but not over $1\frac{1}{2}$ inches (38 mm)</td>
</tr>
<tr>
<td></td>
<td>- Knot in D backs over $2\frac{1}{2}$ inches (64 mm) but not over 3 inches (76 mm)</td>
</tr>
<tr>
<td></td>
<td>- Knothole in D veneer over $2\frac{1}{2}$ inches (64 mm) but not over 3 inches (76 mm)</td>
</tr>
<tr>
<td></td>
<td>- Crossband lap adjacent to faces per Section 23.205.4</td>
</tr>
<tr>
<td></td>
<td>- Crossband lap adjacent to backs per Section 23.205.4</td>
</tr>
<tr>
<td>Structural I and II C-D Plugged</td>
<td>No splits in backs over $\frac{1}{2}$ inch (13 mm)</td>
</tr>
<tr>
<td></td>
<td>No more than a total of 2 of any combination of the following:</td>
</tr>
<tr>
<td></td>
<td>- Knot in D backs over $2\frac{1}{2}$ inches (64 mm) but not over 3 inches (76 mm)</td>
</tr>
<tr>
<td></td>
<td>- Knothole in D veneer over $2\frac{1}{2}$ inches (64 mm) but not over 3 inches (76 mm)</td>
</tr>
<tr>
<td></td>
<td>- Crossband lap adjacent to faces per Section 23.205.4</td>
</tr>
<tr>
<td></td>
<td>- Crossband lap adjacent to backs per Section 23.205.4</td>
</tr>
<tr>
<td>Structural I and II Underlayment</td>
<td>No knotholes in core veneer next to face over 1 inch (25 mm)</td>
</tr>
<tr>
<td></td>
<td>No crossband laps adjacent to faces</td>
</tr>
<tr>
<td></td>
<td>No splits in backs over $\frac{1}{2}$ inch (13 mm)</td>
</tr>
<tr>
<td></td>
<td>No more than a total of 2 of any combination of the following:</td>
</tr>
<tr>
<td></td>
<td>- Knot in D backs over $2\frac{1}{2}$ inches (64 mm) but not over 3 inches (76 mm)</td>
</tr>
<tr>
<td></td>
<td>- Knothole in D veneer over $2\frac{1}{2}$ inches (64 mm) but not over 3 inches (76 mm)</td>
</tr>
<tr>
<td></td>
<td>- Crossband lap adjacent to backs per Section 23.205.4</td>
</tr>
</tbody>
</table>
### TABLE 23-2-C—PANEL CONSTRUCTIONS

<table>
<thead>
<tr>
<th>PANEL GRADES</th>
<th>FINISHED PANEL NOMINAL THICKNESS RANGE (inch)</th>
<th>MINIMUM NUMBER OF PLYS</th>
<th>MINIMUM NUMBER OF LAYERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marine</td>
<td>Through $\frac{3}{8}$</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Special Exterior</td>
<td>Over $\frac{3}{8}$, through $\frac{3}{4}$</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>B-B concrete form</td>
<td>Over $\frac{3}{4}$</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>High Density Overlay</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interior</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N-N, N-A, N-B, N-D, A-A, A-B, A-D, B-B, B-D</td>
<td>Through $\frac{3}{8}$</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Structural I (C-D, C-D Plugged and Underlayment)</td>
<td>Over $\frac{3}{8}$, through $\frac{1}{2}$</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Structural II (C-D, C-D Plugged and Underlayment)</td>
<td>Over $\frac{1}{2}$, through $\frac{3}{8}$</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Exterior</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A-A, A-B, A-C, B-B, B-C</td>
<td>Through $\frac{1}{2}$</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Structural I and Structural II C-C and C-C Plugged</td>
<td>Over $\frac{1}{2}$, through $\frac{3}{4}$</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>(See Section 23.205.4)</td>
<td>Over $\frac{3}{4}$</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Medium Density and Special Overlays</td>
<td>Over $\frac{3}{4}$</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Interior</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(including grades with Exterior glue) Underlayment</td>
<td>Through $\frac{1}{2}$</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Exterior</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-C Plugged</td>
<td>Through $\frac{5}{8}$</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Interior</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(including grades with Exterior glue) C-D</td>
<td>Over $\frac{5}{8}$, through $\frac{3}{4}$</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>C-D Plugged</td>
<td>Over $\frac{3}{4}$</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Exterior</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-C</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**TABLE 23-2-D—INTERIOR-TYPE GRADES**

<table>
<thead>
<tr>
<th>PANEL GRADES DESIGNATIONS</th>
<th>MINIMUM VENEER QUALITY</th>
<th>SURFACE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Face</td>
<td>Back</td>
</tr>
<tr>
<td>N-N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>N-A</td>
<td>N</td>
<td>A</td>
</tr>
<tr>
<td>N-B</td>
<td>N</td>
<td>B</td>
</tr>
<tr>
<td>N-D</td>
<td>N</td>
<td>D</td>
</tr>
<tr>
<td>A-A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>A-B</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>A-D</td>
<td>A</td>
<td>D</td>
</tr>
<tr>
<td>B-B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>B-D</td>
<td>B</td>
<td>D</td>
</tr>
<tr>
<td>Underlayment¹</td>
<td>C Plugged</td>
<td>D</td>
</tr>
<tr>
<td>Structural I C-D Plugged,</td>
<td>C Plugged</td>
<td>D</td>
</tr>
<tr>
<td>Underlayment</td>
<td>See Section 23.205.4</td>
<td></td>
</tr>
<tr>
<td>Structural II C-D Plugged,</td>
<td>See Section 23.205.4</td>
<td></td>
</tr>
<tr>
<td>Underlayment</td>
<td>See Section 23.205.4</td>
<td></td>
</tr>
<tr>
<td>C-D</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>C-D with Exterior glue</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>(See Section 23.215)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹See Section 23.205.6 for special limitations.
²Except for decorative grades, panels shall not be sanded, touch-sanded, surface textured or thickness sized by any mechanical means.

**TABLE 23-2-E—EXTERIOR-TYPE GRADES¹**

<table>
<thead>
<tr>
<th>PANEL GRADES DESIGNATIONS</th>
<th>MINIMUM VENEER QUALITY</th>
<th>SURFACE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Face</td>
<td>Back</td>
</tr>
<tr>
<td>Marine, A-A, A-B, B-B,</td>
<td>Section 23.205.1</td>
<td></td>
</tr>
<tr>
<td>HDO, MDO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Special Exterior, A-A,</td>
<td>Section 23.205.5</td>
<td></td>
</tr>
<tr>
<td>A-B, B-B, HDO, MDO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A-A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>A-B</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>A-C</td>
<td>A</td>
<td>C</td>
</tr>
<tr>
<td>B-B (concrete form)</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>B-C</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>C-C Plugged²</td>
<td>C Plugged</td>
<td>C</td>
</tr>
<tr>
<td>C-C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>A-A High Density Overlay</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>B-B High Density Overlay</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>B-B High Density</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concrete Form Overlay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(See Section 23.205.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-B Medium Density Overlay</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Special Overlays</td>
<td>C</td>
<td>C</td>
</tr>
</tbody>
</table>

¹Available also in Structural I and Structural II classifications as provided in Section 23.205.4.
²See Section 23.205.6 for special limitations.
³Except for decorative grades, panels shall not be sanded, touch-sanded, surface textured or thickness sized by any mechanical means.
⁴C centers may be used in panels of five or more plies.

3-735
TABLE 23-2-F—PREMIUM GRADES

<table>
<thead>
<tr>
<th>GRADE</th>
<th>GLUE BOND</th>
<th>SPECIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-D&lt;sup&gt;1,1&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-D Plugged&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underlayment&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural II</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-D&lt;sup&gt;1,1&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-D Plugged&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underlayment&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural I Exterior grades</td>
<td>Exterior</td>
<td>Face, back and all inner plies limited to Group I species</td>
</tr>
<tr>
<td>(see Table 23-2-E)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural II Exterior</td>
<td>Exterior</td>
<td>Face, back and all inner plies may be of any Group 1, 2 or 3 species</td>
</tr>
<tr>
<td>All Exterior grades</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(see Table 23-2-E)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup>Special limitations applying to Structural (C-D, C-D Plugged, Underlayment) grade panels are:

1.1 In D grade veneers white pocket in any area larger than the size of the largest knot-hole, pitchpocket or split specifically permitted in D grade shall not be permitted in any ply.

1.2 Sound tight knots in D grade shall not exceed 2\(1/2\) inches (64 mm) measured across the grain, except as provided in Table 23-2-B.

1.3 Plugs, including multiple repairs, shall not exceed 4 inches (102 mm) in width.

1.4 Panel construction shall be as specified in Section 23.203.1.
### TABLE 23-2-G—SPAN RATINGS FOR SHEATHING AND SINGLE-FLOOR PANELS

(For special ply-layer and species requirements applicable to STRUCTURAL panels, see Section 23.205.4 and Tables 23-2-C and 23-2-F. For crossband and total inner-ply thickness proportion requirements, see Section 23.203.1.)

<table>
<thead>
<tr>
<th>SPAN RATING</th>
<th>MINIMUM PANEL THICKNESS (inch)</th>
<th>MINIMUM NUMBER OF PLYES-LAYERS</th>
<th>MINIMUM FACE AND BACK VENEER THICKNESS BEFORE PRESSING, FOR SPECIES GROUP¹ (inches)</th>
<th>INNER-PLY SPECIES GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>× 25.4 for mm</td>
<td></td>
</tr>
<tr>
<td>SHEATHING PANELS (C-D, C-C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12/0</td>
<td>5/16</td>
<td>3-3</td>
<td>1/12</td>
<td>1/12</td>
</tr>
<tr>
<td>16/0</td>
<td>5/16 1/32</td>
<td>3-3</td>
<td>1/12</td>
<td>1/12</td>
</tr>
<tr>
<td>20/0</td>
<td>5/16 1/32 3/8</td>
<td>3-3</td>
<td>1/12</td>
<td>1/12</td>
</tr>
<tr>
<td>24/0</td>
<td>3/8 1/32 1/2</td>
<td>3-3</td>
<td>1/10</td>
<td>1/10</td>
</tr>
<tr>
<td>32/16</td>
<td>1/2 1/32 5/32 3/8</td>
<td>3-3</td>
<td>1/10</td>
<td>1/10</td>
</tr>
<tr>
<td>40/20</td>
<td>5/8 23/32 3/4 25/32</td>
<td>3-3</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>48/24</td>
<td>3/4 25/32 5/8 29/32</td>
<td>4-3</td>
<td>1/10</td>
<td>1/10</td>
</tr>
</tbody>
</table>

SINGLE-FLOOR PANELS (UNDERLAYMENT, C-C PLUGGED)

<table>
<thead>
<tr>
<th>SPAN RATING</th>
<th>MINIMUM PANEL THICKNESS (inch)</th>
<th>MINIMUM NUMBER OF PLYES-LAYERS</th>
<th>MINIMUM FACE AND BACK VENEER THICKNESS BEFORE PRESSING, FOR SPECIES GROUP¹ (inches)</th>
<th>INNER-PLY SPECIES GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>× 25.4 for mm</td>
<td></td>
</tr>
<tr>
<td>16 o.c.</td>
<td>1/2 1/32 5/8 3/4</td>
<td>3-3</td>
<td>1/10</td>
<td>5</td>
</tr>
<tr>
<td>20 o.c.</td>
<td>1/32 5/8 23/32 3/4</td>
<td>4-3</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>24 o.c.</td>
<td>23/32 3/4 5/8 29/32</td>
<td>4-3</td>
<td>1/10</td>
<td>1/10</td>
</tr>
<tr>
<td>48 o.c.</td>
<td>1/8 11/16 7/8 1/16</td>
<td>7-7</td>
<td>1/8</td>
<td>1/8</td>
</tr>
</tbody>
</table>

¹See Section 23.209 for description.

²Panels for which there is no span rating shall be identified by largest species group number of the face and back, or by the span rating of the next thinner comparable panel. Sheathing panels manufactured 1/32-inch (0.8 mm) over standard thickness may be identified as the standard thickness.

³Intermixing between species groups and/or thicknesses in the faces and backs of panel is permitted. Use the lowest applicable span rating to identify the panel.

⁴Not permitted.

⁵One-eighth-inch minimum for 3-, 4- and 5-ply three-layer panels per Section 23.204.1. May be 1/16 inch (2.5 mm) minimum for five-ply, five-layer panels.
### Table 23-2-H—Face Plies of Different Species Group Than Inner Plies

(Includes all standard grades except those noted in Table 23-2-I)

<table>
<thead>
<tr>
<th>NOMINAL THICKNESS (inches)</th>
<th>APPROXIMATE WEIGHT (psf)</th>
<th>EFFECTIVE THICKNESS FOR SHEAR (inches)</th>
<th>STRESS APPLIED PARALLEL TO FACE GRAIN</th>
<th>STRESS APPLIED PERPENDICULAR TO FACE GRAIN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>A Area (in.²/ft.)</td>
<td>I/ Moment of Inertia (in.⁴/ft.)</td>
</tr>
<tr>
<td>× 25.4 for mm</td>
<td>× 4.882 for kg/m²</td>
<td>× 25.4 for mm</td>
<td>× 2.117 for mm²/in²</td>
<td>× 1305.6 for mm²/in²</td>
</tr>
<tr>
<td>Unsanded Panels</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5/16-U</td>
<td>1.0</td>
<td>0.268</td>
<td>1.491</td>
<td>0.022</td>
</tr>
<tr>
<td>3/8-U</td>
<td>1.1</td>
<td>0.278</td>
<td>1.866</td>
<td>0.037</td>
</tr>
<tr>
<td>15/32 and 1/2-U</td>
<td>1.5</td>
<td>0.298</td>
<td>2.292</td>
<td>0.074</td>
</tr>
<tr>
<td>19/32 and 5/8-U</td>
<td>1.8</td>
<td>0.319</td>
<td>2.330</td>
<td>0.146</td>
</tr>
<tr>
<td>23/32 and 3/4-U</td>
<td>2.2</td>
<td>0.445</td>
<td>3.247</td>
<td>0.227</td>
</tr>
<tr>
<td>7/8-U</td>
<td>2.6</td>
<td>0.607</td>
<td>3.509</td>
<td>0.340</td>
</tr>
<tr>
<td>I-U</td>
<td>3.0</td>
<td>0.842</td>
<td>3.916</td>
<td>0.493</td>
</tr>
<tr>
<td>11/8-U</td>
<td>3.3</td>
<td>0.859</td>
<td>4.725</td>
<td>0.676</td>
</tr>
<tr>
<td>Sanded Panels</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/4-S</td>
<td>0.8</td>
<td>0.267</td>
<td>0.996</td>
<td>0.008</td>
</tr>
<tr>
<td>11/32-S</td>
<td>1.0</td>
<td>0.284</td>
<td>0.996</td>
<td>0.019</td>
</tr>
<tr>
<td>3/8-S</td>
<td>1.1</td>
<td>0.288</td>
<td>1.307</td>
<td>0.027</td>
</tr>
<tr>
<td>15/32-S</td>
<td>1.4</td>
<td>0.421</td>
<td>1.947</td>
<td>0.066</td>
</tr>
<tr>
<td>19/32-S</td>
<td>1.5</td>
<td>0.425</td>
<td>1.947</td>
<td>0.077</td>
</tr>
<tr>
<td>5/8-S</td>
<td>1.7</td>
<td>0.546</td>
<td>2.423</td>
<td>0.115</td>
</tr>
<tr>
<td>23/32-S</td>
<td>1.8</td>
<td>0.550</td>
<td>2.475</td>
<td>0.129</td>
</tr>
<tr>
<td>7/8-S</td>
<td>2.1</td>
<td>0.563</td>
<td>2.822</td>
<td>0.179</td>
</tr>
<tr>
<td>I-S</td>
<td>2.2</td>
<td>0.568</td>
<td>2.884</td>
<td>0.197</td>
</tr>
<tr>
<td>11/8-S</td>
<td>2.6</td>
<td>0.868</td>
<td>2.942</td>
<td>0.278</td>
</tr>
<tr>
<td>13/8-S</td>
<td>3.0</td>
<td>0.817</td>
<td>3.721</td>
<td>0.423</td>
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<tr>
<td>Touch-sanded Panels</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11/2-T</td>
<td>3.3</td>
<td>0.836</td>
<td>3.854</td>
<td>0.548</td>
</tr>
<tr>
<td>19/32 and 5/8-T</td>
<td>1.5</td>
<td>0.342</td>
<td>2.698</td>
<td>0.083</td>
</tr>
<tr>
<td>23/32 and 3/4-T</td>
<td>1.8</td>
<td>0.408</td>
<td>2.354</td>
<td>0.122</td>
</tr>
<tr>
<td>13/8-T</td>
<td>2.2</td>
<td>0.439</td>
<td>2.715</td>
<td>0.196</td>
</tr>
<tr>
<td>11/8-T</td>
<td>3.3</td>
<td>0.839</td>
<td>4.548</td>
<td>0.633</td>
</tr>
<tr>
<td>NOMINALTHICKNESS (inches)</td>
<td>APPROXIMATEWEIGHT (psf)</td>
<td>EFFECTIVETHICKNESS FOR SHEAR (inches)</td>
<td>STRESSAPPLIED PARALLEL TO FACE GRAIN</td>
<td>STRESSAPPLIED PERPENDICULAR TO FACE GRAIN</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-------------------------</td>
<td>--------------------------------------</td>
<td>---------------------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A (in.²/ft)</td>
<td>J/ Moment of Inertia (in.⁴/ft)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(in.⁴/ft)</td>
<td>(in.⁴/ft)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>KS Eff. Section Modulus (in.⁷/ft)</td>
<td>J/ Moment of Inertia (in.⁴/ft)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(in.⁷/ft)</td>
<td>(in.⁴/ft)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>J/ Rolling Shear Constant (in.²/ft)</td>
<td>J/ Rolling Shear Constant (in.²/ft)</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unsanded Panels</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5/16-U</td>
<td>1.0</td>
<td>0.356</td>
<td>1.619</td>
<td>0.022</td>
</tr>
<tr>
<td>3/8-U</td>
<td>1.1</td>
<td>0.371</td>
<td>2.226</td>
<td>0.041</td>
</tr>
<tr>
<td>15/32 and 1/2-U</td>
<td>1.5</td>
<td>0.535</td>
<td>2.719</td>
<td>0.074</td>
</tr>
<tr>
<td>19/32 and 5/8-U</td>
<td>1.8</td>
<td>0.707</td>
<td>3.464</td>
<td>0.154</td>
</tr>
<tr>
<td>23/32 and 3/4-U</td>
<td>2.2</td>
<td>0.739</td>
<td>4.219</td>
<td>0.241</td>
</tr>
<tr>
<td>7/8-U</td>
<td>2.6</td>
<td>0.776</td>
<td>4.388</td>
<td>0.346</td>
</tr>
<tr>
<td>1-U</td>
<td>3.0</td>
<td>1.088</td>
<td>5.200</td>
<td>0.529</td>
</tr>
<tr>
<td>1/8-U</td>
<td>3.3</td>
<td>1.118</td>
<td>6.654</td>
<td>0.751</td>
</tr>
<tr>
<td>Sanded Panels</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/4-S</td>
<td>0.8</td>
<td>0.342</td>
<td>1.280</td>
<td>0.012</td>
</tr>
<tr>
<td>11/32-S</td>
<td>1.0</td>
<td>0.365</td>
<td>1.280</td>
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<td>1.1</td>
<td>0.373</td>
<td>1.680</td>
<td>0.038</td>
</tr>
<tr>
<td>15/32-S</td>
<td>1.4</td>
<td>0.537</td>
<td>1.947</td>
<td>0.067</td>
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<td>1.5</td>
<td>0.545</td>
<td>1.947</td>
<td>0.078</td>
</tr>
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<td>5/8-S</td>
<td>1.7</td>
<td>0.709</td>
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<tr>
<td>23/32-S</td>
<td>1.8</td>
<td>0.717</td>
<td>3.112</td>
<td>0.131</td>
</tr>
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<td>3/4-S</td>
<td>2.1</td>
<td>0.741</td>
<td>3.735</td>
<td>0.183</td>
</tr>
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<td>7/8-S</td>
<td>2.2</td>
<td>0.748</td>
<td>3.848</td>
<td>0.202</td>
</tr>
<tr>
<td>1-S</td>
<td>3.0</td>
<td>1.091</td>
<td>5.215</td>
<td>0.479</td>
</tr>
<tr>
<td>1/8-S</td>
<td>3.3</td>
<td>1.121</td>
<td>5.939</td>
<td>0.623</td>
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<tr>
<td>Touch-sanded Panels</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/2-T</td>
<td>1.5</td>
<td>0.543</td>
<td>2.698</td>
<td>0.084</td>
</tr>
<tr>
<td>19/32 and 5/8-T</td>
<td>1.8</td>
<td>0.707</td>
<td>3.127</td>
<td>0.124</td>
</tr>
<tr>
<td>23/32 and 3/4-T</td>
<td>2.2</td>
<td>0.739</td>
<td>4.059</td>
<td>0.201</td>
</tr>
</tbody>
</table>
### TABLE 23-2-J—VALUES OF G FOR USE WITH EFFECTIVE THICKNESS FOR SHEAR (TABLES 23-2-H AND 23-2-I) IN CALCULATING DEFLECTION OF PLYWOOD DIAPHRAGMS

<table>
<thead>
<tr>
<th>Plywood Grades or Species Group Nos.</th>
<th>G (Modulus of Rigidity—psi) × 0.00689 for N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>90,000</td>
</tr>
<tr>
<td>Group 2</td>
<td>75,000</td>
</tr>
<tr>
<td>Group 3</td>
<td>60,000</td>
</tr>
<tr>
<td>Group 4</td>
<td>50,000</td>
</tr>
<tr>
<td>Structural I</td>
<td>90,000</td>
</tr>
<tr>
<td>Structural II</td>
<td>60,000</td>
</tr>
<tr>
<td>Exterior C-C and C-D with Exterior glue</td>
<td></td>
</tr>
</tbody>
</table>

The combination of Identification Index designation and panel thickness determines the minimum species group and, therefore, the modulus of rigidity to be used:
- 5/16 (7.9 mm)—20/0, 3/8 (9.5 mm)—24/0;
- 15/32, 1/2 (12, 13 mm)—32/16, 19/32, 5/8 (16 mm)—42/20;
- 23/32, 3/4 (18, 19 mm)—48/24

All other combinations of C-C and C-D with Exterior glue: 50,000

1 Values of “G” shown apply to plywood bonded with Exterior glue. For plywood bonded with Interior glue, multiply by 0.91.

### TABLE 23-2-K—“e₁” VALUES (INCHES) FOR USE IN CALCULATING DIAPHRAGM DEFLECTION DUE TO NAIL SLIP (STRUCTURAL I)

<table>
<thead>
<tr>
<th>Load per Nail (pounds)</th>
<th>Nail Designation</th>
<th>6d</th>
<th>8d</th>
<th>10d</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>0.012</td>
<td>0.008</td>
<td>0.006</td>
<td>0.010</td>
</tr>
<tr>
<td>80</td>
<td>0.020</td>
<td>0.012</td>
<td>0.013</td>
<td>0.011</td>
</tr>
<tr>
<td>100</td>
<td>0.030</td>
<td>0.018</td>
<td>0.023</td>
<td>0.018</td>
</tr>
<tr>
<td>120</td>
<td>0.045</td>
<td>0.031</td>
<td>0.029</td>
<td>0.018</td>
</tr>
<tr>
<td>140</td>
<td>0.068</td>
<td>0.041</td>
<td>0.034</td>
<td>0.023</td>
</tr>
<tr>
<td>160</td>
<td>0.102</td>
<td>0.056</td>
<td>0.037</td>
<td>0.029</td>
</tr>
<tr>
<td>180</td>
<td>—</td>
<td>0.074</td>
<td>0.047</td>
<td>0.037</td>
</tr>
<tr>
<td>200</td>
<td>—</td>
<td>0.096</td>
<td>0.047</td>
<td>0.060</td>
</tr>
<tr>
<td>220</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.077</td>
</tr>
<tr>
<td>240</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

1 Increase “e₁” values 20 percent for plywood grades other than Structural I.

Values apply to common wire nails.

Load per nail = maximum shear per foot divided by the number of nails per foot at interior panel edges.

Decrease values 50 percent for seasoned lumber.
### TABLE 23-2-L—CONCENTRATED STATIC AND IMPACT TEST PERFORMANCE CRITERIA FOR PANELS TESTED ACCORDING TO SECTION 23.216—SHEATHING

<table>
<thead>
<tr>
<th>END USE—SPAN RATING</th>
<th>TEST EXPOSURE CONDITIONS</th>
<th>PERFORMANCE REQUIREMENTS</th>
<th>Minimum Ultimate Load (lb.)</th>
<th>Maximum Deflection (in.) under 200-Lb. (890 N) Load&lt;sup&gt;3&lt;/sup&gt;</th>
<th>x 4.448 for N</th>
<th>Maximum Deflection (in.) x 25.4 for mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof—16</td>
<td>Dry</td>
<td>Static</td>
<td>400</td>
<td>300</td>
<td>3/16 (0.438)</td>
<td>7/16 (0.469)</td>
</tr>
<tr>
<td></td>
<td>Wet</td>
<td>Following Impact&lt;sup&gt;2&lt;/sup&gt;</td>
<td>400</td>
<td>300</td>
<td>7/16 (0.469)</td>
<td>7/16 (0.469)</td>
</tr>
<tr>
<td>Roof—20</td>
<td>Dry</td>
<td>Static</td>
<td>400</td>
<td>300</td>
<td>3/16 (0.438)</td>
<td>3/16 (0.438)</td>
</tr>
<tr>
<td></td>
<td>Wet</td>
<td>Following Impact&lt;sup&gt;2&lt;/sup&gt;</td>
<td>400</td>
<td>300</td>
<td>3/16 (0.438)</td>
<td>3/16 (0.438)</td>
</tr>
<tr>
<td>Roof—24</td>
<td>Dry</td>
<td>Static</td>
<td>400</td>
<td>300</td>
<td>1/2 (0.500)</td>
<td>1/2 (0.500)</td>
</tr>
<tr>
<td></td>
<td>Wet</td>
<td>Following Impact&lt;sup&gt;2&lt;/sup&gt;</td>
<td>400</td>
<td>300</td>
<td>1/2 (0.500)</td>
<td>1/2 (0.500)</td>
</tr>
<tr>
<td>Roof—32</td>
<td>Dry</td>
<td>Static</td>
<td>400</td>
<td>300</td>
<td>1/2 (0.500)</td>
<td>1/2 (0.500)</td>
</tr>
<tr>
<td></td>
<td>Wet</td>
<td>Following Impact&lt;sup&gt;2&lt;/sup&gt;</td>
<td>400</td>
<td>300</td>
<td>1/2 (0.500)</td>
<td>1/2 (0.500)</td>
</tr>
<tr>
<td>Roof—40</td>
<td>Dry</td>
<td>Static</td>
<td>400</td>
<td>300</td>
<td>1/2 (0.500)</td>
<td>1/2 (0.500)</td>
</tr>
<tr>
<td></td>
<td>Wet</td>
<td>Following Impact&lt;sup&gt;2&lt;/sup&gt;</td>
<td>400</td>
<td>300</td>
<td>1/2 (0.500)</td>
<td>1/2 (0.500)</td>
</tr>
<tr>
<td>Roof—48</td>
<td>Dry</td>
<td>Static</td>
<td>400</td>
<td>300</td>
<td>1/2 (0.500)</td>
<td>1/2 (0.500)</td>
</tr>
<tr>
<td></td>
<td>Wet</td>
<td>Following Impact&lt;sup&gt;2&lt;/sup&gt;</td>
<td>400</td>
<td>300</td>
<td>1/2 (0.500)</td>
<td>1/2 (0.500)</td>
</tr>
<tr>
<td>Subfloor—16</td>
<td>Dry</td>
<td>Static</td>
<td>400</td>
<td>300</td>
<td>3/16 (0.188)</td>
<td>3/16 (0.188)</td>
</tr>
<tr>
<td></td>
<td>Wet/Redry</td>
<td>Following Impact&lt;sup&gt;2&lt;/sup&gt;</td>
<td>400</td>
<td>300</td>
<td>3/16 (0.188)</td>
<td>3/16 (0.188)</td>
</tr>
<tr>
<td>Subfloor—20</td>
<td>Dry</td>
<td>Static</td>
<td>400</td>
<td>300</td>
<td>7/32 (0.219)</td>
<td>7/32 (0.219)</td>
</tr>
<tr>
<td></td>
<td>Wet/Redry</td>
<td>Following Impact&lt;sup&gt;2&lt;/sup&gt;</td>
<td>400</td>
<td>300</td>
<td>7/32 (0.219)</td>
<td>7/32 (0.219)</td>
</tr>
<tr>
<td>Subfloor—24</td>
<td>Dry</td>
<td>Static</td>
<td>400</td>
<td>300</td>
<td>1/4 (0.250)</td>
<td>1/4 (0.250)</td>
</tr>
<tr>
<td></td>
<td>Wet/Redry</td>
<td>Following Impact&lt;sup&gt;2&lt;/sup&gt;</td>
<td>400</td>
<td>300</td>
<td>1/4 (0.250)</td>
<td>1/4 (0.250)</td>
</tr>
</tbody>
</table>

<sup>1</sup>Wet/Redry is exposure to three days continuous wetting followed by testing dry. Wet conditioning is exposure to three days continuous wetting and tested wet.

<sup>2</sup>Impact shall be 75 foot-pounds (102 N•m) for span ratings up to 24 on center (610 mm), 90 foot-pounds (122 N•m) for 32 on center (813 mm), 120 foot-pounds (163 N•m) for 40 on center (1016 mm), and 150 foot-pounds (203 N•m) for 48 on center (1219 mm).

<sup>3</sup>Criteria apply under static concentrated load according to Section 23.216. They do not apply following impact.

<sup>4</sup>Not applicable.

### TABLE 23-2-M—UNIFORM LOAD PERFORMANCE CRITERIA FOR PANELS TESTED ACCORDING TO SECTION 23.217—SHEATHING

<table>
<thead>
<tr>
<th>END USE—SPAN RATING</th>
<th>TEST EXPOSURE CONDITIONS&lt;sup&gt;1&lt;/sup&gt;</th>
<th>PERFORMANCE REQUIREMENTS</th>
<th>Average Deflection (in.) under Load (psf)</th>
<th>Minimum Ultimate Uniform Load (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof—16</td>
<td>Dry</td>
<td>Static</td>
<td>0.067 at 35 psf</td>
<td>150</td>
</tr>
<tr>
<td>Roof—20</td>
<td>Dry</td>
<td>Static</td>
<td>0.080 at 35 psf</td>
<td>150</td>
</tr>
<tr>
<td>Roof—24</td>
<td>Dry</td>
<td>Static</td>
<td>0.100 at 35 psf</td>
<td>150</td>
</tr>
<tr>
<td>Roof—32</td>
<td>Dry</td>
<td>Static</td>
<td>0.133 at 35 psf</td>
<td>150</td>
</tr>
<tr>
<td>Roof—40</td>
<td>Dry</td>
<td>Static</td>
<td>0.167 at 35 psf</td>
<td>150</td>
</tr>
<tr>
<td>Roof—48</td>
<td>Dry</td>
<td>Static</td>
<td>0.200 at 35 psf</td>
<td>150</td>
</tr>
<tr>
<td>Subfloor—16</td>
<td>Dry</td>
<td>Static</td>
<td>0.044 at 100 psf</td>
<td>330</td>
</tr>
<tr>
<td></td>
<td>Wet/Redry</td>
<td>Following Impact&lt;sup&gt;2&lt;/sup&gt;</td>
<td>0.044 at 100 psf</td>
<td>330</td>
</tr>
<tr>
<td>Subfloor—20</td>
<td>Dry</td>
<td>Static</td>
<td>0.053 at 100 psf</td>
<td>330</td>
</tr>
<tr>
<td></td>
<td>Wet/Redry</td>
<td>Following Impact&lt;sup&gt;2&lt;/sup&gt;</td>
<td>0.053 at 100 psf</td>
<td>330</td>
</tr>
<tr>
<td>Subfloor—24</td>
<td>Dry</td>
<td>Static</td>
<td>0.067 at 100 psf</td>
<td>330</td>
</tr>
<tr>
<td></td>
<td>Wet/Redry</td>
<td>Following Impact&lt;sup&gt;2&lt;/sup&gt;</td>
<td>0.067 at 100 psf</td>
<td>330</td>
</tr>
</tbody>
</table>

<sup>1</sup>Wet/Redry is exposure to three days continuous wetting followed by testing dry.
TABLE 23-2-N—CONCENTRATED STATIC AND IMPACT TEST PERFORMANCE CRITERIA
FOR PANELS TESTED ACCORDING TO SECTION 23.216—SINGLE FLOOR

<table>
<thead>
<tr>
<th>SPAN RATING</th>
<th>TEST EXPOSURE CONDITIONS</th>
<th>PERFORMANCE REQUIREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Minimum Ultimate Load (lb.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>× 4.45 for N</td>
</tr>
<tr>
<td>16</td>
<td>Dry</td>
<td>550</td>
</tr>
<tr>
<td></td>
<td>Wet/redry</td>
<td>550</td>
</tr>
<tr>
<td>20</td>
<td>Dry</td>
<td>550</td>
</tr>
<tr>
<td></td>
<td>Wet/redry</td>
<td>550</td>
</tr>
<tr>
<td>24</td>
<td>Dry</td>
<td>550</td>
</tr>
<tr>
<td></td>
<td>Wet/redry</td>
<td>550</td>
</tr>
</tbody>
</table>

1 Wet/redry is exposure to three days continuous wetting followed by testing dry.
2 Criteria apply under static concentrated load and following a 75 foot-pounds (102 N•m) impact according to Section 23.216.

TABLE 23-2-O—UNIFORM LOAD PERFORMANCE CRITERIA
FOR PANELS TESTED ACCORDING TO SECTION 23.217—SINGLE FLOOR

<table>
<thead>
<tr>
<th>SPAN RATING</th>
<th>TEST EXPOSURE CONDITIONS</th>
<th>PERFORMANCE REQUIREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Average Deflection (in.) (mm) under Load (psf) (N/mm²)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>× 0.00689 for N/mm²</td>
</tr>
<tr>
<td>16</td>
<td>Dry or wet/redry</td>
<td>0.0444 at 100 psf</td>
</tr>
<tr>
<td>20</td>
<td>Dry or wet/redry</td>
<td>0.053 at 100 psf</td>
</tr>
<tr>
<td>24</td>
<td>Dry or wet/redry</td>
<td>0.067 at 100 psf</td>
</tr>
</tbody>
</table>

1 Wet/redry is exposure to three days continuous wetting followed by testing dry.
UNIFORM BUILDING CODE STANDARD 23-3
PERFORMANCE STANDARD FOR WOOD-BASED
STRUCTURAL-USE PANELS


SECTION 23.301 — ADOPTION OF USVPS CODE

Wood-based structural-use panels shall be in accordance with United States Voluntary Product Standard PS 2-92, "Performance Standard for Wood-Based Structural-Use Panels," published by the Department of Commerce and the American Plywood Association, copyright 1992, Post Office Box 11700, Tacoma, Washington 98411, as if set out at length herein.

When a provision of the standard adopted hereby is found to be in conflict with a provision of this code, the provision of this code take precedence.
UNIFORM BUILDING CODE STANDARD 23-4
WOOD PARTICLEBOARD

Based on American National Standard for
Wood Particleboard, ANSI A208.1-1989

See Sections 2302.1, 2303.1, 2320 and 2326.10, Uniform Building Code

SECTION 23.401 — SCOPE

23.401.1 General. The particleboards covered by this standard are made from particles of wood or combinations of wood particles and wood fibers bonded together with synthetic resins or other suitable bonding systems by a process in which the interparticle bond is created by the bonding system. Other materials may be added during manufacture to improve certain properties. This standard includes dimensional tolerances, physical and mechanical property requirements and maximum formaldehyde emissions for different grades of wood particleboard. Also included are test methods, inspection practices and methods of identification.

23.401.2 Property Values. The property values in this standard are minimum or maximum values for each grade as the context requires and as determined by the specified test methods. It should be clearly recognized, however, that the strength values are not engineering design values.

SECTION 23.402 — DEFINITIONS

The following are definitions of some trade terms commonly used in the particleboard industry:

ADDITIVE is any material included in wood particleboard other than the primary components which are wood and bonding systems.

BINDER is an extraneous bonding agent, either organic or inorganic, used to bind wood particles together to produce a particleboard.

BONDING SYSTEM is any system used to bind wood particles together to produce particleboard.

FIBERS are the slender threadlike elements or groups of wood fibers resulting from chemical or mechanical defiberization, or both, and sometimes referred to as fiber bundles.

FLAKE is a wood particle of predetermined dimensions, specifically produced by specialized equipment of various types. Each flake is essentially flat, of uniform thickness, and has the grain of the wood running essentially in the plane of the flake.

FORMALDEHYDE TEST METHOD (FTM 2-1985) is a large chamber test method for determining formaldehyde emissions from wood products.

MAT-FORMED PARTICLEBOARD is a particleboard in which the coated particles are formed first into a mat having substantially the same length and width as the finished board before being flatplaten pressed.

PARTICLES are the aggregate component of a particleboard manufactured by mechanical means from wood, including all small subdivisions of wood such as flakes, shavings, slivers and wafers. Particle size may be measured by screen mesh that permits passage of particles and another screen upon which they are retained, or by measured dimensions as for flakes.

SHAVING is a thin slice or strip of wood pared off with a knife, planer or other cutting instrument in which the cut may be either across, parallel to, or at an angle to the axis of the fibers.

SLIVER is a particle of nearly square or rectangular cross section with a length parallel to the grain of the wood at least four times the thickness.
**WAFER** is a flake having a length in the direction of the grain of the wood which is at least \(1\frac{1}{4}\) inches (32 mm).

**SECTION 23.403 — REQUIREMENTS**

**23.403.1 General.** All particleboard represented as complying with any grade in this standard shall meet the requirements specified for that grade when tested in accordance with the provisions of this section.

All values obtained in accordance with such procedures shall be rounded off to the nearest unit in the last righthand place of figures used in expressing the limiting value.

**23.403.2 Materials.**

**23.403.2.1 Wood.** The wood material shall be in the form of flakes, shavings, slivers, fibers and other types of particles that are produced from wood by cutting, hammermilling, grinding and similar processes.

**23.403.2.2 Bonding system.** The wood particles shall be bonded by one of the following systems:

Type 1—A system, e.g., urea-formaldehyde, which enables the products to meet all applicable requirements specified herein for the relevant Type 1 grade.

Type 2—A system, e.g., phenol-formaldehyde, which enables the products to meet all applicable requirements specified herein for the relevant Type 2 grade.

**23.403.2.3 Additives.** Additives that enhance dimensional stability, fire retardation, resistance to fungi and insects or impart other desired properties may be incorporated into the particleboard at the time of manufacture, or subsequently, provided that the products containing the additives meet all applicable requirements specified herein.

**23.403.3 Dimensional Tolerances.**

**23.403.3.1 Width and length.** The trimmed width and length of the panels shall conform to specified dimensions tolerances as shown for each grade in Tables 23-4-A and 23-4-B. Width and length shall be determined by measuring the width of each end and at midlength and by measuring the length near each edge and at midwidth.

**23.403.3.2 Thickness.** Thickness of a panel and variance from a panel’s average thickness shall conform to the thickness tolerance requirements of Table 23-4-A or 23-4-B. Thickness shall be determined by measuring the caliper [to the nearest 0.001 inch (0.025 mm)] 1 inch (25 mm) from the edge at each panel corner and 1 inch (25 mm) from the edge at the midlength of each panel edge. The average of these eight measurements shall constitute the panel average thickness and shall be compared with the nominal thickness as stated by the manufacturer. Each individual measurement shall be compared to the panel average for variance.

**23.403.3.3 Squareness.** The two diagonal measurements of a trimmed panel shall not differ more than \(\frac{1}{32}\) inch per foot (2.6 mm/m) of panel width when trimmed length and width satisfy tolerance requirements.

**23.403.3.4 Straightness.** Trimmed edges of panels 24 inches (610 mm) wide or wider shall not deviate more than \(\frac{1}{64}\) inch per each 2 feet (1 mm/1.5 m) of panel length or width. Straightness shall be determined by measuring to the nearest \(\frac{1}{64}\) inch (0.4 mm) the maximum deviation from a straight line extending from corner to corner on the same trimmed panel edge.

**23.403.4 Physical and Mechanical Properties.**

**23.403.4.1 General.** Particleboard shall conform to the physical and mechanical requirements in Tables 23-4-A and 23-4-B and the applicable parts of this section for the respective grade. The values specified in Tables 23-4-A and 23-4-B and the other requirements of Section 23.403 for
physical and mechanical properties are averages obtained in testing five panels. In addition, no property of a single panel in any multipanel sample may be more than 20 percent out of compliance with the value shown for that particular grade in the tables.

23.403.4.2 Moisture Content. The average moisture content at the time of shipment from the manufacturer shall not be in excess of 10 percent (based on the overdry weight of the board) for grades listed in Tables 23-4-A and 23-4-B. Moisture specimens shall be cut from three different bending specimens in each panel tested. The moisture content of the panel shall be the average of the test results of the three specimens.

23.403.4.3 Density tolerance. The average density of the particleboard shall not be more than 10 percent below the nominal density as stated by the manufacturer. Panel density shall be determined by calculation based on the weight and the volume of the six modulus of elasticity specimens.

23.403.4.4 Bonding system durability (Type 2 only). The durability of the bonding system shall be determined by evaluating the modulus of rupture in static bending of specimens that have been subjected to the following "Six-Cycle Soak-Steam-Freeze-Dry" conditioning regimen:

1. Six cycles, each comprising the following steps:
   1.1 Immersion in water at 120°F. ± 3°F. (48.9°C. ± 1.7°C.) for one hour.
   1.2 Exposure to steam and water vapor at 200°F. ± 5°F. (93.3°C. ± 2.8°C.) for three hours.
   1.3 Freezing at 10°F. ± 5°F. (−12.2°C. ± 2.8°C.) for 20 hours.
   1.4 Heating at 210°F. ± 3°F. (98.9°C. ± 1.7°C.) for three hours.
   1.5 Exposure to steam and water vapor at 200°F. ± 5°F. (93.3°C. ± 2.8°C.) for three hours.
   1.6 Heating in dry air at 210°F. ± 3°F. (98.9°C. ± 1.7°C.) for 18 hours.
2. After the six cycles, condition for at least 48 hours at 68°F. ± 6°F. (20.0°C. ± 3.3°C.) and 65 plus 1 percent humidity.

   The average modulus of rupture after accelerated aging shall not be less than 50 percent of the modulus of rupture listed for the particular grade in Table 23-4-B. The modulus of rupture shall be calculated based upon the thickness before the bonding system durability test.

23.403.4.5 Exterior durability (Grade 2-M-W only). The probable effect of adverse weather exposure shall be determined by evaluating the modulus of rupture and the modulus of elasticity in static bending of specimens that have been subjected to the following "Three-Cycle Soak" conditioning regimen:

1. Three cycles, each comprising the following steps:
   1.1 Immersion in water at 120°F. ± 3°F. (48.9°C. ± 1.7°C.) for six hours.
   1.2 Heating in dry air at 210°F. ± 3°F. (98.9°C. ± 1.7°C.) for 18 hours.
2. After the three cycles, condition for at least 24 hours at 68°F. ± 6°F. (20.0°C. ± 3.3°C.) and 65 plus 1 percent relative humidity.

   The average modulus of rupture tested shall not be less than 1,700 psi (11.7 N/mm²) and the average modulus of elasticity shall not be less than 342,000 psi (2358 N/mm²). In all cases, the results shall be based upon the thickness before soaking.

23.403.4.6 Modulus of rupture and modulus of elasticity. The values for modulus of rupture and modulus of elasticity shall be determined by static bending tests with the specimens tested without soaking. In static bending tests, it is not necessary to obtain a full load-deflection curve; only two load values (and corresponding deflections) within the elastic range need to be recorded. The stiffness shall be calculated by the following formula:

\[ E = P_1L^3/4bd^3Y_1 \]
In this formula, $P_1$ (load at proportional limit) shall be the difference between the two recorded loads, and $Y_1$ (center deflection at proportional limit load) shall be the difference between the two corresponding recorded deflections. Three specimens shall be cut parallel to the length of each panel to be tested and a like number of specimens shall be cut perpendicular to the length of each panel. The average property values of the six specimens shall determine the modulus of rupture and modulus of elasticity values for one panel.

23.403.4.7 Internal bond. The internal bond shall be determined in accordance with procedures testing tensile strength perpendicular to the surface. Three specimens shall be cut from each panel to be tested. The average of the three specimen tests shall determine the internal bond of one panel.

23.403.4.8 Linear expansion. The linear expansion (between 50 and 90 percent relative humidity) shall be made to measure dimensional stability. One specimen shall be cut parallel to the length of each panel to be tested, and one shall be cut perpendicular to the length of the same panel. The average of the two specimen tests shall determine the value for the panel.

23.403.4.9 Face screw-holding capacity. The face screw-holding capacity shall be determined by direct screw withdrawal with the specimen in the dry condition. Either a 1-inch (25.4 mm) No. 10, Type A or Type AB sheet metal screw shall be used and the speed of testing shall be 0.6 inch (15 mm) per minute. If the boards are less than $\frac{3}{4}$ inch (19 mm) thick, the specimen shall be made up of 2 thicknesses bonded together with an adhesive. Boards less than $\frac{3}{8}$ inch (9.5 mm) thick (nominal) shall not be tested. Test specimens shall be at least 3 inches by 4 inches (76 mm by 102 mm) in size. A $\frac{1}{8}$-inch (3.2 mm) pilot hole $\frac{1}{2}$ inch (13 mm) deep shall be used. Four tests shall be made on each panel to be tested. The results of the four tests shall be averaged to determine the screw-holding capacity of one panel.

23.403.4.10 Edge screw-holding capacity. The average edge screw-holding capacity shall be determined by direct screw withdrawal with the specimen in the dry condition. Either a 1-inch (25.4 mm) No. 10, Type A or Type AB sheet metal screw shall be used. The speed of testing shall be 0.6 inch (15 mm) per minute. Boards less than $\frac{5}{8}$ inch (16 mm) thick shall not be tested. The test specimens shall be 3 inches (76 mm) wide by any convenient length greater than 6 inches (152 mm). A $\frac{1}{8}$-inch (3.2 mm) pilot hole $\frac{1}{2}$ inch (13 mm) deep shall be used. Four tests shall be made on each panel to be tested. The results of the four tests shall be averaged to determine the edge screw-holding capacity of one panel.

23.403.4.11 Hardness. The hardness shall be determined in accordance with the modified Janka ball test. Two specimens shall be cut from each panel to be tested. The results of all test penetrations shall be averaged to determine the hardness of the panel.

23.403.5 Formaldehyde Provisions.

23.403.5.1 Maximum emissions. Emissions of formaldehyde from all Type 1 grades shall not exceed 0.30 parts per million when tested in accordance with the following sections.

23.403.5.2 Testing method. Formaldehyde emissions shall be determined in accordance with the Large Scale Test Method for Determining Formaldehyde Emissions from Wood Products, FTM 2-1985, except as otherwise provided in this section.

23.403.5.3 Test conditions. The following conditions shall prevail when testing for formaldehyde:

<table>
<thead>
<tr>
<th>Condition</th>
<th>GRADES 1-H, 1-M</th>
<th>GRADE 1-LD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loading ratio:</td>
<td>0.13 ft.$^2$/ft.$^3$ (4.3 m$^2$/m$^3$)</td>
<td>0.04 ft.$^2$/ft.$^3$ (1.3 m$^2$/m$^3$)</td>
</tr>
<tr>
<td>Air change rate:</td>
<td>0.05/hr</td>
<td>0.05/hr</td>
</tr>
<tr>
<td>Test temperature:</td>
<td>77°F ± 2°F (25°C ± 1.1°C)</td>
<td>77°F ± 2°F (25°C ± 1.1°C)</td>
</tr>
</tbody>
</table>

Loading ratio is an expression of the total exposed surface area of the product in square feet (ft$^2$) divided by the test chamber volume in cubic feet (ft$^3$). The surface area of the edges shall be in-

3-747
cluded in the calculation of total exposed surface area only if it constitutes 5 percent or more of the total surface area. Air change rate is the ratio of hourly indoor air change and indoor space volume measured in identified volume units expressed in air changes per hour.

SECTION 23.404 — CONFORMANCE TESTING

Produce test values of board for the most recent five panels tested in each panel grade and thickness shall be used as the sample for determining conformance with the property requirements in Table 23-4-A or 23-4-B and Sections 23.403.4 and 23.403.5. At least one sample of product per 200,000 square feet (18,580 m²) [3/4-inch (19 mm) basis] shall be tested, except that the testing for conformance to Sections 23.403.4.3 and 23.403.4.4, and 23.403.5.1 shall be conducted once per year.

SECTION 23.405 — IDENTIFICATION

23.405.1 Explanation of Grades. The particleboard grades in this standard have three parts: a first digit, a letter designation and a final digit or letter. The first digit indicates the type of bonding system used (see Section 23.403.2.2). The letters have the following meanings:

- **M** Medium nominal density [40 to 50 lb./ft³ (641 to 801 kg/m³)].
- **LD** Lower nominal density [less than 40 lb./ft³ (641 kg/m³)].

The final digit or letter indicates the grade identification within a particular description. For instance, 1-M-2 indicates Type 1 medium density particleboard, Grade 2.

23.405.2 Information to Be Provided. All particleboard which is represented as conforming to this standard shall be identified with the following information:

1. Manufacturer’s name or trademark.
2. Compliance with the requirements of this standard in accordance with Section 2305 of this code.
3. The grade.
4. The lot number or date of production.
5. With respect only to particleboard intended for use as underlayment, the word “underlayment.”
6. With respect only to Type 2 products intended for exterior application, the words “exterior glue.”

23.405.3 Methods of Identification. The information required by Section 23.405.2 shall be stamped on each panel of particleboard intended for use as underlayment.

With respect to all other grades, the information shall be provided by either stamping each panel or providing a written statement in a unit label, invoice or other commercial document.
### TABLE 23-4-A—REQUIREMENTS FOR GRADES OF TYPE 1 WOOD PARTICLEBOARD

<table>
<thead>
<tr>
<th>GRADE</th>
<th>LENGTH AND WIDTH TOLERANCE (inches)</th>
<th>THICKNESS TOLERANCE</th>
<th>PANEL AVERAGE from Nominal (inches)</th>
<th>PANEL VARIANCE from Panel Average (inches)</th>
<th>MODULUS OF RUPTURE (psi)</th>
<th>MODULUS OF ELASTICITY (psi)</th>
<th>INTERNAL BOND (psi)</th>
<th>HARDNESS (pounds)</th>
<th>SCREW HOLDING</th>
<th>FORMALDEHYDE DET.</th>
<th>MAXIMUM EMISSIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-M-1</td>
<td>±0.015</td>
<td>±0.010</td>
<td>1,600</td>
<td>250,000</td>
<td>60</td>
<td>500</td>
<td>0.35</td>
<td>NS</td>
<td>NS</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>1-M-2</td>
<td>±0.010</td>
<td>±0.005</td>
<td>2,100</td>
<td>325,000</td>
<td>60</td>
<td>500</td>
<td>0.35</td>
<td>225</td>
<td>200</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>1-M-3</td>
<td>±0.010</td>
<td>±0.005</td>
<td>2,400</td>
<td>400,000</td>
<td>80</td>
<td>500</td>
<td>0.35</td>
<td>250</td>
<td>225</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>1-M-8</td>
<td>±0.010</td>
<td>±0.005</td>
<td>1,800</td>
<td>275,000</td>
<td>60</td>
<td>500</td>
<td>0.45</td>
<td>200</td>
<td>175</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>1-LD-1</td>
<td>±0.005</td>
<td>±0.005</td>
<td>400</td>
<td>80,000</td>
<td>20</td>
<td>NS</td>
<td>0.35</td>
<td>90</td>
<td>NS</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>1-LD-2</td>
<td>±0.005</td>
<td>±0.005</td>
<td>800</td>
<td>150,000</td>
<td>20</td>
<td>NS</td>
<td>0.35</td>
<td>125</td>
<td>NS</td>
<td>0.30</td>
<td></td>
</tr>
</tbody>
</table>

1. Thickness tolerance values are only for sanded panels as defined by the manufacturer. Unsanded panels shall be in accordance with the thickness tolerances specified by agreement between the manufacturer and the purchaser.

2. Particleboard made with phenol formaldehyde-based resins do not emit significant quantities of formaldehyde. Therefore, such products and other particleboard products made with resin not containing formaldehyde are not subject to the formaldehyde emission requirements.

3. Product loading ratios used in formaldehyde testing typically reflect actual end-use loading. For example, products 1-M loading ratios [0.13 ft. 2/ft. 3 (1.3 m 2/m 3)] simulate full floor coverage, while loading ratios for 1-LD [0.04 ft. 2/ft. 3 (4.3 m 2/m 3)] more closely reflect loading for use in interior door cores.

NS—Not specified.
TABLE 23-4-B—REQUIREMENTS FOR GRADES OF TYPE 2 WOOD PARTICLEBOARD

<table>
<thead>
<tr>
<th>GRADE</th>
<th>LENGTH AND WIDTH TOLERANCE (inch)</th>
<th>THICKNESS TOLERANCE</th>
<th>MODULUS OF RUPTURE (psi)</th>
<th>MODULUS OF ELASTICITY (psi)</th>
<th>INTERNAL BOND (psi)</th>
<th>HARDNESS (pounds)</th>
<th>LINEAR EXPANSION (plates)</th>
<th>SCREW HOLDING</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Panel Average from Nominal (inch)</td>
<td>Variance from Panel Average (inch)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Face (pounds)</td>
</tr>
<tr>
<td>2-M-1</td>
<td>+0 -1/8</td>
<td>+0.015 ±0.010</td>
<td>1,800</td>
<td>250,000</td>
<td>60</td>
<td>500</td>
<td>0.35</td>
<td>225</td>
</tr>
<tr>
<td>2-M-2</td>
<td>+0 -1/8</td>
<td>+0.015 ±0.010</td>
<td>2,500</td>
<td>450,000</td>
<td>60</td>
<td>500</td>
<td>0.35</td>
<td>250</td>
</tr>
<tr>
<td>2-M-3</td>
<td>+0 -1/8</td>
<td>+0.015 ±0.010</td>
<td>3,000</td>
<td>500,000</td>
<td>60</td>
<td>500</td>
<td>0.35</td>
<td>NS</td>
</tr>
<tr>
<td>2-M-W³</td>
<td>+0 -1/8</td>
<td>+0.015 ±0.010</td>
<td>2,500</td>
<td>450,000</td>
<td>50</td>
<td>500</td>
<td>0.20</td>
<td>NS</td>
</tr>
</tbody>
</table>

1 Particleboard made with phenol formaldehyde-based resins do not emit significant quantities of formaldehyde. Therefore, such products and other particleboard products made with resin not containing formaldehyde are not subject to the formaldehyde emission requirements.

2 Thickness tolerance values are only for sanded panels as defined by the manufacturer. Values for unsanded 2-M-W graded panels shall be 0.030 inch (± 0.76 mm) for panel average from nominal and 0.030 inch (± 0.76 mm) for variance from panel average.

3 "S" indicates that this product is made from wafers.

NS—Not specified.
UNIFORM BUILDING CODE STANDARD 23-5
FIRE-RETARDANT-TREATED WOOD TESTS ON DURABILITY AND HYGROSCOPIC PROPERTIES


See Sections 201, 207 and 2303.1, Uniform Building Code

SECTION 23.501 — SCOPE
These methods cover the (1) durability of a fire-retardant treatment of wood and wood-base products under exposure to accelerated weathering, (2) measurement of the hygroscopic properties of fire-retardant-treated wood, and (3) identification classifications for material having qualified under these tests. The fire-retardant treatment for lumber and plywood is by pressure impregnation.

SECTION 23.502 — ACCELERATED WEATHERING
23.502.1 Scope. This section describes the conditioning method for a test specimen prior to subjecting that specimen to an appropriate fire test. The condition simulates effects of leaching, drying and temperature such as might reasonably be anticipated on a wood element exposed to the weather over a long term.

23.502.2 Apparatus. The test apparatus shall be capable of subjecting the specimen uniformly to the test conditions described in Section 23.502.4.

No special means of protecting the specimen back and edges are required, but water shall not impinge directly on those surfaces which are not exposed either to the weather in the assembled form, or to fire in the subsequent test. Water spray nozzles shall be provided and arranged so as to distribute water evenly over the exposed specimen surface.

Heating shall be thermostatically controlled. Forced-air movement shall be uniform across the specimen surface, with provisions made for adequate air changes to assure thorough drying.

23.502.3 Test Specimen. The test specimen shall include all those essential parts of the corresponding fire test specimen that may be subjected to weather exposure in normal use.

Specimens may be mounted in sections which can be reassembled subsequently without trimming into the appropriate fire test specimen.

The specimen surface shall have a slope of 4 in 12.

23.502.4 Exposure Cycle. Subject the specimens to an exposure cycle consisting of twelve one-week cycles. Each cycle is to consist of 96 hours of water exposure and 72 hours of drying.

Apply water in a moderately fine spray uniformly over the exposed specimen surfaces by spray nozzles that deliver an average of 0.7 inch of water (174 Pa) per hour [0.0073 gallons per minute per square foot (0.000307 m³/minute/m²) of specimen surface] at a temperature between 35°F. and 60°F. (1.7°C. to 15.6°C.). Do not recirculate the water.

Dry at a thermostatically controlled temperature of 135°F. to 140°F. (57.2°C. to 60.0°C.) in a room or cell. The controlling temperature shall be the air temperature measured 1 inch (25.4 mm) above the specimen surface. Accompany drying with the air movement directed across the face of the specimens at a rate of at least 25 feet (7620 mm) per minute.
At the end of each cycle, change the position of each specimen within the apparatus so that each specimen or segment occupies approximately an equal number of cycles in each location used.

23.502.5 Conditioning. Upon completion of the prescribed exposure, the specimen shall be conditioned to a moisture content specified by the applicable fire test standard.

SECTION 23.503 — HYGROSCOPIC PROPERTIES OF FIRE-RETARDANT WOOD

23.503.1 Scope. This section prescribes the method for determining the moisture content of fire-retardant-treated wood samples after exposure to a standard high relative humidity condition of 92 ± 2 percent at 77°C ± 2°C.

23.503.2 Apparatus. Conditioning room or chamber with air circulation and controlling instruments capable of being maintained at 77°C ± 2°C and a relative humidity of 92 ± 2 percent. Other suitable means of maintaining these conditions are also acceptable.

- Oven, air-circulated and vented, capable of maintaining a temperature of 103°C ± 2°C.
- A weighing scale or balance that will weigh a specimen within an accuracy of ± 0.2 percent.

23.503.3 Test Specimens. Specimens shall be selected that represent the lot. Unless otherwise specified, specimens shall be full cross sections, no less than 75.4 millimeters along the grain, but longer as needed to provide a minimum volume of 33 cubic centimeters.

The specimens shall be penetrated by the chemical to be representative for the treated product.

The specimens shall be in moisture equilibrium with a laboratory ambient condition of 30 to 65 percent relative humidity or shall be exposed for at least seven days at such a condition prior to high-humidity exposure.

Untreated specimens, when available, of the same species or wood-base product and of the same size, shall be exposed to the preconditioning, high-humidity exposure, and drying along with the treated specimens.

23.503.4 Procedure. Weigh each specimen to an accuracy of ± 0.2 percent.

Expose all specimens under constant humidity conditions of 92 ± 2 percent at 77°C ± 2°C for seven days. Specimens shall be suitably suspended so that all surfaces are exposed.

Weigh each specimen immediately to an accuracy of ± 0.2 percent one at a time as they are removed from the conditioning chamber. Observe and record the general appearance of the specimens.

Dry each specimen in an oven at 103°C ± 2°C until approximately constant weight is attained, and reweigh. Constant weight can be assumed when two consecutive readings taken two hours apart agree within 0.2 percent. Avoid drying for periods longer than necessary to achieve constant weight, since thermal decomposition of chemical or wood might occur reflecting a higher than actual moisture content.

23.503.5 Calculations. Calculate the “apparent” moisture content of each sample prior to high-humidity exposure as follows:

\[ \text{Moisture content: percent} = \frac{(A - B)}{B} \times 100 \]

WHERE:

- \( A \) = weight prior to high-humidity exposure.
- \( B \) = oven-dry weight.

Calculate the “apparent” moisture content of each sample after high-humidity exposure as follows:

\[ \text{Moisture content: percent} = \frac{(C - B)}{B} \times 100 \]
WHERE:

\[ B = \text{oven-dry weight.} \]
\[ C = \text{weight after high-humidity exposure.} \]

The change in the "apparent" moisture content of the specimens shall be calculated as the difference between the average moisture content for the treated and untreated specimens as calculated in this section.

23.503.6 Report. The report shall include the following:

- Complete identification of the fire-retardant product as to species of wood, wood product, and treatment.
- Description of sampling procedure and number and dimensions of test specimens.
- General description of humidity chamber and controls used for the test.
- The average moisture content of the untreated specimens shall be reported.
- The average "apparent" moisture content for the treated specimens, both before and after high-humidity exposure, including the basis of the computation; treated specimen (wood and chemical) or wood-only basis, shall be reported. The change in the average moisture content after high-humidity exposure compared to the moisture content of untreated specimens shall also be reported.
- Report any change in the appearance of the specimen during exposure, including surface wetness, chemical exudation, or crystals on surface.

SECTION 23.504 — CLASSIFICATION

23.504.1 Scope. This part establishes the classification of fire-retardant-treated wood.

23.504.2 Classifications.

23.504.2.1 Interior Type A. Material that has been fire tested in accordance with Section 207 of the code to qualify as fire-retardant-treated wood and has an equilibrium moisture content of not over 28 percent when tested at 92 ± 2 percent relative humidity when conditioned as specified in Section 23.503.

23.504.2.2 Interior Type B. Material that has been fire tested in accordance with Section 207 of the code to qualify as fire-retardant-treated wood, but does not qualify as Interior Type A when conditioned as specified in Section 23.503.

23.504.2.3 Exterior type. Material that has been subjected to the weathering test of Section 23.502 and then fire tested in accordance with Section 207 of the Building Code to qualify as fire-retardant-treated wood.
UNIFORM BUILDING CODE STANDARD 23-6
FIRE-RETARDANT-TREATED WOOD

Based on National Design Specification for Wood Construction Policy on Design Values for Fire-retardant-treated Lumber

See Sections 207, 2303.1 and 2304.3.3, Uniform Building Code

SECTION 23.601 — SCOPE
This standard establishes the test protocol, acceptance criteria, and quality control procedure for assuring that fire-retardant treatments qualify for the design values assigned and that appropriate treating and redrying methods are used. Only lumber pressure impregnated with fire-retardant chemicals that is identified by the quality mark of an approved inspection agency shall be eligible for the design values specified in Section 2304.3 of the Building Code.

Part I—Test Protocol

SECTION 23.602 — TYPE OF MATERIAL
The effects of fire-retardant treatment shall be determined on the basis of tests on matched samples of clear, straight-grain material. This is consistent with procedures presently used to establish design values and modifications for condition of use for visually graded sawn lumber.

SECTION 23.603 — NUMBER OF SPECIES
The effects of fire-retardant treatment may vary depending upon species. Because evaluation of such treatment for all species and properties is considered prohibitive, testing of three species representative of a range of wood density and treating characteristics is recommended. A specific treatment may be evaluated for only one of these species, but testing of three species representative of a range of wood density and treated characteristics is recommended.

Qualification may be obtained for any one species by evaluation of that species.

SECTION 23.604 — IDENTIFICATION
Each fire-retardant treatment shall be identified by the commercial name assigned by the developer of the treatment and each specimen shall be marked to identify the drying temperatures and relative humidity schedules used.

SECTION 23.605 — STRENGTH TESTING
Material to be subjected to strength testing shall be treated to the penetration and retention level required for that treatment and species to meet the definition of fire-retardant-treated wood given in Section 207.

To allow for variability in treatment especially for species classified as moderate to difficult to treat, it may be necessary to treat up to twice the number of samples required for test. Equal numbers of samples of low and high treatability may be excluded from strength testing to ensure that material of average treatability is evaluated.

Following treatment, strength test material shall be dried at a maximum temperature of 160°F. (71.1°C.) with relative humidity schedules and air velocities that will simulate commercial conditions. A record of the operating conditions of the kiln shall be kept for the entire run and shall include humidity conditions and temperature in the hottest part of the kiln.
SECTION 23.606 — SAMPLING AND TREATMENT

23.606.1 Species. For each fire-retardant treatment to be evaluated for general qualification, strength test material shall be selected from each of the following species:

- Southern pine (Pinus taeda or echinata)
- Coast Douglas fir
- White spruce (Picea glauca)

The southern pine material shall be all sapwood. Where a treatment is to be evaluated only for a particular species, strength test material shall be selected from each such species.

23.606.2 Number of Samples, Size and Quality. For each species to be evaluated, 25 essentially clear, straight-grained 2 by 4s (51 by 102), 8 feet (2438 mm) or longer shall be selected from the production of one or more mills. All pieces shall be identified as being Surfaced Dry and shall have an average specific gravity within ± 10 percent of the average specific gravity (green volume basis) of the species.

23.606.3 Sample Identification. From each 2-inch by 4-inch (51 mm by 102 mm) member selected for sampling, two end-matched 4-foot (1219 mm) blanks shall be cut for strength testing. One blank shall be designated for treatment and the other as control. All blanks shall be coded as to member number and treatment or control.

23.606.4 Pressure Treatment of Samples. All blanks to be fire-retardant treated shall be processed in accordance with the specific procedures established for the treatment being evaluated. Blanks shall be pressure treated and dried to a maximum moisture content of 19 percent in 2-inch by 4-inch (51 mm by 102 mm) by 4-foot (1219 mm) size. The same treatment and drying times, stacking practices, and other procedures to be employed in commercial charges shall be used.

23.606.5 Conditioning of Blanks. After redrying to a maximum moisture content of 19 percent, treated blanks and untreated controls shall be conditioned at 68°F. ± 6°F. (20°C. ± 3.3°C.) and 65 percent ± 1 percent relative humidity until approximate equilibrium weight is attained.

SECTION 23.607 — STRENGTH TESTS

23.607.1 Type and Number of Specimens. One and one-half-inch by 1 1/2-inch by 23-inch (38 mm by 38 mm by 584 mm) static bending specimen, two 1-inch by 1/4-inch by 16-inch (25 mm by 6.4 mm by 406 mm) tension specimens, one 1 1/2-inch by 1 1/2-inch by 6-inch (38 mm by 38 mm by 152 mm) compression specimen, one 1/2-inch by 1/2-inch by 2 1/2-inch (38 mm by 38 mm by 64 mm) shear specimen, and one 1/2-inch by 1/2-inch by 2-inch (38 mm by 38 mm by 51 mm) specific gravity specimen shall be cut from each treated and untreated blank. Bending and compression specimens from both treated and control blanks shall be cut such that three sides of the specimen represent the original surfaces or edge of the 2-inch by 4-inch (51 mm by 102 mm) member. Two sides of the shear and specific gravity specimens shall represent original surfaces. One of the 1-inch-wide (25 mm) faces of one of the tension specimens shall represent one original surface of the blank and one of the wide surfaces of the other specimen shall represent the opposite original blank surface.

One method of selecting specimens to obtain the required placement of original surfaces is shown in Figure 23-6-1. Any orientation of growth rings relative to the edge of the specimens shall be acceptable.

Tension specimens shall be further machined to the size and shape shown in Figure 23-6-2. Shear specimens shall be notched as shown in Figure 23-6-3.

23.607.2 Slope of Grain. The slope of grain in all bending specimens and in the critical section of tension specimens shall be 1 in 20 or less. Compression and shear specimens shall have a slope of grain of 1 in 16 or less.
23.607.3 Identification and Conditioning. The blank identification of each treated and control specimen shall be retained. After final machining, test specimens shall be reconditioned to constant weight before test.

SECTION 23.608 — TESTING PROCEDURE

23.608.1 General. Testing procedures of an approved nationally recognized test standard shall be used. Load deformation curves shall be taken for static bending tests only. Maximum load shall be observed in all tests.

23.608.2 Order of Testing. The treated specimen and the matching untreated control from each blank shall be tested consecutively.

23.608.3 Measurement. The dimensions of the critical cross-sectional area, or in the case of the shear specimen the area of the shear plane of each specimen, shall be measured to an accuracy of at least 0.01 inch (0.254 mm).

23.608.4 Static Bending. Bending specimens shall be center loaded at span of 21 inches (533 mm). A machine cross-head speed of 0.075 inch per minute (1.9 mm per minute) shall be used. Bending specimens shall be positioned in the testing machine such that two opposite original surfaces represent the compression and tension faces of the beam.

23.608.5 Moisture Samples. All moisture samples selected from each specimen after test shall be oven dried at 130°C ± 2°C until approximately constant weight of the untreated control is reached.

23.608.6 Specific Gravity. Dimensions of the specific gravity samples shall be measured after final conditioning to determine volume at 65 percent relative humidity. Samples shall be dried at 103°C ± 2°C until approximate constant weight of the untreated control is reached.

SECTION 23.609 — REPORT

The treatment and redrying procedures shall be described in accordance with Section 23.605.

The species evaluated and testing procedures followed shall be fully described.

Individual values of treated and control specimens shall be reported for specific gravity, moisture content, modulus of elasticity, modulus of rupture, maximum tensile stress, maximum compression stress, and maximum shear stress. Average values, standard deviations, average ratios of treated to control values, and median ratios of treated to control values shall be reported for each strength and stiffness property and each species.

Part II—Acceptance Criteria

SECTION 23.610 — MINIMUM PROPERTY RATIO

A fire-retardant treatment evaluated for a particular species under this standard shall qualify for the design value adjustments in Section 2304.3 of the Building Code if the median ratio of treated to untreated strength or stiffness for each of the following properties equals or exceeds the specified adjustment factor for that property:

- Extreme fiber in bending
- Modulus of elasticity
- Maximum stress in tension parallel to grain
- Maximum stress in compression parallel to grain
Maximum stress in horizontal shear

Qualification of the adjustment factor for compression perpendicular to grain shall be based on the median factor for maximum stress in compression parallel to grain. Qualification of the adjustment factor for fastener loads shall be based on the lower of the median ratio for maximum stress in compression parallel to grain and the median ratio for maximum stress in horizontal shear.

SECTION 23.611 — RESAMPLING

Where marginal results occur for one property, a second 25-piece sample may be taken for that property and the combined results of the first and second samples be used to determine qualification.

SECTION 23.612 — GENERAL QUALIFICATION

A treatment meeting the requirements of Section 23.610 for each of the three species identified in Section 23.606 of this standard shall be considered qualifying for the design value adjustments in Section 2304.3 of the Building Code for all species.

Part III—Identification

SECTION 23.613 — PRODUCT ELIGIBILITY

Only lumber pressure impregnated with fire-retardant chemicals that is identified by the quality mark of an approved inspection agency shall be eligible for the design value adjustments given in Section 2304.3 of the Building Code. Such agency shall maintain continuing supervision, testing and inspection over the quality of the treated product as necessary to (1) assure compliance with the fire performance requirements for fire-retardant-treated wood in Section 207 and (2) assure eligibility for strength classification under the provisions of this standard.

SECTION 23.614 — QUALIFICATION COMPLIANCE

The approved agency shall review and analyze the test data developed in accordance with Part I of this standard and shall attest to the following:

1. Competency of the personnel and the adequacy of the facilities of the testing laboratory.
2. Conformance of reported sampling and testing procedures to Part I of this standard.
3. Compliance of test results with acceptance criteria in Part II of this standard.

SECTION 23.615 — QUALITY MARK

The quality symbol shall indicate that the treated lumber bearing the mark has been treated and redried in conformance with the procedures established by the manufacturer of the treatment which were used in the evaluation and qualification of that treatment under Parts I and II of this standard.
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**FIGURE 23-6-1—MATCHING DIAGRAM**

- 11\(\frac{1}{2}\)" x 11\(\frac{1}{2}\)" x 23" (38 x 38 x 584 mm) Bending
- 1" x 1\(\frac{1}{4}\)" x 16" (25 x 6.4 x 406 mm) Tension
- 11\(\frac{1}{2}\)" x 11\(\frac{1}{2}\)" x 6" (38 x 38 x 152 mm) Compression
- 11\(\frac{1}{2}\)" x 11\(\frac{1}{2}\)" x 2" (38 x 38 x 51 mm) Specific Gravity
- 11\(\frac{1}{2}\)" x 11\(\frac{1}{2}\)" x 2\(\frac{1}{2}\)" (38 x 38 x 64 mm) Shear

**FIGURE 23-6-2—TENSION SPECIMEN**

- Original Surface
- \(\frac{3}{4}\)" (19.1 mm)
- \(\frac{1}{2}\)" (12.7 mm)
- \(\frac{3}{4}\)" (19.1 mm)
- 2" (50.8 mm)
- 2\(\frac{1}{2}\)" (63.5 mm)

**FIGURE 23-6-3—SHEAR SPECIMEN**

- 1\(\frac{1}{2}\)" (38.1 mm)
- 1\(\frac{1}{2}\)" (38.1 mm)
UNIFORM BUILDING CODE STANDARD 24-1

FLAT GLASS


See Sections 2401.2 and 2401.4, Uniform Building Code

SECTION 24.101 — SCOPE

This standard provides general material requirements for glass regulated by the Building Code.

SECTION 24.102 — DEFINITIONS

For the purpose of this standard, certain terms are defined as follows:

FLOAT GLASS is glass formed in a continuous ribbon by floating molten glass on a bath of molten tin in a controlled atmosphere; the glass is smooth with parallel surfaces and requires no further treatment.

FULLY TEMPERED GLASS is regular glass that has been heated and quenched in a controlled operation to provide a high level of surface compression; its strength is roughly four times that of regular glass for most types of loads; when fractured, it breaks into small, relatively harmless particles; it is a safety glazing material.

HEAT-STRENGTHENED GLASS is regular glass that has been heated and quenched in a controlled operation to provide a degree of surface compression; its strength is roughly two times that of regular glass; when fractured, this glass breaks into large fragments, much like regular glass; it is not a safety glazing material.

INSULATING GLASS is factory-fabricated double glazing with the periphery of the air space sealed to minimize infiltration of water vapor.

LAMINATED GLASS is a sandwich of two or more glass plies bonded together with a resilient plastic interlayer, normally polyvinyl butyral; when this glass breaks, the fragments are held together by the plastic interlayer.

PATTERNED GLASS is rolled glass with a pattern or texture impressed on one or both surfaces; some glasses with shallow patterns can be tempered or heat strengthened.

REGULAR (ANNEALED) GLASS is sheet (window) glass and plate glass with smooth surfaces that have not been modified after manufacture; it breaks into large pieces; although the terms "sheet" and "plate glass" are commonly used, they are misnomers since virtually all glass is made by the float process; this glass may be clear or tinted.

SAFETY GLASS is glass designed to minimize cutting and piercing injuries when impacted by people; fully tempered glass, laminated glass and wired glass are recognized safety glazing materials.

TEMPERED GLASS, see “fully tempered glass.”

WIRED GLASS is a single sheet of glass which has had a wire mesh embedded in roughly the thickness center during production; this glass, coupled with a suitable framing system, is fire rated; for low levels of impact, the wire in the glass will retain the broken fragments.

SECTION 24.103 — DESIGN CRITERIA

The maximum allowable areas of glass subjected to wind loads, snow loads and dead loads shall not be greater than those determined from Table 24-A of this code.
Table 24-1-A lists the coefficients of variation for various glass types. These values are used as part of the basis for Table 24-A of this code. Each value applies for all glass products using each glass type. For example, the value for annealed glass would apply for laminated annealed glass and insulating glass units using annealed glass panes, as well as for single annealed glass.

In cases where more than one glass type is used in a fabricated glass product (e.g., laminated glass, insulating glass), the more conservative values from Table 24-1-A apply.

SECTION 24.104 — FLOAT GLASS

24.104.1 Thickness. For each nominal thickness, the furnished glass thickness shall not be less than that listed in Table 24-1-B.

24.104.2 Allowable Imperfections. Imperfections shall not exceed those allowed in Table 24-1-C.

SECTION 24.105 — WIRED GLASS

24.105.1 Wire. The diameter of wires shall be from 0.017 inch to 0.025 inch (0.43 mm to 0.64 mm). Discoloration and slight distortion of wire is permissible.

24.105.2 Mesh. Diamond mesh shall be welded and the opening in mesh shall not exceed 1 1/4 inches (31.8 mm) measured across diagonals of the diamond; square mesh shall be welded and the openings in mesh shall not exceed 5/16 inch (15.9 mm) measured along a side of the square; parallel stand-spacing as specified.

24.105.3 Thickness. The minimum thickness shall not be less than that listed in Table 24-1-D.

SECTION 24.106 — PATTERNED GLASS

24.106.1 Thickness. The thickness shall not be less than that listed in Table 24-1-E for each nominal thickness.

24.106.2 Fire Cracks and Stones. Glass shall not have continuous fire cracks and stones that can cause spontaneous breakage in annealed glass.

SECTION 24.107 — A GLOSSARY OF TERMS FOR GLASS IMPERFECTIONS

For the purpose of this standard, certain terms are defined as follows:

- **CRUSH** is a lightly pitted area resulting in a dull gray appearance over the region.
- **DIGS** are deep, short scratches.
- **DIRT** is a small particle of foreign matter embedded in the glass surface.
- **GASEOUS INCLUSIONS** are round or elongated bubbles in the glass.
- **KNOT** is a transparent area of incompletely assimilated glass having an irregular knotty or tangled appearance.
- **LINES** are fine cords or strings, usually on the surface of sheet glass.
- **OPEN GASEOUS INCLUSIONS** are bubbles at the surface of glass which are open, leaving a cavity in the finished surface.
- **PROCESS SURFACE DEFECTS.** The surfaces of plate glass have very fine surface defects remaining from the grinding and polishing process, consisting of fine pits and cracks which are denoted as “finish.” When this condition is visible it is called “short finish.” Float glass can also have some slight surface defects which originate in the process. These can be small particles of foreign materials on either surface or slight defects in the bottom (float) surface.
REAM is inclusions within the glass or layers or strings of glass which are not homogeneous with the main body of the glass.

RUBS are abrasions of the glass surface producing a frosted appearance. A rub differs from a scratch in having appreciable width.

SCRATCHES are any marking or tearing of the surface produced in manufacturing or handling which appear as though they were done by a sharp or rough instrument.

SMOKE is streaked areas appearing as slight discoloration.

STONES are any crystalline inclusions embedded in the glass.

STRINGS are transparent lines appearing as though a thread of glass had been incorporated into the sheets.

WAVES are defects resulting from irregularities of the surface of the glass, making objects viewed at varying angles appear wavy or bent.

**TABLE 24-1-A—COEFFICIENTS OF VARIATION FOR GLASS STRENGTH**

<table>
<thead>
<tr>
<th>GLASS TYPE</th>
<th>COEFFICIENT OF VARIATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular (annealed)</td>
<td>0.25</td>
</tr>
<tr>
<td>Heat-strengthened</td>
<td>0.15</td>
</tr>
<tr>
<td>Fully tempered</td>
<td>0.10</td>
</tr>
</tbody>
</table>

**TABLE 24-1-B—MINIMUM ALLOWABLE THICKNESSES FOR FLOAT GLASS**

<table>
<thead>
<tr>
<th>NOMINAL THICKNESS OR DESIGNATION (Inch)</th>
<th>MINIMUM ALLOWABLE THICKNESS (Inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single</td>
<td>0.085</td>
</tr>
<tr>
<td>Lami</td>
<td>0.102</td>
</tr>
<tr>
<td>Double-1/8 in.</td>
<td>0.115</td>
</tr>
<tr>
<td>5/32 in.</td>
<td>0.149</td>
</tr>
<tr>
<td>3/16 in.</td>
<td>0.180</td>
</tr>
<tr>
<td>7/32 in.</td>
<td>0.200</td>
</tr>
<tr>
<td>1/4 in.</td>
<td>0.219</td>
</tr>
<tr>
<td>5/16 in.</td>
<td>0.292</td>
</tr>
<tr>
<td>1/8 in.</td>
<td>0.355</td>
</tr>
<tr>
<td>1/2 in.</td>
<td>0.469</td>
</tr>
<tr>
<td>5/8 in.</td>
<td>0.595</td>
</tr>
<tr>
<td>3/4 in.</td>
<td>0.719</td>
</tr>
<tr>
<td>7/8 in.</td>
<td>0.844</td>
</tr>
</tbody>
</table>
TABLE 24-1-C-MAXIMUM ALLOWABLE IMPERFECTIONS FOR THICKNESSES OF \( \frac{1}{4} \) INCH (6.4 mm) OR LESS

<table>
<thead>
<tr>
<th>Imperfections</th>
<th>Up to 2.5 m²</th>
<th>2.5 To 7.0 m²</th>
<th>Over 7.0 m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaseous inclusions, maximum size</td>
<td>Central²</td>
<td>Outer²</td>
<td>Central²</td>
</tr>
<tr>
<td>Open or translucent gaseous inclusions, maximum size</td>
<td>1.2 mm⁴�</td>
<td>1.6 mm⁴</td>
<td>1.2 mm⁴</td>
</tr>
<tr>
<td>Knots, dirt and stones, maximum size</td>
<td>0.4 mm⁴</td>
<td>0.8 mm⁴</td>
<td>1.6 mm⁴</td>
</tr>
<tr>
<td>Scratches and rubs (intensity)</td>
<td>medium⁷</td>
<td>medium⁷</td>
<td>medium⁷</td>
</tr>
<tr>
<td>Crush (intensity, maximum length)</td>
<td>medium⁷</td>
<td>&gt;1.0 mm</td>
<td>medium⁷</td>
</tr>
<tr>
<td>Digs, maximum length</td>
<td>1.6 mm⁴</td>
<td>2.4 mm⁴</td>
<td>3.2 mm⁴</td>
</tr>
<tr>
<td>Ream, strings, lines and other linear distortion (maximum angle or intensity)</td>
<td>45° or medium⁹</td>
<td>90° or heavy</td>
<td>90° or heavy</td>
</tr>
<tr>
<td>Wave (intensity)</td>
<td>medium¹⁰</td>
<td>medium¹⁰</td>
<td>medium¹⁰</td>
</tr>
<tr>
<td>Process surface imperfections (intensity)</td>
<td>medium¹¹</td>
<td>medium¹¹</td>
<td>medium¹¹</td>
</tr>
</tbody>
</table>

¹Glass greater than 6.0 mm (\( \frac{1}{4} \) in.) in thickness may contain proportionally more and larger imperfections.
²The central area is considered to form an oval or circle centered on the light whose axes or diameters do not exceed 80 percent of the overall dimension. The remaining area is considered the outer area.
³Gaseous inclusions, knots, dirt and stones may be round or elongated. For elongated imperfections of this type(s) the maximum size specified shall be determined by adding the length and width of the imperfection and dividing by two, for example \((l + w)/2\).
⁴Separated by at least 305 mm (12 in.).
⁵For imperfections of a smaller size or of less intensity, the minimum separation shall be proportionately less. The larger of the two imperfections shall govern the separation.
Imperfections not specifically mentioned shall be compared to the imperfection they most closely resemble.
⁶Separated by at least 610 mm (24 in.).
⁷Intensity (scratches, rubs and crush)—When looking through the glass and perpendicular to it, using daylight without direct sunlight or with background light suitable for observing each type of imperfection, the imperfection shall not be detectable at distances greater than the following, except for heavy intensity (see Note 3).

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faint</td>
<td>203 mm</td>
</tr>
<tr>
<td>Light</td>
<td>914 mm</td>
</tr>
<tr>
<td>Medium</td>
<td>3.3 m</td>
</tr>
<tr>
<td>Heavy</td>
<td>detected at distances greater than 3.3 m</td>
</tr>
</tbody>
</table>

(Continued)
### TABLE 24-1-C—MAXIMUM ALLOWABLE IMPERFECTIONS FOR THICKNESSES OF 1/4 INCH (6.4 mm) OR LESS—(Continued)

8Vision interference angle (see Note 1).

9Intensity (ream, strings, lines and other linear distortion)—When evaluated using the shadowgraph, the intensities of these imperfections are defined as having a shadowgraph readout at distances greater than or equal to the following (see Note 2).

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Minimum Distance, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>76</td>
</tr>
<tr>
<td>Medium</td>
<td>51</td>
</tr>
<tr>
<td>Heavy</td>
<td>25</td>
</tr>
</tbody>
</table>

10Intensity (wave)—When evaluated using the shadowgraph, the intensities of wave are defined as having shadowgraph readouts at distances greater than or equal to the following (see Note 2).

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Minimum Distance, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium</td>
<td>254</td>
</tr>
<tr>
<td>Heavy</td>
<td>152</td>
</tr>
</tbody>
</table>

11Intensity (process surface imperfections)—When viewed in normal reflected light, the imperfections are classified as follows: faint—visible only to the trained eye; light—just noticeable; medium—visible as a slight grayish haze; and heavy—readily visible as a cloudy surface.

**Note 1**—Ream, Strings and Distortion (Method A)—Place specimen in a vertical position at a distance of approximately 914 mm from a brick wall or similar background showing straight lines. The viewer shall look through the sample at a distance of 914 mm from the sample using daylight without direct sunlight or with background light suitable for observing each type of imperfection. View the sample at an angle to the surface of not less than vision interference angle in Table 24-1-C, for the applicable glass. The line of vision shall be perpendicular to the wall.

**Note 2**—Ream, Strings, Lines and Wave (Method B, Shadowgraph)—Focus a light projector with a 500-W lamp, or equivalent, and an objective lens with an approximate 51-mm aperture and an approximate 305-mm focal length on a flat white projection screen positioned 8 m from the light source in a dark room. Place the glass in a vertical position parallel to the screen between the light and the screen. Move the glass slowly toward the screen with a circular motion in the plane perpendicular to the light beam. The shadowgraph readout is the distance at which the distortion just blends with the general shadow of the glass on the screen.

**Note 3**—Scratches, Rubs, Stones and Gaseous Inclusions—Place samples in a vertical position approximately 914 mm from the viewer's position. The viewer shall look through the sample using daylight without direct sunlight or with background light suitable for observing each type of imperfection.
### TABLE 24-1-D—MINIMUM ALLOWABLE THICKNESSES FOR WIRED GLASS

<table>
<thead>
<tr>
<th>NOMINAL THICKNESS (Inch)</th>
<th>MINIMUM ALLOWABLE THICKNESS (Inch)</th>
<th>× 25.4 for mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/32</td>
<td>0.203</td>
<td></td>
</tr>
<tr>
<td>1/4</td>
<td>0.250</td>
<td></td>
</tr>
<tr>
<td>3/8</td>
<td>0.328</td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 24-1-E—MINIMUM ALLOWABLE THICKNESSES FOR PATTERNED GLASS

<table>
<thead>
<tr>
<th>NOMINAL THICKNESS OR DESIGNATION (Inch)</th>
<th>MINIMUM ALLOWABLE THICKNESS (Inch)</th>
<th>× 25.4 for mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS</td>
<td>0.085</td>
<td></td>
</tr>
<tr>
<td>DS</td>
<td>0.110</td>
<td></td>
</tr>
<tr>
<td>1/8</td>
<td>0.110</td>
<td></td>
</tr>
<tr>
<td>5/32</td>
<td>0.142</td>
<td></td>
</tr>
<tr>
<td>3/16</td>
<td>0.172</td>
<td></td>
</tr>
<tr>
<td>7/32</td>
<td>0.203</td>
<td></td>
</tr>
<tr>
<td>1/4</td>
<td>0.234</td>
<td></td>
</tr>
<tr>
<td>5/16</td>
<td>0.281</td>
<td></td>
</tr>
<tr>
<td>3/8</td>
<td>0.344</td>
<td></td>
</tr>
</tbody>
</table>
UNIFORM BUILDING CODE STANDARD 24-2
SAFETY GLAZING

Part I—Based on Safety Standard for Architectural Glazing Materials

See Sections 2401.2, 2401.3, 2406.2, 2406.3, 2406.5 and 2408.1,
Uniform Building Code

SECTION 24.201 — SCOPE

Part I of this standard covers safety glazing materials for use in areas subject to human impact as specified in this code. Part I is applicable to safety glazing material other than polished wired glass or glazing in wardrobe doors.

SECTION 24.202 — DEFINITIONS

For the purpose of this part, the definitions in Section 24.102 of U.B.C. Standard 24-1 are applicable.

SECTION 24.203 — IDENTIFICATION

Each light of safety glazing material shall be identified in accordance with Sections 2402 and 2406.2 of this code and in addition with the following:

1. The category class as noted in Table 24-2-A shall be specified as part of a permanent label.
2. Safety plastic that only meets the requirements of Section 24.206.4 entitled “Aging Tests (for plastic used in indoor applications only)” shall bear a statement INDOOR USE ONLY as part of a permanent label.
3. Organic-coated glass that meets the requirements of Section 24.206.3.2, entitled “Specimen weathering and test—organic-coated glass” and tested for exposure from one side only, shall bear a permanent label on the coating stating GLAZE THIS SIDE IN and shall bear in the central 50 percent of the surface area the following message in letters at least 1/4 inch (6.4 mm) high: SEE PERMANENT LABEL FOR IMPORTANT MOUNTING INSTRUCTION. The latter message shall be attached to either side of the glazing by any means which shall ensure the message will remain in place until installation.

SECTION 24.204 — CATEGORY CLASSIFICATION

Glazing required to conform with Part I of this standard shall be classified as Category I or II glazing in accordance with the impact test requirements in Section 24.206.1. Glass classified as Category I glazing shall not be used where Category II glass is required by Table 24-2-A. The categories noted in the table are based on the maximum size in square feet of the largest single glazing in the unit and the intended use of the unit.

SECTION 24.205 — SPECIMENS TO BE TESTED

24.205.1 Thickness. The thickness of the samples to be tested shall be recorded as a nominal thickness for glass as set forth in U.B.C. Standard 24-1.

24.205.2 Specimens.

24.205.2.1 Classification. Safety glazing panels shall be classed in accordance with their size as “limited” or “unlimited” as set forth in Table 24-2-B.
24.205.2.2 Condition of specimens. All specimens shall be tested as supplied by the manufacturer following removal of any temporary protective masking materials. Tests shall not commence before the specimens have been stored in the laboratory for four hours. Specimens shall be arranged to permit free circulation of air to all surfaces during this period.

24.205.2.3 Number of specimens. For impact test of any safety glazing material, four specimens of the thickness and size described in Section 24.205.2.1 shall be provided.

For impact test after aging of plastic used in indoor applications, four specimens of the thickness and size described in Section 24.205.2.1 shall be provided.

For boil test, three specimens 12 inches by 12 inches (305 mm by 305 mm), manufactured in a manner identical to the impact specimens and of like thickness, shall be provided.

For boiling test, the number of test specimens shall comply with the following and be of identical manufacture as the impact specimens and of like thickness: For plastic, 10 specimens, 1/2 inch by 5 inches (13 mm by 127 mm); for orientation specified, six organic-coated glass specimens, 2 inches by 6 inches (51 mm by 152.4 mm); for orientation unspecified, nine organic-coated glass specimens, 2 inches by 6 inches (51 mm by 152.4 mm), except that when the glazing material is symmetric across its thickness, six specimens may be used.

Samples for boil and weathering tests shall be cut from production samples of the size and thickness submitted for impact testing.

SECTION 24.206 — TEST SPECIFICATIONS
24.206.1 Impact Test.

24.206.1.1 General. Unless it has been established that specimens have a modulus of elasticity less than 750,000 psi (5171 MPa) and a Rockwell hardness less than 140 M or R scale, four specimens shall be impact tested in accordance with this subsection.

24.206.1.2 Apparatus. The test apparatus consists of two basic parts: (1) the test frame, and (2) the impactor.

24.206.1.2.1 Test frame. The test frame shall be designed to minimize movement and deflection of its members during testing. For this purpose, the structural framing and bracing members shall be steel angles [L5 x 3 x 1/4 (L127 x 76 x 6.4)] or channels [C4 x 7.25 (C100 x 11)], or other sections and materials of equal or greater rigidity, as shown in Figure 24-2-1.

This structural framing shall be welded or securely bolted at the corners to minimize racking or twisting during testing. Also, it shall be securely bolted to the floor and braced by one of the alternate methods shown in Figure 24-2-1.

The clamping frame for securing the test specimen on all four edges shall be reinforced at the corners. See Detail A of Figure 24-2-1. Other materials may be used, provided there is positive assurance that the test specimen will contact only the neoprene strips.

Pressures on the test specimen shall be controlled, and the compression of the neoprene strips shall be between 10 and 15 percent of the original thickness of the neoprene. Securing methods such as wing bolts as shown in Detail A of Figure 24-2-1 and clamps shall be uniformly spaced no greater than 18 inches (457.2 mm) apart with no fewer than two on any edge. To limit the compression of the neoprene and prevent distortion of the clamping frame, metal shims of an appropriate thickness shall be used as shown in Detail A of Figure 24-2-1.

Any reasonable means may be used to secure the clamping frame to the test frame so long as the mounting is secure and the pressure on the glazing in the clamping frame is not significantly altered when the clamping frame is removed.

24.206.1.2.2 Impactor. The impactor shall be a standard leather punching bag modified as shown in Figure 24-2-3. The bag shall be filled with No. 7 1/2 [0.095 inch (2.4 mm) diameter]
chilled lead shot to a total weight of completed assembly of 100 pounds ± 4 ounces (45.4 kg ± 0.11 kg). The rubber bladder shall be left in place and filled through a hole cut into the upper part. After filling the rubber bladder, the top shall either be twisted around the threaded metal rod below the metal sleeve or pulled over the metal sleeve and tied with a cord or leather thong. Note that the hanging strap shall be removed. The bag shall be laced in the normal manner. The exterior of the bag shall be completely covered with \( \frac{1}{2} \)-inch (12.7 mm) tape as indicated in Figure 24-2-3.

24.206.1.3 Procedure. The impacting object (shot bag), constructed in accordance with Figure 24-2-3, shall be suspended from an overhead support so located that the impacting object, when at rest will, at its maximum diameter, be no more than \( \frac{1}{2} \) inch (13 mm) from the surface of the specimen and no more than 2 inches (50.8 mm) from the center of the specimen (see Figure 24-2-1).

Each specimen shall be centered within the neoprene mounting strips before impacting, such that approximately \( \frac{1}{3} \)-inch (9.53 mm) grip is provided on each edge of the specimen.

Specimens for Category I shall be impacted one time from a drop height of 18 inches to 18\( \frac{1}{2} \) inches (457 mm to 469.9 mm). Specimens for Category II shall be impacted one time from a drop height of 48 inches to 48\( \frac{1}{2} \) inches (1219 mm to 1231.9 mm). For all specimens that are not symmetric from surface to surface, an equal number of specimens shall be impacted on each side. The drop height is to be measured from the maximum diameter of the impacting object to the horizontal center line of the specimen (see Figure 24-2-1). The impacting object shall be stabilized before release.

24.206.1.4 Interpretation of results. A glazing material shall be judged to pass the impact test if each of the four specimens tested meets any one of the following criteria:

1. When breakage occurs (numerous cracks and fissures may occur), no opening shall develop in the test sample through which a 3-inch-diameter (76.2 mm) solid steel sphere, weighing 4 pounds ± 3 ounces (18.14 kg ± 0.085 kg), passes when placed (not dropped) in the opening and permitted to remain for a period of one second. For this criterion, the sample, after being impacted, shall be placed, while remaining in the clamping frame, in a horizontal, impact side-up position with a minimum of 1 foot (305 mm) of free space immediately beneath the specimen.

2. When breakage occurs, what appear to be the 10 largest particles shall be selected within five minutes subsequent to the test and shall weigh no more than the equivalent weight of 10 square inches (6452 mm\(^2\)) of the original specimen. For the purposes of this section, "particle" means a portion of a broken test specimen which is determined by identifying the smallest possible perimeter around all points in the portion of the broken test specimen, always passing along cracks or exposed surfaces.

3. The specimen remains intact after the drop test, though not necessarily remaining within the clamping frame.

24.206.2 Boil Test (for laminated glass only).

24.206.2.1 General. The test is made to determine the probable effect of exposure to high temperature and humidity conditions for a long period of time.

24.206.2.2 Procedure. Three 12- by 12-inch (305 mm by 305 mm) flat specimens, as submitted, shall be immersed vertically on edge in water at 150°F ± 5°F (65.5°C ± 3°C) for three minutes and then quickly transferred to and similarly immersed in boiling water. The rack shall be positioned so that each specimen is surrounded by at least 1 inch (25.4 mm) of water. The specimen shall be kept in the boiling water for two hours and then removed.

24.206.2.3 Interpretation of results. The glass itself may crack in this test, but bubbles or other defects shall not develop more than \( \frac{1}{2} \) inch (12.7 mm) from the outer edge of the specimen or from any cracks that may develop. Any specimen in which the glass cracks to such an extent that the results are confused shall be discarded without prejudice and another specimen shall be tested in its stead.
24.206.3 Weathering Tests (for organic-coated glass used in exterior exposure applications only).

24.206.3.1 Purpose. The purpose of these tests is to determine whether these safety glazing materials will successfully retain their safety characteristics after exposure to weathering conditions for an extended period of time. Specimens shall be exposed to weathering and then tested in accordance with this subsection.

24.206.3.2 Specimen weathering and tests—organic-coated glass.

24.206.3.2.1 Weathering.

24.206.3.2.1.1 Apparatus. The specimens shall be subject to exposure in a xenon arc (water-cooled) Weather-Ometer employing a lamp rated at 6,500 watts and automatic light-monitoring and control systems. Borosilicate inner and outer filters shall be used. An appropriate water-spray cycle shall be used. Operating procedures shall be in accordance with ASTM Recommended Practice for Operating Light- and Water-exposure Apparatus (Xenon-arc Type) for Exposure of Nonmetallic Materials.

24.206.3.2.1.2 Procedure. The specimens shall be retained in the Weather-Ometer for a period of 1,200 ± 1 hour, and exposed to a radiant flux of 50 microwatts per square centimeter (12 calories per second per square centimeter) while monitoring at a wavelength of 340 nanometers.

For organic-coated glass having orientation specified, three specimens shall be mounted with the surface that is intended to be oriented indoors faced away from the radiation source; the other three specimens shall be kept in darkness at 73°F. (23°C.) for use as controls.

For organic-coated glass having orientation unspecified, three specimens shall be mounted with one of the surfaces toward the radiation, three specimens shall be mounted with the other surface toward the radiation, and three specimens shall be kept in darkness at 73°F. (23°C.) for use as controls. When the glazing material is symmetric across its thickness, three specimens shall be irradiated.

24.206.3.2.2 Interpretation of results. Specimens shall be judged satisfactory if they pass the adhesion test and the tensile strength test.

24.206.3.2.2.1 Adhesion test. The specimens for this test are the six 2-inch by 6-inch (51 mm by 152.4 mm) specimens prepared for the weathering test. The specimens shall be conditioned just prior to the performance of the adhesion test at 73.5°F. ± 3.5°F. (23°C. ± 2°C.) and 50 percent ± 2 percent relative humidity for 24 hours.

The test apparatus shall consist of a constant rate of extension (CRE)-type tensile tester with the moving crosshead set to move at 12 inches per minute (305 mm/min.) and load range such that the average peel force will fall at 30 percent to 50 percent of full scale, and a cutter containing new razor blades for cutting 1-inch-wide (25.4 mm) specimens (use blades one time only).

Using the 1-inch (25.4 mm) razor cutter, cut a straight strip of the organic coating in the lengthwise direction of the glass sample. Peel back about 2 inches (51 mm) of one end of the 1-inch-wide (25.4 mm) organic strip. Attach a strip of pressure-sensitive tape to the side of the organic strip opposite the adhesive to extend this free end to about 8 inches (203.2 mm) in length. Place the end of the glass panel from which the organic strip was removed in the lower clamp of the tensile tester and the free end of the tape in the upper clamp. Peel the remainder of the organic strip from the glass mechanically and obtain a record of the peel value. Determine the average pull for each specimen from the chart record.

The organic-coated glass adhesion shall be judged satisfactory if the average adhesion value of the three exposed specimens is no less than 90 percent of the average of the adhesion value of the three control specimens.

24.206.3.2.2.2 Tensile strength test. The samples for this test are the same six 2-inch by 6-inch (50.8 mm by 152.4 mm) specimens used in the adhesion test and conditioned as in Section 24.206.3.2.1.
The CRE tensile tester shall be set as follows: gage length—2 inches (50.8 mm); crosshead speed—2 inches per minute (50.8 mm/min.); load range—set full-scale load so that specimens will break at 30 percent to 60 percent of full scale.

Using a 1/2-inch (13 mm) razor cutter (use blade one time only), cut a straight strip of the organic coating in the lengthwise direction of the glass sample for the full 6-inch (152.4 mm) length. Carefully peel this strip from the glass panel and test it for breaking strength in the tensile tester.

The organic coating tensile strength shall be judged satisfactory if the average tensile value of the three exposed specimens is no less than 75 percent of the average of the three control specimens.

24.206.4 Aging Tests (for plastics used in indoor applications only.)

24.206.4.1 Purpose. The purpose of this test is to determine whether plastic for indoor use only will successfully retain its safety characteristics after exposure to simulated aging conditions for an extended period of time.

24.206.4.2 Apparatus. The safety glazing materials shall be subjected to exposure to warm, humid and dry cycles, using the following apparatus:

24.206.4.2.1 Balance. A balance capable of weighing accurately of 0.05 percent for a test specimen weighing 0.250 pound (0.113 kg) or less, and to 0.1 percent for a test specimen weighing over 0.250 pound (0.113 kg).

24.206.4.2.2 Oven. A circulating-air oven capable of maintaining the required temperature of test within ±1.8°F. (±1°C.).

24.206.4.2.3 Containers. Noncorroding containers with a shelf to support the test specimen above the solution used for maintaining the required humidity. The container shall be tightly sealed except for a small capillary which permits release of vapor pressure that might otherwise lift the top off the container. Each test specimen shall be tested, preferably in a separate container.

24.206.4.2.4 Desiccator. A clean, dry, uncharged desiccator or equivalent closed container in which to bring test specimens to room temperature.

24.206.4.2.5 Absorbent cloth. Clean, nonlinting absorbent cloth for use in wiping exudation or condensed moisture from test specimens.

24.206.4.2.6 Micrometer. A micrometer capable of measuring dimensions of test specimens to 0.001 inch (0.0254 mm).

24.206.4.2.7 Cold box. A cold box capable of maintaining the required temperature of test within ±5.4°F. (±3°C.).

24.206.4.3 Procedure. The four plastic specimens shall be subjected to 10 complete humid/dry test cycles (480 hours) in accordance with the following:

1. The test cycle shall be as follows: 24 hours at 140°F. (60°C.) and 95 percent humidity, followed by 24 hours at 140°F. (60°C.) in the oven.

2. Condition the specimen, weigh and measure dimensions as follows. One additional specimen shall be retained unexposed as a control for the effects of the exposure cycling.

2.1 Conditioning. Condition the test specimens at 73.4°F. ± 3.6°F. (23°C. ± 2°C.) and 50 ± 5 percent relative humidity for not less than 40 hours prior to test.

2.2 Test conditions. Conduct tests in the Standard Laboratory Atmosphere of 73.4°F. ± 3.6°F. (23°C. ± 2°C.) and 50 ± 5 percent relative humidity, unless otherwise specified in the test methods or in this specification. In cases of disagreement, the tolerances shall be 1.8°F. (1°C.) and ±2 percent relative humidity.

2.3 Measurements of test specimens. The following measurements shall be made on conditioned test specimens prior to testing, after reconditioning at the end of a test procedure, and at any intermediate stage as prescribed in the test procedures:
Weight—The weight within 0.05 percent if the specimen weighs 0.250 pound (0.113 kg) or less, and within 0.1 percent if the specimen exceeds 0.250 pound (0.113 kg) in weight.

Dimensions—The thickness to 0.001 inch (0.03 mm), the plane dimension in the direction of injection or transfer to 0.001 inch (0.03 mm), and the plane dimension across the direction of injection or transfer to 0.001 inch (0.03 mm).

Dimensions of compression-molded specimen—The thickness to 0.001 inch (0.03 mm), and the perpendicular dimensions in the plane at right angles to the direction of molding to 0.001 inch (0.03 mm).

3. Expose the specimen for 24 hours on the shelf of a container maintained at 140°F. ± 1.8°F. (60°C. ± 1°C.) in the oven, and containing a saturated solution of sodium sulfate to maintain a relative humidity of 95 percent.

4. Remove the specimen from the container, place it in the uncharged desiccator and bring to room temperature.

5. Wipe the specimen with the absorbent cloth, then weigh, measure dimensions and examine visually. Noticeable qualitative changes in surfaces, outline and general appearance of the test specimen shall be recorded after each stage of the testing procedure. These changes include color, surface irregularities, odor and splits. Changes shall also be noted as they occur, especially those which alter the shape so that intended dimensions are no longer significant.

6. Within two hours after completion of the operation described in Item C above, expose the specimen for 24 hours in the oven at 140°F. ± 1.8°F. (60°C. ± 1°C.).

7. Place the specimen in the uncharged desiccator and bring to room temperature.

24.206.4.4 Interpretation of results. Specimens shall be judged satisfactory if, after the indoor aging test, they again pass the impact test in Section 24.206.1.

Part II—Based on Performance Specifications and Methods of Test for Transparent Safety Glazing Material Used in Buildings, ANSI Z97.1-1975 of the American National Standards Institute, Inc.

See Sections 2401.2, 2401.4, 2406.3 and 2406.5, Uniform Building Code

SECTION 24.207 — SCOPE

Part II of this standard covers safety glazing materials for use in areas subject to human impact as specified in this code. Part II is applicable to polished wired glass and glazing in wardrobe doors.

SECTION 24.208 — DEFINITIONS

For the purpose of this part, the definitions in Section 24.102 of U.B.C. Standard 24-1 are applicable.

SECTION 24.209 — IDENTIFICATION

Each light of safety glazing material shall be identified in accordance with Sections 2402 and 2406.2 of this code and, in addition, safety plastic that only meets the requirements of Section 24.211.4 entitled “Aging Tests (for plastics used in indoor applications only)” shall bear the statement INDOOR USE ONLY as part of a permanent label.

SECTION 24.210 — SPECIMENS TO BE TESTED

The specimens, size and number shall be in accordance with the requirements of Section 24.205.
SECTION 24.211 — TEST SPECIFICATIONS

24.211.1 Impact Test.

24.211.1.1 General. The specimens tested shall be in accordance with the requirements of Section 24.206.1.1

24.211.1.2 Apparatus. The test apparatus requirements for the impact test shall be in accordance with Section 24.206.1.2.

24.211.1.3 Procedure. The test procedure requirements for the impact test shall be in accordance with Section 24.206.1.3, except the specimen shall be struck with the impactor object swinging in a pendulum arc from a drop height of 12 inches (305 mm). When no breakage occurs, the same specimen shall again be impacted at a drop of 18 inches (457 mm), and if no breakage occurs, again at 48 inches (1219 mm).

24.211.1.4 Interpretation of results. The impact test shall be judged to have been satisfactorily completed if any one of the following safety criteria shall be met by each of the four specimens tested:

1. When breakage occurs at 12 inches (305 mm), 18 inches (457 mm) or 48 inches (1219 mm), numerous cracks and fissures may occur, but a 3-inch-diameter (76 mm) sphere shall not be freely passed.

2. When disintegration occurs at 12 inches (305 mm), 18 inches (457 mm) or 48 inches (1291 mm), the 10 largest crack-free particles selected five minutes subsequent to the test shall weigh no more than the equivalent weight of 10 square inches (6452 mm²) of the original test specimen.

   NOTE: Breakage by other means could produce particles exceeding this weight.

3. When breakage occurs at 12 inches (305 mm), 18 inches (457 mm) or 48 inches (1291 mm), the stiffness and hardness of the specimen shall be determined. A modulus of elasticity less than 750,000 psi (5171 MPa) and a Rockwell hardness less than 140 M or R scale shall indicate satisfactory compliance.

4. The specimen remains intact after one 48-inch (1219 mm) drop test, though not necessarily remaining within the clamping frame.

24.211.2 Boil Test (for laminated glass only). The boil test shall be in accordance with the requirements of Section 24.206.2.

24.211.3 Weathering Tests (for plastic and organic-coated glass used in exterior exposure applications only).

24.211.3.1 General. The purpose of these tests is to determine whether these safety glazing materials will successfully retain their safety characteristics after exposure to weathering conditions for an extended period of time. Specimens shall be exposed to simulated weathering and then tested in accordance with this subsection.

24.211.3.2 Specimen weathering and tests—organic-coated glass.

24.211.3.2.1 Weathering.

24.211.3.2.1.1 Apparatus. The specimens shall be subject to exposure in a twin enclosed carbon-arc lamp apparatus, such as specified as Type D or DH in ASTM Recommended Practice for Operating Light- and Water-exposure Apparatus (Carbon-arc Type) for exposure of nonmetallic materials, or equivalent.

24.211.3.2.1.2 Procedure. The specimens shall be exposed for 2,000 hours in accordance with ASTM Recommended Practice for Operating Light- and Water-exposure Apparatus (Carbon-arc Type). For the organic-coated glass, three specimens with the side marked for exterior exposure shall be exposed to the energy source. The other three specimens of organic-coated glass are controls and shall be held in darkness at 73.5°F ± 3.5°F (23°C ± 2°C) until needed.
24.211.3.2.2 Interpretation of results. The specimen test after weathering shall be in accordance with the requirements of Section 24.206.3.2.2.

24.211.3.3 Specimen weathering and test—plastic material.

24.211.3.3.1 Weathering.

24.211.3.3.1.1 Apparatus. The specimen shall be subjected to exposure by any one of the following methods:

1. Twin enclosed carbon-arc such as specified as Type D or DH in ASTM G23-69 (1975).
2. 6,000 or 6,500 watt xenon-arc light exposure apparatus as specified as Type B or BH in ASTM G26-77.
3. Fixed-rack outdoor exposure in south Florida.

24.211.3.3.1.2 Procedure. Depending upon the exposure method chosen in Section 24.211.3.3.1.1, the appropriate procedure from the following shall apply:

1. Twin-carbon arc. The panel shall be exposed for 2,000 hours in accordance with ASTM D1499-64.
2. Xenon-arc apparatus. The panel shall be exposed for 2,900 hours in accordance with ASTM G26-77 using method A with 102 minutes of light-only exposure and 18 minutes of water spray and light exposure.
3. Outdoor exposure. The unbacked panel shall be exposed for one year on a fixed rack at station latitude in south Florida.

24.211.3.3.2 Tests after weathering. Specimens shall be evaluated before and after exposure in accordance with the Charpy unnotched impact test. The exposed specimen shall be tested with the exposed surface subjected to tension. In the case of thin materials, the span of the specimen shall be reduced to 2 inches (51 mm) to avoid having the specimen bend enough to slip between the supports without breaking. The average of five specimens shall be reported. Plastic material shall be acceptable for safety glazing if the impact strength is not reduced by more than 25 percent after exposure. Some discoloration may develop, but defects other than this discoloration shall not develop. Bubbles or other noticeable decomposition shall not develop in the irradiated portion.

24.211.4 Aging Tests (for plastic used in indoor applications only). The aging tests shall be in accordance with the requirements of Section 24.206.4.3, Item 3, except that the humidity shall be 88 percent in Section 24.206.4.3, Item 3 and 85 to 95 percent in Section 24.206.4.3, Item 3.

| TABLE 24-2-A—MINIMUM CATEGORY CLASSIFICATION OF GLAZING |
|-------------------------------|-------------------|-------------------|-------------------|-------------------|
| SURFACE AREA OF ONE SIDE OF SINGLE GLAZING IN THE UNIT | GLAZING IN STORM OR COMBINATION DOORS (Category Class) | GLAZING IN DOORS (Category Class) | FIXED GLAZED PANELS (Category Class) | GLAZING IN DOORS AND ENCLOSURES FOR BATHTUBS AND SHOWERS (Category Class) | SLIDING GLASS DOORS (PATIO TYPE) (Category Class) |
| 9 square feet (0.837 m²) or less of surface area | I | I | I | II |
| More than 9 square feet (0.837 m²) of surface area | II | II | II | II |

| TABLE 24-2-B—DESCRIPTION OF SPECIMENS |
|-------------------------------|-------------------|
| CLASSIFICATION | DIMENSIONS OF SPECIMEN |
| Limited (for all sizes up to and including dimensions of specimens tested) | Largest size commercially produced by the manufacturer up to 34 inches by 76 inches (864 mm by 1930 mm) |
| Unlimited (for all sizes) | 34 inches by 76 inches (864 mm by 1930 mm) |
SWIVEL ATTACHMENT—LOCATE AT VERTICAL CENTER LINE OF TEST SPECIMEN AND A MINIMUM OF 60° ABOVE HORIZONTAL CENTER LINE

STRANDED STEEL CABLE APPROX. 1/8" (3 mm) DIA.

CONCRETE WALL, STEEL BEAM, OR OTHER STURDY CONSTRUCTION

36" (914 mm) MIN.

ALTERNATE MEANS OF BRACING FRAME, USE ONE BRACE AT EACH VERTICAL MEMBER

60" (1524 mm) MIN.

NOTE: CLAMPING FRAME FOR HOLDING TEST SPECIMEN NOT SHOWN

FIGURE 24-2-1—TEST FRAME
C4 x 7.25 (C100 x 11) STEEL CHANNEL
(or L5 x 3 x 1/4 Steel Angle) (L127 x 76 x 6.4 mm)

3/8" x 3/8" (9.5 x 19 mm)
NEOPRENE STRIPS—SHORE A
DUROMETER HARDNESS 30-50

WOOD

3/4" MIN. (19 mm)
METAL SHIMS:
MATCHED TO
GLAZING
THICKNESS

2" MIN. (51 mm)

DETAIL A
SECTION A-A OF FIGURE 24-2-1
FIGURE 24-2-2—GLASS TEST SPECIMEN CLAMPING FRAME (EXPLODED) AND STAND
FILL BAG WITH LEAD SHOT SO THAT TOTAL WEIGHT OF ASSEMBLY IS 100 LB. ± 4 OZ. (45.36 kg ± 0.113 kg)

TAPE BAG WITH 1/2" (13 mm) MIN. WIDE TAPE EQUIVALENT TO 3M NO. 898. USE 3 ROLLS (180 YDS.) (165 mm) AND TAPE IN DIAGONAL, OVERLAPPING MANNER, COVER ENTIRE SURFACE OF BAG. TAPE NECK SEPARATELY

EYE NUT FOR LIFTING BRIDLE
METAL WASHERS—1/16" ± 1/64" THICK (4.8 mm ± 1.6 mm)

FIGURE 24-2-3—IMPACTOR
SECTION 25.101 — SCOPE
This standard covers plastic cement for use in plastering.

SECTION 25.102 — PHYSICAL REQUIREMENTS
Plastic cement shall conform to the requirements set forth in Table 25-1-A.

SECTION 25.103 — PACKAGE LABELING
Plastic cement packages shall carry a statement indicating that the product conforms to requirements of this standard and shall include the brand, name of manufacturer and net weight of the package in pounds.

SECTION 25.104 — CERTIFICATION
Certification shall be submitted upon request of the building official and shall certify compliance with the requirements of this standard.

SECTION 25.105 — TEMPERATURE AND HUMIDITY
The temperature of the air in the vicinity of the mixing slab and dry materials, molds, base plates and mixing bowl shall be maintained between 68°F. and 81.5°F. (20°C. and 27.5°C). The temperature of the mixing water, moist cabinet or moist room, and water in the storage tank shall not vary from 73.4°F. by more than 3°F. (23°C. ± 1.7°C.).

The relative humidity of the laboratory air shall not be less than 50 percent. The moist cabinet or moist room atmosphere shall have a relative humidity of not less than 90 percent.

The moist cabinet or moist room shall conform to applicable standards.

SECTION 25.106 — FINENESS
The fineness of the cement shall be determined from the residue on the No. 325 sieve (45 μm).

SECTION 25.107 — NORMAL CONSISTENCY
Determine normal consistency by the Vicat apparatus.

SECTION 25.108 — AUTOCLAVE EXPANSION
The autoclave expansion of plastic cement shall be determined. After molding, the specimens shall be stored in the moist cabinet or moist room for 48 hours ± 30 minutes before removal.

SECTION 25.109 — TIME OF SETTING
The time of setting shall be determined by the Gillmore needle method.
SECTION 25.110 — DENSITY

The density of the plastic cement shall be determined by using kerosene as the liquid. Use the density so determined in the calculation of the air content of the specimens.

SECTION 25.111 — APPARATUS FOR MORTAR TESTS

The apparatus for mortar tests shall be in accordance with applicable standards.

SECTION 25.112 — BLENDED SAND

The sand shall be a blend of equal parts by weight of graded standard sand and Standard 20-30 sand.

SECTION 25.113 — PREPARATION OF MORTAR

25.113.1 Proportions for Mortar. Mortar for air entrainment, compressive strength, and water retention tests shall be proportioned to contain a mass of cement, in grams, equal to six times the net bag weight in pounds, representing a nominal 1 cubic foot (0.0283 m³) of plastic cement and 1,440 grams of sand. The sand shall consist of 720 grams of graded standard sand and 720 grams of 20-30 standard sand. The quantity of water measured in millimeters shall be such as to produce a flow of 110 ± 5 as determined by the flow table.

25.113.2 Mixing of Mortars. The mortar shall be mixed in accordance with applicable standards.

25.113.3 Determination of Flow. The flow shall be determined in accordance with applicable standards.

SECTION 25.114 — AIR ENTRAINMENT

25.114.1 Procedure. If the mortar has the correct flow, use a separate portion of the mortar for the determination of entrained air. Determine the mass of the 400 milliliters of the mortar.

25.114.2 Calculation. Calculate the air content of the mortar and report it to the nearest 0.1 percent as follows:

\[
A = 100 - \left( \frac{W_m}{4D} \right)
\]

WHERE:

- \(A\) = volume percent of entrained air.
- \(D\) = density of air-free mortar, g/ml.
- \(S_1\) = density of cement, g/ml.
- \(S_2\) = density of standard sand, 2.65 g/ml.
- \(V_w\) = milliliters-grams of water used.
- \(W_1\) = mass of cement, g.
- \(W_2\) = mass of sand, g.
- \(W_m\) = mass of 400 ml.

SECTION 25.115 — COMPRESSIVE STRENGTH

25.115.1 Test Specimens.

25.115.1.1 Molding. Immediately after determining the flow and the mass of 400 milliliters of mortar, return all the mortar to the mixing bowl and remix for 15 seconds at the medium speed. Then
mold test specimens, except that elapsed time for mixing mortar, determining flow, determining air
entrainment and starting the molding of cubes shall be within eight minutes.

25.115.1.2 Storage. Store all test specimens immediately after molding in the molds on plane
plates in a moist cabinet or moist room for 48 to 52 hours, in such a manner that the upper surfaces
shall be exposed to the moist air. Then remove the cubes from the molds and place in the moist cabi­
net or moist room for five days in such a manner as to allow free circulation of air around at least five
faces of the specimens. At the age of seven days, immerse the cubes for the 28-day tests in saturated
lime water in storage tanks of noncorrodible materials.

25.115.2 Procedure. Test the cube specimens immediately after their removal from the moist
 cabinet or moist room for seven-day specimens and immediately after their removal from storage
water for all other specimens. If more than one specimen at a time is removed from the moist cabinet
or moist room for seven-day tests, cover these cubes with a damp cloth until time of testing. If more
than one specimen at a time is removed from the storage water for testing, place these cubes in a pan
of water at a temperature of 73.4°F ± 3°F (23°C ± 1.7°C) and of sufficient depth to completely
immerse each cube until time of testing.

The remainder of the testing procedure shall conform to applicable standards.

SECTION 25.116 — WATER RETENTION

25.116.1 Apparatus. For the water-retention test, an apparatus essentially the same as that shown
in Figure 25-1-1 shall be used. This apparatus consists of a water-aspirator or other source of vacu­
um controlled by a mercury-relief column and connected by way of a three-way stopcock to a fun­
nel upon which rests a perforated dish. The perforated dish shall be made of metal not attacked by
plastic mortar. The metal in the base of the dish shall have a thickness of 1.7 mm to 1.9 mm and shall
conform to the requirements given in Figure 25-1-1. The stopcock bore shall have a 4.0 mm ± 0.5
mm diameter, and the connecting glass tubing shall have a minimum inside diameter of 4 mm. A
mercury manometer, connected as shown in Figure 25-1-1, indicates the vacuum. The contact sur­
faces of the funnel and perforated dish shall be placed and may need to be lapped to ensure intimate
contact. An air-tight seal shall be maintained between the funnel and the dish during a test. This
shall be accomplished by either of the following procedures:

A. A synthetic (grease-resistant) rubber gasket may be permanently sealed to the top of the funnel
using petrolatum or light grease to ensure a seal between the basket and dish.

B. The top of the funnel may be lightly coated with petrolatum or light grease to ensure a seal
between the funnel and dish.

Care shall be taken to ensure that none of the holes in the perforated dish are clogged. Hardened,
very smooth, not rapid, filter paper shall be used. It shall be 150 mm in diameter and be placed so as
to completely cover the perforations in the dish.

A steel straightedge not less than 8 inches (203 mm) long and not less than \( \frac{13}{16} \) inch (1.6 mm) or
more than \( \frac{1}{8} \) inch (3.2 mm) in thickness.

Other apparatus required for the water-retention test shall conform to the requirements of Section
25.111.

25.116.2 Procedure. Adjust the mercury-relief column to maintain a vacuum of 51 mm ± 3 mm as
indicated by the manometer. Seat the perforated dish on the greased gasket or greased rim of the
funnel. Place a wetted filter paper in the bottom of the dish. Turn the stopcock to apply the vacuum
to the funnel and check the apparatus for leaks and to determine that the required vacuum is ob­
tained. Then turn the stopcock to shut off the vacuum from the funnel.

Mix the mortar to a flow of 110 ± 5 percent in accordance with applicable standards. Immediately
after making the flow test, return the mortar on the flow table to the mixing bowl and remix the
entire batch for 15 seconds at medium speed. Immediately after remixing the mortar, fill the perfo­
rated dish with the mortar to slightly above the rim. Tamp the mortar 15 times with the tamper. Apply 10 of the tamping strokes at approximately uniform spacing adjacent to the rim of the dish and with the long axis of the tamping face held at right angles to the radius of the dish. Apply the remaining five tamping strokes at random points distributed over the central area of the dish. The tamping pressure shall be just sufficient to ensure filling of the dish. Upon completion of the tamping, the top of the mortar will extend slightly above the rim of the dish. Smooth off the mortar by drawing the flat side of the straightedge (with leading edge slightly raised) across the top of the dish. Then cut off the mortar to a plane surface flush with the rim of the dish by drawing the straightedge with a sawing motion across the top of the dish in two cutting strokes, starting each cut from near the center of the dish. If the mortar is pulled away from the side of the dish during the process of drawing the straightedge across the dish, gently press the mortar back into contact with the side of the dish using the tamper.

Turn the stopcock to apply the vacuum to the funnel. The time elapsed from the start of mixing the cement and water to the time of applying the vacuum shall not exceed eight minutes. After suction for 60 seconds, quickly turn the stopcock to expose the funnel to atmospheric pressure. Immediately slide the perforated dish off from the funnel, touch it momentarily on a damp cloth to remove droplets of water, and set the dish on the table. Then, using the bowl scraper, plow and mix the mortar in the dish for 15 seconds. Upon completion of mixing, place the mortar in the flow mold and determine the flow. The entire operation shall be carried out without interruption and as quickly as possible, and shall be completed within an elapsed time of 11 minutes after the start of mixing the cement and water for the first flow determination. Both flow determinations shall be made in accordance with applicable standards.

25.116.3 Calculation. Calculate the water-retention value for the mortar as follows:

\[
\text{Water-retention value} = \left( \frac{A}{B} \right) \times 100
\]

WHERE:

\[ A = \text{flow after suction}, \]
\[ B = \text{flow immediately after mixing}. \]

**TABLE 25-1-A—PHYSICAL REQUIREMENTS**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finess, residue on a No. 325 sieve (45 μm), maximum, percentage</td>
<td>24</td>
</tr>
<tr>
<td>Soundness:</td>
<td></td>
</tr>
<tr>
<td>Autoclave expansion, maximum, percentage</td>
<td>1.0</td>
</tr>
<tr>
<td>Time of setting, Gilmore method:</td>
<td></td>
</tr>
<tr>
<td>Initial set, minimum, hour</td>
<td>1 1/2</td>
</tr>
<tr>
<td>Final set, maximum, hour</td>
<td>24</td>
</tr>
<tr>
<td>Compressive strength (average of three cubes):</td>
<td></td>
</tr>
<tr>
<td>Initial compressive strength of mortar cubes, composed of one part cement and three parts blended sand (half graded Ottawa sand, and half Standard 20-30 Ottawa sand) by volume, prepared and tested in accordance with this specification shall be equal to or higher than the values specified for the ages indicated below:</td>
<td>1,800 (12 402 kPa)</td>
</tr>
<tr>
<td>seven days, psi (kPa)</td>
<td>2,900 (19 981 kPa)</td>
</tr>
<tr>
<td>28 days, psi (kPa)</td>
<td></td>
</tr>
<tr>
<td>Air content of mortar:</td>
<td></td>
</tr>
<tr>
<td>Minimum percentage by volume</td>
<td>8</td>
</tr>
<tr>
<td>Maximum percentage by volume</td>
<td>20</td>
</tr>
<tr>
<td>Water retention, flow after suction, minimum, percentage of original flow</td>
<td>70</td>
</tr>
</tbody>
</table>
FIGURE 25-1-1—APPARATUS ASSEMBLY FOR THE WATER-RETENTION TEST

NOTE: The gasket is to be synthetic rubber. The stopcock and the bore of the tubing should measure at least 4 mm. A check valve or water trap, or both, are suggested for the connection to the aspirator.
UNIFORM BUILDING CODE STANDARD 25-2
METAL SUSPENSION SYSTEMS FOR ACOUSTICAL TILE
AND FOR LAY-IN PANEL CEILINGS

Based on Standard Specification C 635-69 and Standard Recommended Practice
C 636-69 of the American Society for Testing and Materials. Extracted, with
permission, from the Annual Book of ASTM Standards, copyright American
Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103

See Table 25-A, Uniform Building Code
Part I—General

SECTION 25.201 — SCOPE
This standard covers metal ceiling suspension systems used primarily to support acoustical tile or
acoustical lay-in panels.

SECTION 25.202 — CLASSIFICATION
The structural performance required from a ceiling suspension system shall be in accordance with
its structural classification.

The load-carrying capacity shall be the maximum uniformly distributed load (pounds per linear
foot) that a simply supported main runner section having a span length of 4 feet 0 inch (1219 mm) is
capable of supporting without a midspan deflection exceeding 0.133 inch (3.4 mm) or $\frac{1}{360}$ of the
4-foot 0-inch (1219 mm) span length.

The structural classification listed in Table 25-2-A shall be determined by the capability of main
runners or nailing bars to support a uniformly distributed load. These classifications shall be:

1. **Light-duty systems.** Used primarily for residential and light commercial structures where
ceiling loads other than acoustical tile or lay-in panels are not anticipated.

2. **Intermediate-duty systems.** Used primarily for ordinary commercial structures where some
ceiling loads, due to light fixtures and air diffusers, are anticipated.

3. **Heavy-duty systems.** Used primarily for commercial structures in which the quantities and
weights of ceiling fixtures (lights, air diffusers, etc.) are greater than those for an ordinary com­
mercial structure.

Cross runners shall be capable of carrying the design load as dictated by job conditions without
exceeding the maximum allowable deflection equal to $\frac{1}{360}$ of its span. A cross runner that supports
another cross runner is a main runner for the purpose of structural classification and shall be capable
of supporting a uniformly distributed load at least equal to the intermediate classification.

SECTION 25.203 — DIMENSIONAL TOLERANCE

25.203.1 **Straightness.** The amount of bow, camber or twist in main runners, cross runners, wall
molding, splines or nailing bars of various lengths shall not exceed the values shown in Table
25-2-B.

Main runners, cross runners, wall moldings, splines or nailing bars of ceiling suspension systems
shall not contain local kinks or bends.

Straightness of structural members shall be measured with the member suspended vertically
from one end.
25.203.2 Length. The variation in the specified length of main runner sections or cross runner sections that are part of an interlocking grid system shall not exceed ± 0.010 inch/4 feet (± 0.25 mm/1219 mm).

The variation in the specified spacing of slots or other cutouts in the webs of main runners or cross runners that are employed in assembling a ceiling suspension grid system shall not exceed 0.010 inch (0.25 mm).

25.203.3 Overall Cross-section Dimensions. For steel systems, the overall height of the cross section of main runners, cross runners, wall molding or nailing bar shall be the specified dimensions ± 0.030 inch (0.76 mm). The width of the cross section of exposed main runners or cross runners shall be the specified dimension ± 0.008 inch (0.20 mm).

25.203.4 Section Squareness. Intersecting webs and flanges of structural members (I, T, or Z sections) shall form angles between them of 90 degrees ± 2 degrees. If deviations from squareness at more than one such intersection are additive with respect to their use in a ceiling, the total angle shall not be greater than 2 degrees.

The ends of structural members that abut or intersect other members in exposed grid systems shall be cut perpendicular to the exposed face, 90 degrees +0, -2 degrees.

25.203.5 Suspension System Devices. Suspension system assembly devices shall satisfy the following requirements and tolerances:

- A joint connection shall be judged suitable both before and after ceiling loads are imposed if the joint provides sufficient alignment so that:
  - The horizontal and the vertical displacements of the exposed surfaces of two abutting main runners do not exceed 0.015 inch (0.38 mm).
  - There shall be no visually apparent angular displacement of the longitudinal axis of one runner with respect to the other.

- Assembly devices shall provide sufficient spacing control so that horizontal gaps between exposed surfaces of either abutting or intersecting members shall not exceed 0.020 inch (0.5 mm).

- Spring wire clips used for supporting main runners shall maintain tight contact between the main runners and the carrying channels when the ceiling loads are imposed on the runners.

SECTION 25.204 — COATINGS AND FINISHES FOR SUSPENSION SYSTEM COMPONENTS

25.204.1 Protective Coatings for Normal Environments. Component materials that oxidize or corrode when exposed to normal-use environments shall be provided with protective coatings except for cut or punched edges fabricated after the coating is applied.

- Components fabricated from sheet steel shall be given an electrogalvanized, hot-dipped galvanized, cadmium or equal protective coating.

- Components fabricated from aluminum alloys shall be anodized or protected by other approved techniques.

- Components formed from other materials shall be provided with an approved protective coating.

25.204.2 Adhesion and Resilience. Finishes shall exhibit good adhesion properties and resilience so that chipping or flaking does not occur as a result of the manufacturing process.

25.204.3 Protective Coatings for Severe Environment. Protected components for acoustical ceilings shall be suitable for their environment. When they are subject to the severe environmental conditions of high humidity and salt spray (fog), or both, they shall be ranked according to their ability to protect the components of suspension systems from deterioration. A salt spray (fog) test conducted in accordance with the following test conditions shall be performed:
1. **Salt solution.** Five parts by weight NaCl to 95 parts distilled water.

2. **Humidity in chamber.** Ninety percent relative humidity.

3. **Temperature in chamber.** 90°F (32°C).

4. **Exposure period.** Ninety-six hours continuous.

5. **Report.** Upon request, the photographs shall be provided showing worst corrosion conditions on components and shall provide comments regarding corrosion that occurs on cut metal edges, on galvanized surfaces without paint, on galvanized and painted surfaces, at edges rolled after being painted, and on any change of paint color or gloss that is apparent at the conclusion of the test. Color and gloss inspection of the component shall be made after washing in a mild soap solution.

**25.204.4 High-humidity Test.** The test and inspection shall be identical to that of the salt spray test, except that distilled water instead of salt solution shall be used.

### SECTION 25.205 — STRUCTURAL MEMBERS

The manufacturer shall determine the load-deflection performance. The structural members tested shall be identical to the sections used in the final system design. All cutouts, slots, etc., as exist in the system component shall be included in the sections evaluated.

Load-deflection studies of structural members shall utilize sections fabricated in accordance with the system manufacturers' published metal thicknesses and dimensions.

### SECTION 25.206 — SECTION PERFORMANCE

The performance of structural members of suspension systems shall be represented by individual load-deflection plots obtained from tests performed at each different span length used in service.

The results of replicate tests of three individual sections, each tested on the same span length, shall be plotted and averaged to obtain a characteristic load-deflection curve for the structural member.

The average load-deflection curve shall be used to establish the maximum uniformly distributed load that the structural member can successfully sustain prior to reaching the deflection limit of \( \frac{1}{360} \) of the span length in inches.

The load-deflection curve shall be used to establish the maximum loading intensity beyond which the structural member begins to yield.

### SECTION 25.207 — SUSPENSION SYSTEM PERFORMANCE

Published performance data for individual suspension systems shall be developed by the manufacturer on the basis of results obtained from load-deflection tests of its principal structural members. Where a ceiling design incorporates a number of components, each of which experiences some deflection as used in the system, the additive nature of these displacements shall be recognized in setting an allowable system deflection criteria.

**Part II—Installation**

### SECTION 25.208 — SCOPE

This part describes procedures for the installation of suspension systems for acoustical tile and lay-in panels.

### SECTION 25.209 — INSTALLATION OF COMPONENTS

**25.209.1 Hangers.** Hangers shall be attached to the bottom edge of the wood joists or to the vertical face of the wood joists near the bottom edge. Bottom edge attachment devices shall be an approved type.
In concrete construction, mount hangers using cast-in-place hanger wires, hanger inserts, or other hanger attachment devices shall be an approved type. If greater center-to-center distances than 4 feet 0 inch (1219 mm) are used for the hangers, the load-carrying capacity of the ceiling suspension system shall be reduced commensurate with the actual center-to-center hanger distances.

Hangers shall be plumb and shall not press against insulation covering ducts or pipes. If some hangers must be spliced, countersplaying or other approved means shall be used to offset the horizontal force.

Hangers formed from galvanized sheet metal shall be suitable for suspending carrying channels or main runners from an existing structure provided that the hangers do not yield, twist or undergo other objectionable movement.

Wire hangers for suspending carrying channels or main runners from an existing structure shall be a minimum of No. 12 gage (2.7 mm), galvanized, soft annealed, mild steel wire.

Special attachment devices that support the carrying channels or main runners shall be approved to support five times the design load.

25.209.2 Carrying Channels. The carrying channels shall be installed so that they are level to within \(\frac{1}{32}\) inch in 12 feet (3.2 m in 3660 mm). Leveling shall be performed with the supporting hangers taut. Local kinks or bends shall not be made in hanger wires as a means of leveling carrying channels. In installations where hanger wires are wrapped around carrying channels, the wire loops shall be tightly formed to prevent any vertical movement or rotation of the member within the loop.

25.209.3 Main Runners. Main runners shall be installed so that they are all level to within \(\frac{1}{32}\) inch in 12 feet (3.2 mm in 3660 mm). Where main runners are supported directly by hangers, leveling shall be performed with the supporting hanger taut. Local kinks or bends shall not be made in hanger wires as a means of leveling main runners. In installations where hanger wires are wrapped through or around main runners, the wire loops shall be tightly wrapped and sharply bent.

25.209.4 Cross Runners. Cross runners shall be supported by either main runners or by other cross runners to within \(\frac{1}{32}\) inch (0.79 mm) of the required center distances. This tolerance shall be noncumulative beyond 12 feet (3528 mm). Intersecting runners shall form a right angle. The exposed surfaces of two intersecting runners shall lie within a vertical distance of 0.015 inch (0.38 mm) of each other with the abutting (cross) member always above the continuous (main) member.

25.209.5 Splines. Splines used to form a concealed mechanical joint seal between adjacent tiles shall be compatible with the tile kerf design so that the adjacent tile will be horizontal when installed. Where splines are longer than the dimension between edges of supporting members running perpendicular to the splines, place the splines so that they rest either all above or all below the main running members.

25.209.6 Assembly Devices. Abutting sections of main runner shall be joined by means of suitable connections such as splices, interlocking ends, tab locks, pin locks, etc. A joint connection shall be judged suitable both before and after ceiling loads are imposed if the joint provides sufficient alignment so that the exposed surfaces of two abutting main runners lie within a vertical distance of 0.015 inch (0.38 mm) of each other and within a horizontal distance of 0.015 inch (0.38 mm) of each other.

There shall be no visually apparent angular displacement of the longitudinal axis of one runner with respect to the other.

Assembly devices shall provide sufficient spacing control so that horizontal gaps between exposed surfaces of either abutting or intersecting members shall not exceed 0.020 inch (0.51 mm).

Spring wire clips used for supporting main runners shall maintain tight contact between the main runners and the carrying channels when the ceiling loads are imposed on the runners.

25.209.7 Ceiling Fixtures. Fixtures installed in acoustical tile or lay-in panel ceilings shall be mounted in a manner that will not compromise ceiling performance.
Fixtures shall not be supported from main runners or cross runners if the weight of the fixtures causes the total dead load to exceed the deflection capability of the ceiling suspension system. In such cases, the fixture load shall be supported by supplemental hangers within 6 inches (152.4 mm) of each corner, or the fixture shall be separately supported.

Fixtures shall not be installed so that main runners or cross runners will be eccentrically loaded except where provision is inherent in the system (or is separately provided for) to prevent undesirable section rotation or displacement, or both. In any case, runners supporting ceiling fixtures shall not rotate more than 2 degrees after the fixture loads are imposed.

Where fixture installation would produce rotation of runners in excess of 2 degrees, the fixtures shall be with the use of suitable accessory devices. These devices shall support the fixture in such a manner that the main runners and cross runners will be loaded symmetrically rather than eccentrically.

Part III—Lateral Design Requirements

SECTION 25.210 — SCOPE

Suspended ceilings which are designed and constructed to support ceiling panels or tiles, with or without lighting fixtures, ceiling-mounted air terminals or other ceiling-mounted services shall comply with the requirements of this standard.

EXCEPTIONS: 1. Ceiling area of 144 square feet (13.38 m²) or less surrounded by walls which connect directly to the structure above are exempt from the lateral load design requirements of this standard.
2. Ceilings constructed of lath and plaster or gypsum board, screw or nail attached to suspended members that support a ceiling on one level extending from wall to wall are exempt from this standard.

SECTION 25.211 — MINIMUM DESIGN LOADS

25.211.1 Lateral Forces. Ceiling systems and their connections to the building structure shall be designed and constructed to resist the lateral force specified in Chapter 16, Part III of the Building Code.

Where the ceiling system provides lateral support for nonbearing partitions, it shall be designed for the prescribed lateral force reaction from the partitions as specified in Section 25.215.

Connection of lighting fixtures to the ceiling system shall be designed for a lateral force of 100 percent of the weight of the fixture in addition to the prescribed vertical loading as specified in Section 25.213.

25.211.2 Grid Members, Connectors and Expansion Devices. The main runners and cross runners of the ceiling system and their splices, intersection connectors and expansion devices shall be designed and constructed to carry a mean ultimate test load of not less than 180 pounds (801 N) or twice the actual load, whichever is greater, in tension with a 5-degree misalignment of the members in any direction, and in compression. In lieu of 5-degree misalignment, the load may be applied with a 1-inch (25.4 mm) eccentricity on a sample not more than 24 inches (610 mm) long on each side of the splice. The connections at splices and intersections shall all be of the mechanical interlocking type.

When the composition or configuration of ceiling systems members or assemblies and their connections are such that calculations of their allowable load-carrying capacity cannot be made in accordance with established methods of analysis, their performance shall be established by test. Evaluation of test results shall be made on the basis of the mean values resulting from tests of three or more identical specimens, provided the deviation of any individual test result from the mean value does not exceed plus or minus 10 percent. The allowable load-carrying capacity as determined by test shall not exceed one half of the mean ultimate test value.
25.211.3 Substantiation. The ceiling systems manufacturer shall furnish lateral loading capacity and displacement or elongation characteristics, indicating the following:

1. Maximum bracing pattern and minimum wire sizes.
2. Tension and compression force capabilities of main runner splices, cross runner connections and expansion devices.

Tests shall be conducted by an approved testing agency.

SECTION 25.212 — INSTALLATION

25.212.1 Vertical Hangers. Suspension wires shall not be smaller than No. 12 gage (2.7 mm) spaced at 4 feet (1219 mm) on center or No. 10 gage (3.4 mm) at 5 feet (1524 mm) on center along each main runner unless calculations justifying the increased spacing are provided.

Each vertical wire shall be attached to the ceiling suspension member and to the support above with a minimum of three turns. Connection devices at the supporting construction shall be capable of carrying not less than 100 pounds (445 N).

Suspension wires shall not hang more than 1 in 6 out-of-plumb unless countersloping wires are provided.

Wires shall not attach to or bend around interfering material or equipment. A trapeze or equivalent device shall be used where obstructions preclude direct suspension. Trapeze suspensions shall be a minimum of back-to-back 1/4-inch (31.75 mm) cold-rolled channels for spans exceeding 48 inches (1219 mm).

25.212.2 Perimeter Hangers. The terminal ends of each cross runner and main runner shall be supported independently a maximum of 8 inches (203.2 mm) from each wall or ceiling discontinuity with No. 12 gage (2.7 mm) wire or approved wall support.

25.212.3 Lateral Force Bracing. Where substantiating design calculations are not provided, horizontal restraints shall be effected by four No. 12 gage (2.7 mm) wires secured to the main runner within 2 inches (50.8 mm) of the cross runner intersection and splayed 90 degrees from each other at an angle not exceeding 45 degrees from the plane of the ceiling. A strut fastened to the main runner shall be extended to and fastened to the structural members supporting the roof or floor above. The strut shall be adequate to resist the vertical component induced by the bracing wires. These horizontal restraint points shall be placed not more than 12 feet (3658 mm) on center in both directions with the first point within 6 feet (1829 mm) from each wall. Attachment of the restraint wires to the structure above shall be adequate for the load imposed.

Lateral-force bracing members shall be spaced a minimum of 6 inches (154 mm) from all horizontal piping or ductwork that is not provided with bracing restraints for horizontal forces. Bracing wires shall be attached to the grid and to the structure in such a manner that they can support a design load of not less than 200 pounds (890 N) or the actual design load, whichever is greater, with a safety factor of 2.

25.212.4 Perimeter Members. Unless perimeter members are a structural part of the approved system, wall angles or channels shall be considered as aesthetic closures and with no structural value. Ends of main runners and cross members shall be tied together to prevent their spreading.

25.212.5 Attachment of Members to the Perimeter. To facilitate installation, main runners and cross runners may be attached to the perimeter member at two adjacent walls with clearance between the wall and the runners maintained at the other two walls or as otherwise shown or described for the approved system.

SECTION 25.213 — LIGHTING FIXTURES

Intermediate or heavy-duty ceiling systems as defined in Section 25.202 shall be used for the support of lighting fixtures.
All lighting fixtures shall be positively attached to the suspended ceiling system. The attachment device shall have a capacity of 100 percent of the lighting fixture weight acting in any direction.

When intermediate systems are used, No. 12 gage (2.7 mm) hangers shall be attached to the grid members within 3 inches (76 mm) of each corner of each fixture. Tandem fixtures may utilize common wires.

When heavy-duty systems are used, supplemental hangers are not required if a 48-inch (1219 mm) modular hanger pattern is followed. When cross runners are used without supplemental hangers to support lighting fixtures, these cross runners shall provide the same carrying capacity as the main runner.

Lighting fixtures weighing less than 56 pounds (25.4 kg) shall have, in addition to the requirements outlined above, two No. 12 gage (2.7 mm) hangers connected from the fixture housing to the structure above. These wires may be slack.

Lighting fixtures weighing 56 pounds (25.4 kg) or more shall be supported directly from the structure above by approved hangers.

Pendant-hung lighting fixtures shall be supported directly from the structure above with No. 9 gage (3.8 mm) wire or approved alternate support without using the ceiling suspension system for direct support.

SECTION 25.214 — MECHANICAL SERVICES

Ceiling-mounted air terminals or services weighing less than 20 pounds (9.07 kg) shall be positively attached to the ceiling suspension main runners or to cross runners with the same carrying capacity as the main runners.

Terminals or services weighing 20 pounds (9.07 kg), but not more than 56 pounds (25.4 kg), in addition to the above, shall have two No. 12 gage (2.7 mm) hangers connected from the terminal or service to the ceiling system hangers or to the structure above. These wires may be slack.

Terminals or services weighing more than 56 pounds (25.4 kg) shall be supported directly from the structure above by approved hangers.

SECTION 25.215 — PARTITIONS

Where the suspended ceiling system is required to provide lateral support for permanent or relocatable partitions, the connection of the partition to the ceiling system, the ceiling system members and their connections, and the lateral force bracing shall be designed to support the reaction force of the partition from prescribed loads applied perpendicular to the face of the partition. These partition reaction forces shall be in addition to the loads described in Section 25.211. Partition connectors, the suspended ceiling system and the lateral-force bracing shall be engineered to suit the individual partition application and shall be shown or defined in the drawings or specifications.

SECTION 25.216 — DRAWINGS AND SPECIFICATIONS

The drawings shall clearly identify all systems and shall define or show all supporting details, lighting fixture attachment, lateral-force bracing, partition bracing, etc. Such definition may be by reference to this standard, or approved system, in whole or in part. Deviations or variations shall be shown or defined in detail.
TABLE 25-2-A—MINIMUM LOAD-CARRYING CAPABILITIES OF MAIN RUNNER MEMBERS

<table>
<thead>
<tr>
<th>MAIN RUNNER MEMBERS</th>
<th>SUSPENSION SYSTEM (pounds per linear foot) ( \times 14.59 ) for ( N/m )</th>
<th>Direct-Hung</th>
<th>Indirect-Hung</th>
<th>Furring Bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light-duty</td>
<td>5.0</td>
<td>2.0</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>Intermediate-duty</td>
<td>12.0</td>
<td>3.5</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>Heavy-duty</td>
<td>16.0</td>
<td>8.0</td>
<td>—</td>
<td></td>
</tr>
</tbody>
</table>

TABLE 25-2-B—STRAIGHTNESS TOLERANCES OF STRUCTURAL MEMBERS OF SUSPENSION SYSTEMS

<table>
<thead>
<tr>
<th>DEFORMATION</th>
<th>STRAIGHTNESS TOLERANCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bow</td>
<td>( \frac{1}{32} ) in. in any 2 ft. (1.3 mm in any 1 m), or ( \frac{1}{32} ) in. \times ) ( \frac{\text{total length, ft.}}{2} )]</td>
</tr>
<tr>
<td>Camber</td>
<td>( \frac{1}{32} ) in. in any 2 ft. (1.3 mm in any 1 m), or ( \frac{1}{32} ) in. \times ) ( \frac{\text{total length, ft.}}{2} )]</td>
</tr>
<tr>
<td>Twist</td>
<td>1 degree in any 2 ft. (610 mm), or 1 degree ( \times ) ( \frac{\text{total length, ft. (m)}}{2} )]</td>
</tr>
</tbody>
</table>
UNIFORM BUILDING CODE STANDARD 26-1
TEST METHOD TO DETERMINE POTENTIAL HEAT OF BUILDING MATERIALS

Test Standard of the International Conference of Building Officials
See Sections 601.3, 2602.4 and 2602.5.2, Uniform Building Code

SECTION 26.101 — SCOPE

26.101.1 General. This method of test defines a means of determining the potential release of heat of materials (typically involved in building fires) under specified conditions. The method is applicable to a variety of materials including metals and especially materials with low combustible content. Determinations may be made on simple materials or on composite assemblies of materials from which a representative sample can be taken and pulverized into a homogeneous mixture.

26.101.2 Definition of Potential Heat. Potentional heat of a material is the difference between the heat of combustion of a representative specimen of the material and the heat of combustion of any residue remaining after exposure to a specified standard fire using combustion, calorimetric techniques.

SECTION 26.102 — TEST PROCEDURES

26.102.1 General. One of two specimens removed from the material to be tested shall be pulverized, pelleted and burned in a high-pressure-oxygen atmosphere in accordance with approved standard procedures for determination of the heat of combustion. Caution should be observed when performing bomb calorimetric measurements on materials containing significant proportions of metallic ingredients. Apart from the high reaction temperatures which may occur with the resulting possible involvement of portions of the bomb, consideration should be given to the possibility of electrical shorts in the ignition system.

26.102.2 Test Specimens. Two air-dry specimens representative of the material or assembly involved are required for each determination. A specimen is considered "air dry" when it has reached constant weight in an atmosphere maintained at 73°F ± 2°F (23°C ± 1°C) and 50 ± 5 percent relative humidity. The two specimens are subject to separate test procedures as set forth in Sections 26.102.3 and 26.102.4 below.

26.102.3 Procedure for Direct Bomb Test. The following steps shall be used for the direct bomb test:

Step 1. All or a representative portion of this specimen shall be pulverized into a form suitable to pass a No. 60 sieve (250 μm).

Step 2. A 1-gram pellet of a representative sample of the powder formed in Step 1 is prepared.

Step 3. The pellet formed in Step 2 shall be used as the test specimen following the procedures described in Section 26.102.1. The usual sulfur and acid corrections shall be made. These take into account the oxidation of sulfur and nitrogen, if present, which would not normally occur during fire exposure.

Step 4. If after being fired in the oxygen bomb the pellet is found to have burned completely or to have left no significant amount of residue or ash, the heat of combustion on an air-dry basis shall be computed and Steps 5, 6 and 7 shall be omitted.

Step 5. If the pellet does not burn or a residue remains after the firing, another 1-gram pellet shall be prepared with a mixture of the powdered sample and a standard sample of benzoic acid combustion promoter in approximately equal weight proportions.
Step 6. The pellet prepared in Step 5 shall be used as a test specimen following the same procedures as for the original specimen.

Step 7. A correction for the heat of combustion of the benzoic acid present in the pellet is supplied to the measured heat release by the specimen. The heat of combustion of the specimen material on an air-dry basis is then computed.

26.102.4 Procedure for Muffle Furnace and Bomb Test. The following steps shall be used for the muffle furnace and bomb test:

Step 1. An air-dry specimen representative of the test material or assembly shall be cut in the form of a rectangular prism $\frac{1}{2}$ inch by $\frac{3}{4}$ inch by 3 inches (13 mm by 19 mm by 76 mm). Sheet materials may be folded or laminated to these dimensions.

Step 2. The muffle furnace is preheated to 1,382°F ± 18°F. (750°C ± 10°C.) The weighed specimen is supported in a fused silica or ceramic container of $\frac{1}{4}$-inch (32 mm) inside diameter by 4 inches (102 mm) in length. The specimen, container cap and the tube for supply air to the bottom of the container are assembled. The assembly is then placed on a firebrick support within the electric muffle furnace. Firing is continued for two hours with a regulated air flow of $\frac{1}{10}$ cubic foot per minute (0.47 L/s) measured under laboratory conditions to assist in oxidation of the specimen. In cases where ignition occurs immediately, application of air is delayed until initial flaming has stopped.

Step 3. The container with the specimen shall be cooled in a desiccator, after which the weight of the residue is determined.

Step 4. If the residue from the muffle-firing procedure is less than 5 percent of the initial weight of the specimen, Steps 5 through 7 following shall be omitted, and the heat of combustion previously determined under the direct bomb test shall be reported as the potential heat of the material.

Step 5. If the residue after the muffle firing is in excess of 5 percent of the original specimen weight, the residue shall be pulverized, mixed with an equal weight of benzoic acid and treated as specified in the procedure for direct bomb test. The resulting heat of combustion is reported as that of the residue.

Step 6. The heat of combustion of the residue is multiplied by the ratio of the residue weight to the original specimen weight.

Step 7. The resulting difference in the heats of combustion is a measure of the gross heat released during the firing process in the muffle furnace and is reported as the potential heat.

26.102.5 Reporting Potential Heat. The potential heat determined either as a result of Step 4 or 7 of Section 26.102.4 shall be reported as the potential heat of the material. The potential heat shall be reported in either Btu per pound (kJ/kg) or Btu per cubic foot (kJ/kg).
UNIFORM BUILDING CODE STANDARD 26-2
TEST METHOD FOR THE EVALUATION
OF THERMAL BARRIERS

Standard of the International Conference of Building Officials
See Sections 601.3 and 2602.4, Uniform Building Code

SECTION 26.201 — SCOPE
This method of test for thermal barriers is applicable to building construction assemblies which incorporate foamed plastics which are required to be covered by a protective membrane.

The purpose of the test is to evaluate the temperature use or thermal transmission performance of the thermal barrier when the assembly is subjected to a standard fire exposure condition. This method does not evaluate the performance of the thermal barrier material with respect to its ability to remain in place under all actual fire exposure conditions.

SECTION 26.202 — TEST SPECIMEN
The thermal barrier material and method of securing the thermal barrier shall be representative of the construction for which the thermal barrier index rating is required.

If the thermal barrier material incorporates joints, at least one such joint shall be incorporated in the test specimen.

SECTION 26.203 — SPECIMEN CONDITIONING
Prior to fire test, assemblies shall be conditioned so as to provide a moisture conditioning within the specimen approximately representative of that likely to exist in similar construction in buildings. For that purpose of standardization, this condition is to be considered as that which would be established at equilibrium resulting from conditioning in an ambient atmosphere of 50±5 percent relative humidity and 73.4°F. ± 5°F. (23°C. ± 3°C.)

SECTION 26.204 — TEST CONDITIONS
26.204.1 General. The dimensions of the furnace shall be as shown in Figure 26-2-1 entitled "Small-scale Horizontal Exposure Furnace."

The thermal barrier shall be installed in a manner representative of the construction for which the thermal barrier index rating is required. The specimen exposed to the fire shall have minimum horizontal dimensions of 28 inches by 28 inches (711 mm by 711 mm).

The calcium silicate board shall be installed as shown in Figure 26-2-2, shall have a thickness of 1/2 inch (13 mm) and a density of 46 pounds per cubic foot (736 kg/m³).

26.204.2 Furnace Temperature. The furnace temperature, as recorded by the thermocouples specified in Section 26.204.3, shall follow the standard time-temperature curve specified in U.B.C. Standard 7-1 for which the temperatures at 5, 10 and 15 minutes following the commencement of the test are as given in Table 26-2-A.

26.204.3 Accuracy of Furnace Control. The accuracy of the furnace control shall be such that the area under the time-temperature curve given by the average of the specified thermocouples shall be within 10 percent of the corresponding area under the standard time-temperature curve specified in Section 26.204.2.
26.204.4 Thermocouple Location. The furnace temperature shall be registered by three or more thermocouples located so as to monitor the uniformity of the exposure to the thermal barrier. They shall be located 12 inches (305 mm) away from the face of the specimen and shall have a length of lead exposed within the furnace of not less than 12 inches (305 mm). They shall be enclosed in sealed porcelain tubes $\frac{3}{4}$ inch (19 mm) in outside diameter and $\frac{1}{8}$ inch (3.2 mm) in wall thickness or, as an alternative in the case of base metal thermocouples, enclosed in sealed, standard-weight, $\frac{1}{2}$-inch (13 mm) black wrought-steel or black wrought-iron pipe.

The temperature of the interface of the thermal barrier and the calcium silicate board shall be sensed by at least nine thermocouples as shown in Figure 26-2-2 located at the center of the specimen, at the center of each quarter of the specimen and at potentially critical locations such as joints in the material. The leads to each thermocouple shall be in the plane of this interface for a length of not less than $1\frac{1}{2}$ inches (38 mm). The wires for the thermocouples shall not be heavier than No. 20 AWG (0.032 inch) (0.81 mm).

26.204.5 Furnace Pressures. Furnace pressures shall be kept as close to atmospheric pressure as possible during the test.

26.204.6 Duration of Test. The test shall be continued for 15 minutes or until the thermal barrier has fallen away or disintegrated.

26.204.7 Recording Temperatures. Throughout the period of test, the temperature registered at each of the thermocouples required by Section 26.204.4 shall be recorded at intervals not exceeding one minute.

SECTION 26.205 — DETERMINATION OF THERMAL BARRIER INDEX

The thermal barrier index shall be determined as the number of minutes at which the temperature rises above initial temperature at the interface of the thermal barrier and the calcium silicate board has not exceeded 250°F (121°C) average or 325°F (163°C) at any one of the thermocouples specified in Section 26.204.4.

<table>
<thead>
<tr>
<th>TABLE 26-2-A—FURNACE TEMPERATURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIME</td>
</tr>
<tr>
<td>5 minutes</td>
</tr>
<tr>
<td>10 minutes</td>
</tr>
<tr>
<td>15 minutes</td>
</tr>
</tbody>
</table>
FIGURE 26-2-1—SMALL-SCALE HORIZONTAL EXPOSURE FURNACE
SECTION A-A
• - THERMOCOUPLE

FIGURE 26-2-2—THERMOCOUPLE LOCATIONS
UNIFORM BUILDING CODE STANDARD 26-3
ROOM FIRE TEST STANDARD FOR INTERIOR OF FOAM PLASTIC SYSTEMS
Test Standard of the International Conference of Building Officials
See Sections 601.3 and 2602.6, Uniform Building Code

SECTION 26.301 — SCOPE

This standard details a test method to evaluate the burning characteristics of foam plastic assemblies in a standard room configuration. It is intended to be a test for use under Section 2602.6 of this code.

SECTION 26.302 — FIRE TEST STRUCTURE

The fire test structure shall consist of a room with interior dimensions of 8 feet ± 1 inch (2438 mm ± 25 mm) by 12 feet ± 1 inch (3658 mm ± 25 mm) having a ceiling height of 8 feet ± 0.5 inch (2438 mm ± 13 mm) located in an enclosed building. A doorway 2 feet 6 inches ± 0.5 inch (762 mm ± 13 mm) by 7 feet 0 inches ± 0.5 inch (2134 mm ± 13 mm) shall be centered in one of the 8-foot-long (2438 mm) walls of the test structure. See Figure 26-3-1.

The wall test area shall consist of wall sections 8 feet (2438 mm) square intersecting at the corner opposite the doorway. Ceiling specimens shall cover an area 8 feet (2438 mm) square with two edges resting on or adjoining the intersecting wall test sections. Vertical and horizontal joints shall be included in the test wall and ceiling specimens to represent field conditions.

Except for composite panels, the construction of the walls and ceiling beyond the test area which serve as a substrate for foam plastic shall consist of 1/2-inch (13 mm) glass-reinforced cement board or 1/2-inch (13 mm) gypsum wallboard supported by suitable framing.

Composite wall and ceiling or roof panels with structural foam plastic cores shall be installed without a substrate and in the manner intended for use, including connections along all joints and perimeters. Panels intended to support superimposed loads shall be fire tested with the panels loaded in a manner resulting in conditions of maximum allowable stress.

**EXCEPTION:** Testing under loaded conditions may be waived in Type V construction when the panels need not be fire resistive.

When the test concerns nonstructural protective material, the foam plastic base shall be applied to the maximum thickness anticipated and have a minimum flame-spread rating of 75.

Material and fabrication of test assemblies must be certified by the testing agency as complying with descriptions or details that are a part of the report of tests.

The building containing the test structure shall have a temperature between 60°F and 90°F (15.6°C and 32.2°C) at the start of the fire test and shall be free of excessive drafts.

SECTION 26.303 — TEST PROCEDURE

**26.303.1 Crib:** The fuel for the room test shall be a wood crib constructed of 1 1/2-inch (38 mm) square white fir, Douglas fir or spruce-pine fir fire sticks cut to 15-inch (381 mm) lengths. The equivalency of other types of wood shall be based on comparative full-scale tests. At a 12 percent moisture content, the crib shall weigh 30 pounds (13.6 kg) and be 15 inches (381 mm) square in plan. One 8d nail shall be driven at each corner of each tier. Each interior stick shall be attached at each end to a perimeter stick with one 8d nail. Approximately 45 to 50 sticks will be involved and must be assembled in nine or 10 tiers with five sticks in each tier. The placement of sticks in each tier
shall be oriented at 90 degrees to sticks in adjacent tiers. After fabrication the crib shall be conditioned to a maximum constant moisture content of 8 percent. Standard bricks cut in half and placed at each corner of the crib shall be used to support the crib not less than 3 inches (76 mm) above the floor located as described in Section 26.303.3 below.

26.303.2 Starter Material. One pound of shredded, fluffed wood excelsior is distributed around the bricks with the excelsior extending from the wall surfaces and covering an area approximately 21 inches by 21 inches (533 mm by 533 mm). To start the test, the wood excelsior is soaked with 4 ounces (0.12 L) of reagent ethyl alcohol or absolute ethyl alcohol, except for a triangular area approximately 6 inches by 6 inches (153 mm by 153 mm) diametrically opposite the intersection of the walls. The crib is then located 1 inch (25 mm) from the intersecting wall surfaces on the bricks.

26.303.3 Ignition. A match is placed in the excelsior to initiate burning. Under proper conditions for ignition, flames typically progress slowly through the dry excelsior for only 10 seconds until the soaked alcohol portion is reached, whereupon flames flash through the entire excelsior, providing uniform application of the ignition flame beneath the entire crib.

26.303.4 Extinguishment. Fire extinguishment is permitted 15 minutes after crib ignition. Charring of the test panels must not be affected by the extinguishing procedures.

26.303.5 Temperature Readings. Temperature readings at locations shown in Figure 26-3-2 shall be taken at maximum two-minute intervals and at 15 minutes from crib ignition with properly calibrated thermocouples of the type described in U.B.C. Standard 7-1.

26.303.6 Smoke Measurement. Smoke generated during the 15-minute test period shall be measured by photoelectric instrumentation if there is sufficient available data to establish a basis of acceptance. In lieu of this, the test report shall include films taken during the test.

SECTION 26.304 — CONDITIONS OF ACCEPTANCE

A foam plastic wall or ceiling assembly shall be considered as meeting the requirements for acceptable performance within the following conditions:

1. Charring of the foam plastic shall not extend to the outer extremities of the test area within a 15-minute period after ignition of the excelsior. Discoloration extending not more than 1/4 inch (6 mm) into the foam plastic shall not be considered as charring.

2. Smoke levels generated during the test period shall not be excessive.

3. Structural panels shall sustain the applied load during the test period.

SECTION 26.305 — REPORT OF TEST

The report of test shall include the following:

1. A detailed description of the foam plastic assembly including specifications on all components and manner of fabrication and installation.

2. A statement by the testing agency that preparation, fabrication and installation of the foam plastic assembly was in accordance with Item 1 and this standard.

3. A statement of compliance or specific points of deviation from test procedures set forth in this standard.

4. An account of visual observation of the foam plastic assemblies during the test.

5. Location and extent of charring in the foam plastic assemblies at the conclusion of the test.

6. Temperature readings during the test as set forth in Section 26.303.5.

7. Smoke measurement during the test or films of the test.
Ignition Source:
30-Pound (13.6 kg) Wood Crib

Blank Panels

Door: 2'-6" (762 mm) Wide by 7'-0" (2134 mm) High

FIGURE 26-3-1—ROOM TEST CONFIGURATION
NOTES:
1. Thermocouples 1, 2 and 3 located 3 inches (76 mm) from adjacent wall surfaces.
2. Thermocouple 4 located 1 inch (25 mm) below the ceiling, 4 feet (1219 mm) from each of three walls.

FIGURE 26-3-2—THERMOCOUPLE LOCATIONS
UNIFORM BUILDING CODE STANDARD 26-4

METHOD OF TEST FOR THE EVALUATION OF FLAMMABILITY
CHARACTERISTICS OF EXTERIOR, NONLOAD-BEARING WALL
panel assemblies using foam plastic insulation

Test Standard of the International Conference of Building Officials
See Sections 601.3 and 2602.5.2, Uniform Building Code

SECTION 26.401 — SCOPE

This test provides a method of determining the flammability characteristics of foam plastic insulated, exterior, nonload-bearing wall panel assemblies. The test structure is intended to simulate a "full-scale" multistory building installation. Test assemblies are evaluated on a "full-scale" basis.

The primary performance characteristics to be evaluated are:
1. Capability of the test panels to resist vertical spread of flame within the core of the panel from one story to the next;
2. Capability to resist flame propagation over the exterior face of the panels;
3. Capability to resist vertical spread of flame over the interior (room side) surface of the panels from one story to the next; and
4. Capability to resist lateral spread of flame from the compartment of fire origin to adjacent spaces.

SECTION 26.402 — FIRE TEST STRUCTURE

The fire test structure shall consist of a two-story, 24-foot-high (7315 mm) building having unfinished/unprotected inside room dimensions of (edge of slab to concrete block) 15 feet ± 2 inches (4572 mm ± 51 mm) wide by 15 feet ± 2 inches (4572 mm ± 51 mm) deep. See Figure 26-4-1. Floor-to-floor height (unfinished/unprotected) shall be 12 feet ± 2 inches (3658 mm ± 51 mm). Floors and roof shall be of reinforced concrete or similar construction supported with columns. The first-floor slab shall be 12 inches ± 1 inch (305 mm ± 25 mm) thick, whereas the second floor and roof shall be 8 inches ± 0.5 inch (203 mm ± 13 mm) thick. Permanent walls of the structure shall be of 8-inch-thick (200 mm) concrete block or similar construction. The concrete block shall completely close two walls of the test structure, except for a 3-foot, 4-inch ± 3 inches (1016 mm ± 76 mm) wide by 6-foot 8-inch ± 3 inches (2032 mm ± 76 mm) high access opening at the first- and second-floor levels. Additional access openings in the second-floor area are permitted, but must be closed off prior to test.

Spandrel beams on the underside of the second floor shall be designed to be replaceable and are required only when the mounting of the test sample requires them to be present. When used, the spandrel beams shall be of W10 by 12 (W250 by 18) and shall be installed as shown in Figure 26-4-1.

Test panels shall be secured to the test structure using a girt system of replaceable 4-inch by 4-inch by 1/16-inch (102 mm by 102 mm by 4.8 mm) steel angles. The test panels shall completely close the two walls of the test structure, except for a window opening in one of the test walls. One of the test walls shall be fabricated with a 4-foot ± 0.5 inch (1219 mm ± 13 mm) high by 8-foot ± 0.5 inch (2438 ± 13 mm) long window opening in the first story. The window opening shall have a sill height of 3-feet ± 1 inch (914 mm ± 25 mm). The window opening shall be the only opening in the first-story burn room enclosure at the time of test.

Test panels shall be secured to the test structure using a method of fastening including all joints and perimeters to represent actual field conditions. Details of erection shall follow the manufacturer-
er's instructions and shall be typical of actual product use. When a product may have vertical or horizontal joints, joints typical of normal construction, including caulking, backing and other details as appropriate, shall be incorporated in the test panels.

Prior to the start of a test, the access opening in the burn room shall be closed using an assembly having a minimum of three layers of 5/8-inch-thick (15.9 mm) Type X gypsum wallboard on the burn room side of any supports. The access door opening in the second story may remain open during testing, but any additional access openings shall be closed.

In the first-floor burn room prior to each test, the two concrete block walls and the ceiling are to be protected with three layers of 5/8-inch (15.9 mm) Type X gypsum wallboard. A framing/attachment system may be used between the concrete block/Type X gypsum wallboard and the concrete ceiling/Type X gypsum wallboard with the provision that the framing/attachment system not be thicker than 1.5 inches (38 mm). The floor is protected with at least one layer of 5/8-inch (15.9 mm) Type X gypsum wallboard. The column located within the burn room shall be protected with appropriate fireproofing and boxed in with a single layer of 5/8-inch (15.9 mm) Type X gypsum wallboard. Spandrel beams if used may or may not be protected at the discretion of the testing laboratory or client. The outriggers and the girt angles are not protected.

In the second story, prior to each test, the concrete block walls and ceiling are protected by one layer of Marinite board or 5/8-inch (15.9 mm) Type X gypsum wallboard. The floor is protected by one layer of 5/8-inch-thick (15.9 mm) Type X gypsum wallboard. The interior steel column shall be appropriately protected and boxed with one layer of 5/8-inch (15.9 mm), Type X gypsum wallboard. Girt angles are left unprotected.

Material and fabrication of test assemblies must be certified by the testing agency as complying with the description or details that are a part of the report of test. The test laboratory shall retain a 1-foot-by-1-foot-square (305 mm by 305 mm) sample of the test system.

For outdoor facilities a windshield shall be utilized (see Figure 26-4-2) to minimize wind action across the face of the test structure.

SECTION 26.403 — INSTRUMENTATION AND DOCUMENTATION

26.403.1 Instrumentation. In this procedure, test instrumentation consists primarily of temperature measurements placed in the following locations:

1. Inside room of fire origin—underside of second-story floor and underside of structural steel members.
2. Window opening—6 inches (153 mm) below top of window opening.
3. On exterior face of wall panels.
4. On interior face of wall panels—at floors and in panel cores at second-floor level and above.

Temperature measurements are made using 20-gage Type K thermocouples. Specific thermocouple locations are provided in Figures 26-4-3 through 26-4-7. Temperatures shall be recorded at intervals not to exceed 15 seconds.

26.403.2 Documentation. Documentation of tests is provided by:

1. Color videotape of exterior, and
2. Color 35 mm slides of exterior.

In order to facilitate documentation of flame penetration (if any) into the second-floor level, a video camera is placed looking inside the second floor. The camera is aimed at the test wall/floor intersection and observations relating to flame penetration and/or smoke development are made.

After the test is terminated by extinguishment of the fire in the wood crib, special note shall be made of the extent and duration of any residual burning in the test panel.
After a cool-down period, the interior and exterior sides of the test walls shall be described as to visual appearance and shall be photographed. The test walls shall then be dismantled and dissected to determine height and depth of char damage within the cavity and condition of panel facings.

SECTION 26.404 — TEST PROCEDURE

26.404.1 Crib Fire Exposure. The burn room shall be provided with a 1,285-pound (583 kg) wood crib fuel load which, when burned, produces the standard time/temperature curve described in Sections 7.102 and 7.103 of U.B.C. Standard 7-1 as measured using the average of thermocouples (see Figure 26-4-3) inside the burn room for a period of not less than 30 minutes. The crib shall generate a fire exposure producing an intermittent flame plume similar to that generated in an actual fire discharging out of the burn room window. During the test the plume shall periodically attach itself to and shall expose the face of the test panel for a minimum of 5 feet (1524 mm) above the top of the burn room window. Makeup air for combustion of the crib shall be supplied solely through the 4-foot by 8-foot (1219 mm by 2438 mm) window opening. No other ventilation is provided. Control temperatures are measured at the underside of the second floor and at the underside of the spandrel beams if used.

The fuel for the fire exposure shall be a 1,285-pound (583 kg) wood crib. The crib shall be constructed of dried 2-inch by 4-inch (51 by 102 mm) No. 1 select grade Douglas fir members having a moisture content of 11 percent plus or minus 1 percent. Crib members are cut into 4-foot and 8-foot (1219 and 2438 mm) lengths. The 2-inch by 4-inch (51 by 102 mm) members shall be nailed into a lattice-type crib consisting of full tiers and one partial tier of three 8-foot (2438 mm) 2 by 4s (51 mm by 102 mm). Overall crib dimensions shall be 48 inches deep (1219 mm), 96 inches (2438 mm) wide and 28 1/2 (724 mm) inches high. See Figure 26-4-8. The determining factor in the crib construction shall be the weight; however, in no case shall less than 18 tiers be used.

The crib shall be centered on the burn room window but located off center toward the window. See Figure 26-4-9.

The crib shall be supported above floor level by 8-inch concrete blocks. A layer of 5/8-inch-thick (15.9 mm) Type X gypsum wallboard is placed between the crib and the concrete block support. See Figure 26-4-10.

26.404.2 Starter Material. Prior to ignition, one gallon (3.8 L) of kerosene is equally divided into eight pans (7 1/4 inches in diameter, 15/16 inch deep) (184 mm in diameter, 24 mm deep) and the pans are interconnected using kerosene-soaked rags that have been soaked sufficiently to facilitate ignition. Additionally, two pints (1 L) of kerosene are poured over the crib just prior to ignition. The kerosene is to provide quick ignition of the crib and also cause an initial rapid increase in temperature within the burn room.

26.404.3 Ignition. After proper operation of all instrumentation and documentation equipment is verified, the pans containing kerosene are placed under the crib.

A match or torch is used to ignite a kerosene-soaked rag which, in turn, causes flames to spread to the kerosene in the eight pans located under the crib. The start of the test is ignition of the kerosene in one of the pans. The fire develops quickly with flames reaching the ceiling of the burn room within several minutes. Flames begin to emerge from the burn room window in three to five minutes.

26.404.4 Control. During the last several minutes of the test, the crib fire may produce higher temperatures than those described in U.B.C. Standard 7-1. Should the average temperature in the burn room as measured by the thermocouples described in Figure 26-4-3 exceed 1,800°F (982°C.) for a period greater than one minute, then a control measure may be used at the discretion of the testing laboratory or the client to maintain the temperatures within the room in accordance with Section 26.404.1. One example of a control measure is the use of water fog such that approximately one gallon (3.8 L) of water is applied directly to the wood crib.

26.404.5 Duration. The test is continued for 30 minutes. At the conclusion of the test, the crib fire is extinguished using a hose line. Any residual burning in or on the surface of the test panels shall be
noted and panels shall be allowed to burn freely until self-extinguishment occurs or fire spreads to
the limits of the test panels.

**26.404.6 Weather Conditions.** Outdoor tests shall not be conducted if, at the start of the test, the
average wind velocity exceeds 10 miles per hour (16 km/h), if the relative humidity is 100 percent
or if there is fog or precipitation present at the test site.

**SECTION 26.405 — CONDITIONS OF ACCEPTANCE**

The performance of a test assembly shall be judged on the basis of visual observations both during
and after the test in conjunction with temperature data. An exterior wall assembly shall be consid­
ered as meeting the requirements for acceptable performance if during the 30-minute test period:

1. Flames do not propagate over the surface of the test walls beyond the immediate area of crib
flame impingement on the exterior face of the wall panels.

2. Flame propagation does not occur vertically or laterally through the core insulation. Flame
propagation may be judged to occur within the test panels when temperatures within the insulation
core as measured by thermocouples 28, 29, 30, 42, 18, 46, 56, 55, 54, 38, 20, 53, 73, 65, 74, 66, 78
and 64 as shown in Figures 26-4-4 and 26-4-5, exceed 750°F. (400°C.) above ambient.

3. Flame propagation shall not occur to the first-floor wall panels extending beyond the concrete
block walls of the test fixture either through core insulation or over the exterior or interior panel
surfaces. Where the flame cannot be directly observed, flame propagation shall be assumed to occur
where the temperatures as measured by thermocouples 58, 57, 79 and 80 within the insulation core
exceed 750°F. (400°C.) above ambient.

4. Temperatures measured 1 inch (25 mm) from the interior surfaces of the wall assembly within
the second story do not exceed 350°F. (180°C.) above ambient.

5. Flames do not enter the second-story room.

**SECTION 26.406 — REPORT OF TEST**

The report of test shall contain the following:

1. Description of test wall assembly to include:
   1.1 Drawings showing structural design, plan, elevation, principal cross section plus other
sections as needed for clarity and joint locations and details.
   1.2 Details of attachment of walls to test facility.
   1.3 Flame-spread and smoke-developed values of foam plastic per U.B.C. Standard 8-1.
   1.4 Ignition temperature of foam plastic.
2. Location of thermocouples.
3. General ambient condition at test time.
4. Temperature data obtained during the test for all thermocouple locations.
5. Visual observations made during the test.
6. Photographs of the following:
   6.1 Test walls prior to test.
   6.2 Test in progress.
   6.3 Test walls exterior—post test.
   6.4 Test walls interior—post test.
   6.5 Core insulation of both walls—post test.
7. Performance of wall system with respect to:
   7.1 Damage to the walls and core.
   7.2 Flame advance over exterior faces.
   7.3 Flame advance over interior faces.
   7.4 Flame penetration into second floor.
   7.5 Smoke accumulation inside the second-story room.
   7.6 Extent of residual burning.

FIRST/SECOND FLOOR PLAN

FIGURE 26-4-1A
1.01 SECTION DETAIL

FIGURE 26-4-1C
1.02 SECTION DETAIL

FIGURE 26-4-1D
FIGURE 26-4-2—TEST ARRANGEMENT
THERMOCOUPLES 1 AND 5 ARE 6\" (153 mm) BELOW CEILING
THERMOCOUPLES 2, 3 AND 4 ARE 2\" (51 mm) BELOW SPANDREL BEAM
AND CENTERED BETWEEN WALL AND BEAM
THERMOCOUPLES 6 AND 7 AND 1\" (25 mm) BELOW BOTTOM SURFACE
OF SPANDREL BEAM

NOTE: If no spandrel beam is used, then thermocouples 2, 3, 4, 6 and 7
are to be 6 inches (153 mm) below ceiling.

FIGURE 26-4-3
NOTES: • Thermocouples placed 1" (25 mm) from wall surfaces except Nos. 8, 9, 10
○ Thermocouples placed 1" (25 mm) into core of panel or into core material beyond external coating surface.

FIGURE 26-4-4
NOTES: • Thermocouples placed 1" (25 mm) from wall surfaces.
○ Thermocouples placed 1" (25 mm) into core of panel

FIGURE 26-4-5
NOTES:  

- Thermocouples placed 1" (25 mm) from wall surfaces
- Thermocouples placed in sating material—center of floor level

FIGURE 26-4-6
NOTES: • Thermocouples placed 1" (25 mm) from wall surfaces
○ Thermocouples placed in sating material—center of floor level

FIGURE 26-4-7

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FIGURE 26-4-8—CRIB CONSTRUCTION

NOTES

Wood—Dried Douglas fir
Sticks—2 x 4 inches (51 x 102 mm) (11/2 x 31/2) 38 x 89 mm
Tiers—Longitudinal: 7 at 8 feet (2438 mm) per each tier
Transverse: 14 at 4 feet (1219 mm) per each tier
Weight—Total crib weight to be 1285 pounds (583 kg)
Nailing—One 8-penny nail per connection

FIGURE 26-4-9—PLACEMENT OF CRIB IN ROOM
FIGURE 26-4-10—CRIB ARRANGEMENT
UNIFORM BUILDING CODE STANDARD 26-5
CHAMBER METHOD OF TEST FOR MEASURING THE DENSITY OF SMOKE FROM THE BURNING OR DECOMPOSITION OF PLASTIC MATERIALS


See Sections 217 and 2603.1.6, Uniform Building Code; and Section 212, Uniform Sign Code

SECTION 26.501 — SCOPE
This test method covers a procedure for measuring and observing the relative amounts of smoke produced by the burning or decomposition of plastics. It is intended to be used for measuring the smoke-producing characteristics of plastics under controlled conditions of combustion or decomposition. The measurements are made in terms of the loss of light transmission through a collected volume of smoke produced under controlled, standardized conditions. The apparatus is constructed so that the flame and smoke can be observed during the test.

SECTION 26.502 — SUMMARY OF METHOD
A 1-inch by 1-inch (25 mm by 25 mm) specimen of the thickness intended for use is placed on a supporting metal screen and is burned in a laboratory test chamber (see Figure 26-5-1) under active flame conditions using a propane burner operating at a pressure of 40 psi (276 kPa). The 12-inch by 12-inch by 31-inch (300 mm by 300 mm by 791 mm) test chamber is instrumented with a light source, a photoelectric cell, and a meter to measure light absorption horizontally across the 12-inch (300 mm) light beam path. The chamber is closed during the four-minute test period except for the 1-inch-high (25 mm) ventilation openings around the bottom.

The light absorption data are plotted versus time. A typical plot is shown in Figure 26-5-2.

SECTION 26.503 — SIGNIFICANCE
This test method is designed to permit the measurement of smoke generation and its visibility-obscuring effects (density). Results of tests made on a plastic material under conditions herein prescribed can be used to evaluate the smoke-production characteristics by determining the smoke density rating of the material. The smoke density rating shall represent the total amount of smoke present in the chamber for the four-minute time interval. It is the area under the curve of light absorption versus time divided by the total area of the graph times 100.

The visual and instrumental observations from this test compare well with the visual observations of the smoke generated by plastic materials when added to a freely burning, large outdoor fire (burning conditions that are favorable to minimum smoke production). Hence, this method serves as a reliable method of identifying materials which could be expected to smoke excessively under almost all conditions of burning and decomposition.

The basic assumption underlying this procedure is that the hazard associated with smoke in human occupancies will be significant only if a material is burning or decomposing in the presence of flame. Therefore, the test specimen is exposed to flame for the duration of the test, and the smoke is substantially trapped in the chamber in which combustion occurs. The usefulness of this test procedure is in its ability to measure the amount of smoke produced, which is done in a simple, direct and meaningful manner.
SECTION 26.504 — APPARATUS

26.504.1 Chamber. The chamber shall consist of a 0.064 inch (1.63 mm) (No. 14 B.&S. gage) 12-inch by 12-inch by 31-inch (300 mm by 300 mm by 790 mm) aluminum box to which is hinged a heat-resistant glazed glass door. This box shall be mounted on a 14-inch by 16-inch by 2\( \frac{1}{4} \) inch (350 mm by 400 mm by 57 mm) base which houses the controls. Depending on the materials tested, the metal may require protection from corrosion.

The chamber shall be sealed except for 1-inch by 9-inch (25.4 mm by 229 mm) openings on the four sides of the bottom of the chamber. A 60 cfm (1700 L/min.) blower shall be mounted on one side of the chamber. The inlet duct to the blower shall be equipped with a close-fitting damper. The outlet of the blower shall be connected through a duct to the laboratory exhaust system.

The two sides adjacent to the door shall be fitted with 2\( \frac{3}{4} \)-inch-diameter (70 mm) smoketight glazed areas centered 19\( \frac{3}{4} \) inches (502 mm) above the base. Boxes containing the optical equipment and additional controls shall be attached at these locations and outside the chamber.

A removable white plastic plate shall be attached to the back of the chamber. There shall be a 3\( \frac{1}{2} \)-inch by 6-inch (90 mm by 150 mm) clear area centered about 19\( \frac{3}{4} \) inches (502 mm) above the bottom of the chamber through which is seen an illuminated white-on-red exit sign. The white background permits observation of the flame, smoke and burning characteristics of the material. The viewing of the exit sign helps to correlate visibility and measured values.

26.504.2 Specimen Holder. The specimen shall be supported on a 2\( \frac{1}{2} \) inch by \( \frac{1}{8} \) inch (64 mm by 6 mm), 0.035-inch-gage (0.9 mm) stainless steel wire cloth 8 inches (203.2 mm) above the base and equidistant from all sides of the chamber. This screen shall lie in stainless steel bezel supported by a rod through the right side of the chamber. From the same rod, a similar bezel shall be located 3 inches (76 mm) below and it shall support a square of asbestos paper which catches any particles that may drip from the specimen during the test. By rotating the specimen holder rod, the burning specimen can be quenched in a shallow pan of water positioned below the specimen holder.

26.504.3 Ignition System. The specimen shall be ignited by a propane flame from a burner operating at a pressure of 40 psi (276 kPa). The fuel shall be mixed with air which has been propelled through the burner by the venturi effect of the propane [commercial grade 85.0 percent minimum, gross heating value 2,590 Btu per cubic foot (23 000 cal/L) propane meets the requirements] as it passes from a 0.006-inch-diameter (0.152 mm) orifice. The burner shall be assembled as shown in the exploded view of the burner in Figure 26-5-3. The burner must be designed to provide adequate outside air. Since the orifice provides the metering effect proportionate to the supply pressure, care must be taken that the orifice is the only means of fuel egress.

The burner shall be capable of being quickly positioned under the specimen so that the axis of the burner falls on a line passing through a point 3\( \frac{1}{10} \) inch (8 mm) above the base at one back corner of the chamber, extending diagonally across the chamber and sloping upward at an angle of 45 degrees with the base. The exit opening of the burner shall be 10\( \frac{7}{12} \) inches (259.56 mm) from the reference point at the rear of the chamber.

A duct at least 6 inches (150 mm) outside of the chamber shall provide the air piped to the burner.

Propane pressure shall be adjustable and preferably automatically regulated. Propane pressure shall be indicated by means of a Bourdon tube gage.

26.504.4 Photometric System. A light source, a barrier-layer photoelectric cell and a temperature-compensated meter shall be used to measure the proportion of a light beam which penetrates a 12-inch (300 mm) path through the smoke. The light path shall be arranged horizontally as shown in Figure 26-5-4.

A light source shall be mounted in a box (4 B1 in Figure 26-5-1) extending from the left side of the chamber at the mean height of 19\( \frac{3}{4} \) inches (502 mm) inches above the base. The light source shall be a
compact filament microscope lamp No. 1493 operated at 5.8 volts and a spherical reflector, with power supplied by a voltage-regulating transformer. (Microscope lamps No. 1493 are manufactured by General Electric Company, Westinghouse and others.) A 2\(\frac{1}{2}\) -inch (63.5 mm) focal length lens shall focus a spot of light on the photocell in the right-hand instrument panel.

Another box containing the photometer (4 B2 in Figure 26-5-1) shall be attached to the right-hand side of the chamber. The barrier-layer photoelectric cell shall have standard observer spectral response. An egg-crate grid in front of the photocell shall be used to protect the cell from stray light. The grid shall be finished in dull black and have openings at least twice as deep as they are wide. The current produced by the photocell is indicated in terms of percent light absorption on a meter. The photocell linearity decreases as the temperature increases; compensations shall therefore be made.

The meter may have two ranges. The range change shall be accomplished by shunting the meter to one-tenth its sensitivity. When enough smoke accumulates to absorb 90 percent of the light beam, a momentary switch shall be depressed returning the meter to its basic sensitivity. By doing this, the meter scale now reads 90 to 100 percent instead of 0 to 100 percent.

**26.504.5 Timing Device.** A clock to indicate 15-second intervals shall be used. If the time intervals are audible, it will be convenient for the operator to record observations.

**26.504.6 Planimeter.** A planimeter or other suitable means shall be used for measuring the area under the light absorption curve.

**SECTION 26.505 — TEST SPECIMENS**

The specimen shall be 1 inch by 1 inch (25.4 mm by 25.4 mm) by the thickness intended for use. Thicknesses other than those intended for use may be tested, and the thickness should be reported with the smoke density values.

The specimens shall be sanded, machined or die cut in a manner that produces a cut surface that is free from projecting fibers, chips and ridges.

The test sample shall consist of three specimens.

**SECTION 26.506 — CONDITIONING**

Specimens shall be preconditioned and tested in accordance with Procedure A of the ASTM Method D618-61 for Method of Conditioning Plastics and Electrical Insulating Materials for Testing, unless otherwise specified.

Tests shall be conducted in a hood which has a window for observing the test.

**SECTION 26.507 — PROCEDURE**

Turn on photometer lamp, exit sign, and exhaust blower.

Turn on propane, ignite burner and adjust the propane pressure to 40 psi (276 kPa). Caution: Do not fail to light burner immediately.

Set temperature compensation.

Adjust lamp control to zero percent light absorption.

Lay the test specimen flat on the screen in such a position that the burner flame will be directly under the specimen when the burner is swung into position.

Set the timer to zero.

Shut off the exhaust blower, close the smoke chamber door, and immediately position the burner under the specimen and start the timer.
Close the hood door to within 2 inches (50 mm) of the bottom of the hood.

Record the percent light absorbed at 15-second intervals for four minutes.

Record observations during the conduct of the test. Include the time it takes for the sample to burst into flame, time for flame extinguishment or specimen consumption, obscuration of the exit sign by smoke accumulation and any general or usual burning characteristics noted, such as melting, dripping, foaming or charring.

Upon completion of the test, turn on exhaust blower to ventilate the combustion products from the chamber. (It should be noted that for some materials the product of burning may be toxic, and care should be taken to guard the operator from the effects of these gases. The ventilating fan in the hood should be turned on and the damper opened immediately after the test is completed and before opening the hood door in order to remove any irritating products of the test. The exhaust fan is turned off and the hood damper closed during the test to prevent backdraft.)

Open the door and clean the combustion deposits from the photometer, exit sign and door glass with detergent and water. Burn off any material remaining on the screen or replace the screen and asbestos square for the next test.

Run all tests in triplicate.

SECTION 26.508 — OPTIONAL PROCEDURES

The output of the photocell may be recorded versus time on an appropriate graphic recorder.

With a suitably sensitive meter, more than one decade change may be used to separate readings in the very dense smoke range.

SECTION 26.509 — TREATMENT OF DATA

The readings of 15-second intervals of light absorption for the three specimens per group shall be averaged. The average light absorption shall be plotted against time on linear paper. Figure 26-5-2 is a sample curve.

The total smoke produced shall be determined by measuring the area under the curve. The smoke density rating shall represent the total amount of smoke present in the chamber for the four-minute time interval. It is the area under the curve of light absorption versus time, divided by the total area of the graph times 100.

SECTION 26.510 — REPORT

The report shall include the following:

Identification of the material.

Thickness of the specimen.

Readings of light absorption at 15-second intervals for each test and average.

Plots of average light absorption versus time.

Area in percent under the light absorption-time curve (smoke density rating).

Observations on behavior of material.

Observations on obscuration of exit sign.

The details of any departure from the specifications of the method of testing.

EXAMPLE: In the light absorption-time plot in Figure 26-5-2, the plot has been made using 1 inch (25.4 mm) equal to 30 percent as the ordinate and 1 inch (25.4 mm) equal to 0.75 minute as the abscissa. The graph area for four minutes is found to be 17.78 square inches (11 470.94 mm²). The
Area under the curve is found to be 14.02 square inches (9045.14 mm$^2$). The smoke density rating is then computed as follows:

\[
\text{Smoke Density Rating} = \frac{14.02}{17.78} \times 100
\]

in percent = 78.8

For SI:

\[
\text{Smoke Density Rating} = \frac{9045.14}{470.94} \times 100
\]

in percent = 78.8

---

**FIGURE 26-5-1—SCHEMATIC DIAGRAM OF SMOKE CHAMBER**

1. Specimen Holder
   A. Stainless Steel Screen
   B. Asbestos Sheet
   C. Adjusting Knob
   D. Quench Pan
2. Ignition
   A. Burner
   B. Propane Tank
   C. Gas Shut-off Valve
   D. Pressure Regulator Adjustment
   E. Pressure Indicator
   F. Burner Positioning Knob
3. Cabinet (Shown without door)
   A. Hinges (Door gasketed three sides)
   B. Vents [1-inch (25.4 mm) high opening four sides]
   C. Blower (Damper on mounting side)
   D. Control (Blower on when damper is open)
4. Photometer
   A. Visual System (Exit sign)
   B. Measuring System
   1. Light Source and Adjusting Transformer
   2. Photronic Cell and Grid (To block stray light)
   3. Meter (Indicating percent to light absorbed)
   4. Temperature Compensation
   5. Photocell Temperature Monitor
   6. Range Change
5. Timer
   A. Indicator, 0 to 5 minutes (Friction reset)
FIGURE 26-5-2—LIGHT ABSORPTION VERSUS TIME

FIGURE 26-5-3—EXPLODED VIEW OF THE BURNER
At 5.3 to 6.3 Volts
21/2 inch (65 mm)
F.L. Lens
Spherical Reflector
1493 Lamp

Glass Smoke Seals

Chamber Walls

Egg-Crate Grid
(Cellular Light Shield)

Thermometer
to follow photocell
temperature through
aluminum bracket and
cell

Range Change
(Momentary Sw.)
N. C.

Photocell

12" (305 mm)

T = Temperature sensitive winding in or on meter case to increase
in resistance in proportion to increase in meter resistance with
temperature.

R = Potentiometer with calibrated scale to reduce resistance in
proportion to decrease in photocell output with rise in tempera­
ture.

C = Potentiometer to calibrate total resistance of shunt to change
meter sensitivity exactly by 10:1 ratio.

FIGURE 26-5-4—SMOKE DENSITY TEST CHAMBER PHOTOMETER
UNIFORM BUILDING CODE STANDARD 26-6
IGNITION PROPERTIES OF PLASTICS


See Sections 217, 2602.6 and 2603.8.1, Item 1, Uniform Building Code; and Section 212, Uniform Sign Code

SECTION 26.601 — SCOPE

This method of test covers a laboratory procedure for determining the self-ignition and flash-ignition temperatures of plastics using a hot-air ignition furnace.

SECTION 26.602 — SIGNIFICANCE

Tests made under conditions herein prescribed can be of considerable value in comparing the relative ignition characteristics of different materials. Values obtained represent the lowest ambient air temperature that will cause ignition of the material under the conditions of this test. Test values are expected to rank materials according to ignition susceptibility under actual use conditions.

This test is not intended to be the sole criterion for fire hazard. In addition to ignition temperatures, fire hazard includes such other factors as burning rate or flame spread, intensity of burning, fuel contribution, products of combustion and others.

SECTION 26.603 — DEFINITIONS

FLASH-IGNITION TEMPERATURE is the lowest initial temperature of air passing around the specimen at which a sufficient amount of combustible gas is evolved to be ignited by a small external pilot flame.

SELF-IGNITION TEMPERATURE is the lowest initial temperature of air passing around the specimen at which, in the absence of an ignition source, the self-heating properties of the specimen lead to ignition or ignition occurs of itself as indicated by an explosion flame or sustained glow.

SELF-IGNITION BY TEMPORARY GLOW. In some cases slow decomposition and carbonization of the plastic result only in glow of short duration at various points in the specimen without general ignition actually taking place. This is a special case of self-ignition temperature defined as "self-ignition by temporary glow."

SECTION 26.604 — APPARATUS

The apparatus shall be a hot-air ignition furnace as shown in Figure 26-6-1 and shall consist primarily of the following parts:

26.604.1 Furnace Tube. A vertical tube with an inside diameter of 4 inches (102 mm) and a length of 8 1/2 inches to 10 inches (216 mm to 254 mm) made of a ceramic that will withstand 1382°F. (750°C.) and with an opening at the bottom fitted with a plug for the removal of accumulated residue.

26.604.2 Inner Ceramic Tube. A ceramic tube with inside diameter of 3 inches (76 mm), length of 8 1/2 inches to 10 inches (216 mm to 254 mm) and thickness of about 0.125 inch (76 mm) placed inside the furnace tube and positioned 3 3/4 (19 mm) inch above the furnace floor on three small
26.604.3 **Air Source.** An outside air source to admit clean air tangentially near the top of the annular space between the ceramic tubes through a copper tube at a steady and controllable rate. Air shall be heated and circulated in the space between the two tubes and enter the inner furnace tube at the bottom. Air shall be metered by a rotameter or other suitable device; refer to air calibration curves (Figure 26-6-2) for proper furnace air velocities.

26.604.4 **Heating Unit.** An electrical heating unit made of 50 turns of No. 16 B.&S. (1.3 mm) wire. (Nichrome V alloy wire.) The wires, contained within an asbestos sleeve, shall be wound around the furnace tube and shall be embedded in cement.

26.604.5 **Insulation.** Consisting of a layer of asbestos wool approximately 2 1/2 inches (64 mm) thick and covered by a sheet iron jacket.

26.604.6 **Pilot Flame.** Consisting of 1/16-inch (1.6 mm) diameter copper tubing attached to a gas supply and placed horizontally 1/4 inch (6.4 mm) above the top surface of the divided disk. The pilot flame shall be adjusted to 3/4 inch (19 mm) in length and centered above the opening in the disk.

26.604.7 **Specimen Support and Holder.** A convenient specimen holder, measuring 1 1/2 inches (38 mm) in diameter by 1/2 inch (13 mm) in depth, is a 1/2-ounce (14.2 g) metal container of approximately 5-mil (0.13 mm) thick steel. One-half of the container shall be used as a specimen holder and
shall be held in a ring of \( \frac{1}{16} \)-inch (1.6 mm) stainless steel welding rod. The ring shall be welded to a length of the same type rod extending through the cover of the furnace as shown in Figure 26-6-1. The specimen holder shall be located 7 inches to \( 7\frac{1}{2} \) inches (178 mm to 191 mm) down from the top of the furnace.

**NOTE:**

CURVES REPRESENT AIR TEMPERATURE IN INNER FURNACE TUBE AT THERMOCOUPLE \( T_1 \). AIR VELOCITY IS THROUGH UNRESTRICTED SECTION OF INNER FURNACE TUBE.

**FIGURE 26-6-2—AIR CALIBRATION CURVES FOR HOT-AIR IGNITION FURNACE**

**26.604.8 Thermocouples.** Chromel-alumel or iron-constantan \( 0.020 \)-inch (0.51 mm) thermocouples for temperature measurement. These shall be conveniently connected to a multipoint recorder and each thermocouple temperature shall be recorded at least every 15 seconds. Thermocouple No. 1 \((T_1)\) measures the temperature of the specimen. It should be located as near the center of the specimen as possible when the specimen is in place in the furnace. Thermocouple No. 2 \((T_2)\) measures the temperature of the air traveling past the specimen. It shall be located slightly below and to the side of the specimen holder. Thermocouple No. 3 \((T_3)\) measures the temperature of the heating coil. Thermocouple No. 1 is used also for measuring initial air temperature in constant-temperature runs before insertion of the specimen.

**SECTION 26.605 — TEST SPECIMENS**

Thermoplastic materials may be tested in pellet form normally supplied for molding. Where only sheet samples are available or for thermosetting materials \( \frac{3}{4} \) -inch by \( \frac{3}{4} \) -inch (19 mm by 19 mm)
squares of the available sheet or film shall be bound together with fine wire. A specimen weight of 3 grams ± 0.5 gram is required.

SECTION 26.606 — CONDITIONING

26.606.1 General. Measurements of temperature and relative humidity during conditioning and testing of specimens shall be recorded and such measurement shall be taken within 2 feet (610 mm) of the specimen.

26.606.2 Conditioning. Condition test specimens at 73.4°F ± 1.8°F (23°C ± 1°C) and 50 ± 2 percent relative humidity. Specimens 0.25 (6.4 mm) or less in thickness shall be conditioned for 40 hours immediately prior to testing. Specimens with a thickness greater than 0.25 (6.4 mm) shall be conditioned for 88 hours immediately prior to testing.

Adequate air circulation on all sides of the test specimen shall be provided by placing them in suitable racks, hanging them from metal clips, or laying them on wiremesh, wire screen frames with at least 1 inch (25 mm) between the screen and the surface of the bench.

26.606.3 Test Conditions. Conduct tests in the standard laboratory atmosphere of 73.4°F ± 1.8°F (23°C ± 1°C) and 50 ± 2 percent relative humidity.

SECTION 26.607 — PROCEDURE A

26.607.1 First Approximation of Flash-ignition Temperature (Effect of Airflow Rate).

26.607.1.1 Low airflow determination. Raise the cup to the cover opening and place the specimen in the furnace. Set the airflow at 5 feet per minute (1.5 m/min). Adjust the transformer controlling current to the furnace coils to provide a rise in the temperature (T2) of approximately 1080°F (582°C) per hour (± 10 percent). Light the gas pilot flame and place it across the hole in the top of the furnace. Note the air temperature (T2) at which the combustible gases are ignited. This point is evidenced by a rapid rise in the specimen temperature (T1). This is an approximation of the flash-ignition temperature.

26.607.1.2 Medium airflow determination. Repeat paragraph 1, but with an air setting of 10 feet per minute (3.0 m/min).

26.607.1.3 High airflow determination. Repeat paragraph 1, but with an air setting at 20 feet per minute.

26.607.2 First Approximation of Self-ignition Temperature (Effect of Airflow Rate). Repeat Section 26.607.1.1, but without the pilot flame. Note the recorded air temperature (T2) at which the specimen flames, explodes or glows.

Repeat Section 26.607.1.2, but without the pilot flame. Note the recorded air temperature (T2) at which the specimen flames explodes or glows.

Repeat Section 26.607.1.3, but without the pilot flame. Note the recorded air temperature (T2) at which the specimen flames, explodes or glows.

26.607.3 Second Approximation of Flash-ignition Temperature. Choose the air setting from Section 26.607.1 that gives the lowest flash temperature, and repeat the appropriate determination, Sections 26.607.1.1, 26.607.1.2 or 26.607.1.3, using a temperature rise of 540°F (282°C) per hour (± 10 percent).

26.607.4 Second Approximation of Self-ignition Temperature. Choose the air setting from Section 26.607.2 that gives the lowest self-ignition temperature, and repeat the appropriate determination, Section 26.607.1.1, 26.607.1.2 or 26.607.1.3, using a temperature rise of 540°F (282°C), per hour (± 10 percent).
26.607.5 Constant-temperature Tests to Determine Minimum Ignition Temperatures.

26.607.5.1 Minimum flash-ignition temperature. Start the furnace with the air setting user in Section 26.607.3. Adjust the transformer setting until the initial air temperature \( T_1 \) stays constant as indicated by the recorded temperature reading for a 15-minute period. The initial temperature should be maintained not more than 18°F. (10°C.) below the flash temperature found in Section 26.607.3. Place the specimen in the furnace, ignite the pilot flame and watch for ignition of gases from the specimen. If ignition occurs, repeat this run with temperature \( T_1 \) maintained at an 18°F. (10°C.) lower setting. Repeat at successively lower temperatures until there is not ignition in 30 minutes. When temperature \( T_1 \) is reached at which no ignition occurs, it is suggested that a second run be made to ensure that this is truly below the self-ignition temperature. Report the lowest air temperature \( T_1 \) setting at which ignition occurred as the minimum flash-ignition temperature.

26.607.5.2 Minimum self-ignition temperature. Repeat paragraph 1 (above) but without the pilot flame. Start with an air temperature 18°F. (10°C.) lower than the ignition temperature found in Section 26.607.4.

SECTION 26.608 — PROCEDURE B (SHORT METHOD)

26.608.1 Minimum Flash-ignition Temperature. Set the air-flow rate to provide a velocity of 5 feet/minute (1.5 m/min) at 752°F. (400°C.) in the test chamber of the furnace. Adjust the current to the heating coil until the initial air temperature \( T_2 \) remains constant at 752°F. for 15 minutes.

**NOTE:** The temperature of 752°F. (400°C.) is used when no prior knowledge of the probable ignition temperature range is available. Other starting temperature may be selected if information about the material indicates better choice.

Locate thermocouple \( T_1 \) centrally in the specimen holder intimately surrounded by the test material and lower the unit into the furnace. Start a timer, ignite the gas pilot flame and watch for ignition. Flash ignition will be evidenced by a flash or mild explosion of combustible gases which may be followed by continuous burning of the specimen. If the specimen burns, by flaming or glowing, a rapid rise will be observed in the temperature at thermocouple \( T_1 \) above that at \( T_2 \).

If at the end of five minutes ignition has or has not occurred, lower or raise the temperature \( T_1 \) 122°F. (68°C.) as required and repeat the test with a fresh specimen. When the minimum ignition temperature has been bracketed, tests are begun 50°F. (28°C.) below the lowest ignition temperature observed and repeated, dropping the temperature in 50°F. (28°C.) intervals until the temperature is reached at which there is no ignition during 13 minutes. A repeat run may be desirable at this temperature using an air velocity of 10 feet/minute (3.0 m/min) to verify the use of 5 feet/minute (1.5 m/min) as optimum.

The lowest air temperature \( T_2 \) at which a flash is observed is recorded as the minimum flash-ignition temperature.

26.608.2 Minimum Self-ignition Temperature. Follow the same procedure as in Section 26.608.1 but without the gas pilot flame.

Self-ignition will be evidenced by flaming or glowing of the specimen. It may be difficult, with some materials, to detect self-ignition visually when burning is by glowing rather than flaming. In such cases, the rapid rise in temperature at thermocouple \( T_1 \) above that at \( T_2 \) is the more reliable reference.

The lowest air temperature \( T_2 \) at which the specimen burns is recorded as the minimum self-ignition temperature.

SECTION 26.609 — REPORT

The report shall include the following:
1. Designation of material, including name of manufacturer, composition and state of subdivision (granules, sheet, etc.).
2. Air velocities used. If air velocity is not critical, this should be noted.
3. Flash-ignition temperature.
4. Self-ignition temperature.
5. Visual observation (melting, bubbling, smoking, etc.).
UNIFORM BUILDING CODE STANDARD 26-7

METHOD OF TEST FOR DETERMINING CLASSIFICATION OF APPROVED LIGHT-TRANSMITTING PLASTICS


See Sections 217 and 2603.1.3, Uniform Building Code, and Section 212, Uniform Sign Code

SECTION 26.701 — SCOPE

This method of test covers a small scale laboratory test for the purpose of classifying approved light-transmitting plastics in the form of bars, molded or cut from sheets, plates or panels tested in the horizontal position. This method should be used to establish the proper classification of approved light-transmitting plastics and should not be used as a fire hazard test method.

SECTION 26.702 — SUMMARY OF METHOD

A bar of the material to be tested is supported horizontally at one end; the free end is exposed to a specified gas flame for 30 seconds. The time and extent of burning are measured and reported if the specimen does not burn more than 4 inches (102 mm). An average burning rate is reported for a material if it burns beyond the 4-inch (102 mm) mark from the ignited end.

SECTION 26.703 — APPARATUS

26.703.1 Test Chamber. The test chamber is to be a laboratory hood totally enclosed with a heat-resistant glass window for observing the test. A mirror is to be provided within the chamber to provide a rear view of the specimen during the test. The exhaust fan is turned off during the test and turned on immediately following the test in order to remove products of combustion which may be toxic when testing some materials. Alternatively, the test may be made in a metal cabinet placed inside the hood leaving the hood exhaust fan turned on. The cabinet must have air holes on the bottom and top. The holes must allow ample passage of air for characteristic burning but must not allow drafts across the burning specimen.

26.703.2 Specimen Holder. The specimen shall be supported in the proper position by laboratory ring stands with two small clamps adjustable, by means of a check nut, to any angle.

26.703.3 Ignition Source. The ignition source shall be a standard 3/8-inch (9.5 mm) diameter Bunsen burner with a laboratory gas supply.

SECTION 26.704 — TEST SPECIMEN

At least 10 test specimens 5 inches (127 mm), plus or minus 1/4 inch (6.4 mm) in length, by 1/2-inch (13 mm), plus or minus 0.008 inch (0.20 mm) in width and of the thickness of material normally supplied, shall be cut from sheets or molded from each of the samples to be tested.

The specimens shall normally be tested in the as-received condition unless otherwise specified.

Each test specimen shall be marked by scribing a line 4 inches (102 mm) from end of the specimen.

The edges of the test specimen shall be smooth. Sawed edges should be fine sanded to a smooth finish.
SECTION 26.705 — PROCEDURE

Clamp the specimen at the marked end in a support with its longitudinal axis horizontal and its transverse axis inclined at 45 degrees to the horizontal. Under the test specimen, clamp a screen of 20-mesh wire gauze, about 4 inches (102 mm) square, in a horizontal position 3/8 inch (9.5 mm) below the edge of the specimen and with about 1/2 inch (13 mm) of the specimen extending beyond the edge of the wire gauze (see Figure 26-7-1). Any material remaining on the screen from the previous test must be burned off on a new screen used for each test. A pan of water should be placed on the floor of the hood in a position to catch any burning particles that may drop during the test.

Adjust a standard 3/8-inch (9.5 mm) diameter Bunsen burner, with air ports open, to produce a blue flame approximately 1 inch (25 mm) high. Place the burner so that the tip of the outer cone of the flame contacts the end of the test specimen starting the stopwatch simultaneously. Apply the flame for 30 seconds. If the specimen warps, melts or shrinks away from the flame, move the flame to keep it in contact with the specimen. Excessive distortion of the specimen during the test may invalidate the results. At the end of 30 seconds, remove the flame and place it at least 18 inches (457 mm) from the specimen to reduce the effects of draft in the hood while the specimen is allowed to burn.

Stop the watch when burning (flame) or glowing combustion (visible glow without flame) ceases, or when it has proceeded to the mark 4 inches (102 mm) from the free end. Record the time in seconds on the watch as burning time, t.

If the burning has not reached the mark, measure the unburned length to the nearest 0.04 inch (1.0 mm) along the lower edge of the specimen from the mark. The extent of burning is defined as 4 inches (102 mm) minus the unburned length in the same units.

If specimen has burned to or beyond the mark, calculate the burning rate as 240/t [inches/minute (6096/t mm/min)].

Repeat the procedure above until three specimens have burned to or beyond the mark or 10 specimens have been tested. If only one of 10 specimens tested burns to the mark or beyond, repeat the procedure above with 10 additional specimens.

SECTION 26.706 — REPORT

26.706.1 Burning Rate. If two or more specimens have burned to the gage mark, average burning rate (inches/minute) (mm/min) shall be reported as the average of the burning rates of all specimens which have burned to the mark.

26.706.2 Average Time of Burning and Average Extent of Burning. The average time of burning and average extent of burning of the samples shall be reported if none of 10 or more than one of 20 specimens has burned to the mark.

26.706.3 Average Time of Burning. The average time of burning shall be equal to the sum of t minus 30 seconds divided by the number of specimens [Σ (t – 30)/number of specimens] rounded (after averaging) to the nearest multiple of five seconds; that is, "less than five seconds" would be reported if burning or flowing continued less than three seconds after removal of flame. In no case is an average time of burning of "zero" to be recorded.

26.706.4 Average Extent of Burning. The average extent of burning is equal to the summation of the quantity of 4 inches (102 mm) minutes the unburned length divided by the number of specimens [Σ (4 inches (102 mm) – unburned length/number of specimens)] rounded (after averaging) to the nearest 0.2 of an inch (5.1 mm); extent of burning less that 1/8 of an inch (3.2 mm), report as "less than 0.2 of an inch (5.1 mm)," in no case reporting "zero." Extent of burning of a single specimen that burns to the mark is counted as 4 inches (102 mm).

26.706.5 Classification. Approved light-transmitting plastic materials shall be classified as either CC1 or CC2 in accordance with the following requirements:
CC1: Plastic materials which have a burning extent of 1 inch (25 mm) or less when tested in nominal 0.060-inch (1.5 mm) thickness (or in the thickness intended for use) by this test.

CC2: Plastic materials which have a burning rate of 2.5 inches per minute (64 mm/min) or less when tested in nominal 0.060-inch (1.5 mm) thickness (or in the thickness intended for use) by this test.

26.706.6 Items to be Reported. The complete report shall include the following:
1. Identification of the sample including method of preparation and condition.
2. Average thickness of the specimen to ± 1 percent.
3. Number of specimens tested.
4. Range of time of burning values.
5. Range of extent of burning values.
6. If a specimen does not bum to the mark because of dripping, flowing or falling burning particles, the report must so indicate.
7. If a specimen's reignited by burning material on the wire gauze, the report must so state.
8. Classification of material in accordance with Section 26.706.5.

FIGURE 26-7-1—TEST APPARATUS
UNIFORM BUILDING CODE STANDARD 31-1
FLAME-RETARDANT MEMBRANES
Test Standard of the International Conference of Building Officials
See Appendix Section 3112.2, Uniform Building Code

SECTION 31.101 — SCOPE
This standard covers requirements for flame-retardant membranes which are not noncombustible, intended for use in membrane structures as defined in this code.

SECTION 31.102 — TEST APPARATUS
The apparatus for conducting the flame test shall consist of a sheet-iron stack 12 inches (305 mm) square transversely, 7 feet (2134 mm) high and supported 1 foot (305 mm) above the floor on legs. The stack shall be open only at top and bottom and shall be provided with an observation window of wired glass extending the full length of the front.

The stack is to be arranged so that the specimen can be suspended vertically in the stack with its full width facing the observer with the bottom of the specimen 4 inches (101.6 mm) above the top of a Bunsen burner having 3/8-inch-diameter (9.5 mm) tube and placed on the floor below the stack. The gas supply to the burner is to be natural gas or a mixture of natural and manufactured gases having a heat value of approximately 800 Btu to 1,000 Btu per cubic foot (29 807.1 kJ/m³ to 37 258.9 kJ/m³). With a gas pressure of 4 1/2 inches of water (1058 Pa), the burner is to be adjusted to produce an 11-inch (279 mm) oxidizing flame having an indistinct inner cone. Guide wire and clamps are to be provided to lightly restrain the edges of the specimen.

SECTION 31.103 — SPECIMENS
At least 10 specimens 5 inches by 7 feet (127 mm by 2134 mm) shall be tested. Specimens shall be taken from as widely separated and symmetrically located sections as possible over the entire area of representative sample of the membrane. Where there is a grain to the sample, one-half of the specimen for each conditioning shall be taken parallel to the grain and the other one-half perpendicular to the grain. At least six of the specimens shall be conditioned as specified in Section 31.104.1 and at least four of the specimens shall be conditioned as specified in Section 31.104.2.

SECTION 31.104 — CONDITIONING
31.104.1 Accelerated Weathering. One of the two procedures described below shall be followed for at least six of the test specimens:

1. The apparatus shall consist of a vertical carbon arc with solid electrodes 0.5 inch (12.7 mm) in diameter (one cored electrode is used if the arc operates on alternating current) and uniform in composition throughout, mounted at the center of a vertical metal cylinder. The arc shall be surrounded by a clear globe of optical heat-resistant glass with a cutoff at 2750A, with an increase in transmission of 91 percent at 3700A, or other enclosure having equivalent absorbing and transmitting properties. The electrodes shall be renewed at intervals sufficiently frequent to insure full operative conditions of the lamp. The globe shall be cleaned when carbons are removed or at least once in each 36 hours of operation. The arc shall be operated on 13 amperes direct current or 17 amperes, 60 cycles alternating current with the voltage at the arc of 140 volts. The specimens for test shall be mounted on the inside of the cylinder facing the arc. The diameter of the cylinder shall be such that the distance of the face of the specimen holder from the center of the arc is 14 3/4 inches (374.7 mm). The cylinder shall rotate about the arc at a uniform speed of approximately three revo-
lutions per hour. A water spray discharging about 0.7 gallon per minute (2.7 L/min.) shall strike each specimen in turn for about one minute during each revolution of the cylinder. Specimens shall be subjected to this exposure for 360 hours. They shall then be allowed to dry thoroughly at a temperature between 70°F and 100°F (21°C and 38°C).

2. The apparatus shall consist of a vertical carbon arc mounted at the center of a vertical cylinder. The arc is designed to accommodate two pairs of carbons, No. 22, upper carbons, and No. 13, lower carbons; however, the arc burns between only one pair of carbons at a time. The arc shall be operated on 60 amperes and 50 volts across the arc for alternating current or 50 amperes and 60 volts across the arc for direct current. The specimens for test shall be mounted on a rotating rack inside the cylinder and facing the arc. The diameter of the rotating rack shall be such that the distance from the center of the arc to the face of the specimen is 183/4 inches (476.3 mm). The rack shall rotate about the arc at a uniform speed of about one revolution in two hours. No filters or enclosures shall be used between the arc and the specimens. Spray nozzles shall be mounted in the cylinder so that the specimens shall be exposed to wetting once during each revolution of the rack. Specimens shall be subjected to this exposure for 100 hours. They shall then be allowed to dry thoroughly at a temperature between 70°F and 100°F (21°C and 38°C).

31.104.2 Unweathered Samples. At least four of the test specimens shall be conditioned in an oven having forced air circulation with free airflow around each specimen at temperatures of 140°F to 145°F (60°C to 46°C) for durations of not less than one hour nor more than one and one-half hours before testing. Materials which distort or melt at the above indicated oven exposure are to be conditioned at 60°F to 80°F (15.5°C to 26.7°C) and 25 to 50 percent relative humidity for not less than 24 hours. Specimens shall be removed from the oven one at a time and immediately subjected to the flame test described in Section 31.105.

SECTION 31.105 — TESTING

Suspend the specimen in the apparatus attaching clamps to the edges to retain the specimen in position. Position the burner so that the flame will be applied near the middle of the lower end of the specimen and fix the barrel of the burner at an angle of 25 degrees.

The test flame shall be applied to the specimen for two minutes, then withdrawn, and the duration of flaming combustion on the specimen recorded. After all flaming and afterglow on the specimen has ceased, the length of char shall be determined. For purposes of this test, the length of char is defined as the vertical distance on the specimen from the tip of the test flame to the top of the charred area resulting from spread of flame and afterglow. For synthetic membranes, the length of char is defined as the vertical distance from the tip of the test flame to a horizontal line, above which all material is sound and in essentially original condition.

SECTION 31.106 — CONDITION OF ACCEPTANCE

When subjected to the test described in Section 31.105, material shall not continue flaming for more than two seconds after the test flame is removed from contact with the specimen. The vertical spread of burning on the material shall not exceed 10 inches (254 mm) above the tip of the test flame. This vertical spread shall be measured as the distance from the tip of the test flame to a horizontal line above which all material is sound and in original condition, except for possible smoke deposits.

Portions or residues of textiles or films which break or drip from the test specimens shall not continue to flame after they reach the floor of the tester.