PROCEEDINGS

of the

THIRD ANNUAL

INDUSTRIAL ENGINEERING INSTITUTE

February 2, 3, 1951

UNIVERSITY OF CALIFORNIA, BERKELEY

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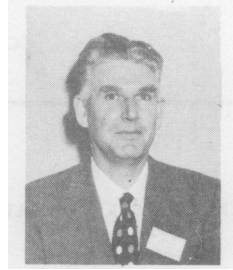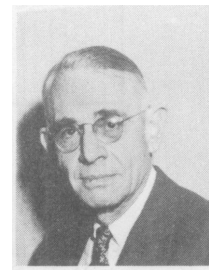
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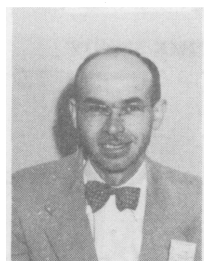
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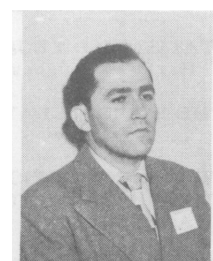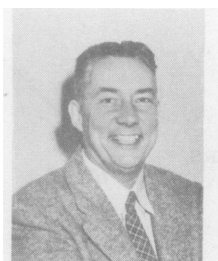
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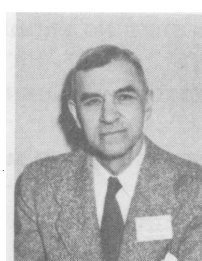
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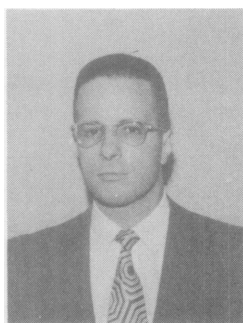
The Proceedings of the Third Annual Industrial Engineering Institute represent the complete prepared talks of the speakers participating and also the results of the Time Study Rating Session. It is hoped that this booklet will serve as a practical guide and reminder to you of the recent developments in Industrial Engineering presented. Sincere thanks are given to all the speakers who journeyed from all points of the country and contributed so much time and expense in explaining their latest techniques. Similar appreciation is extended to the chairmen and organizations for their aid and assistance in the presentation and conduct of the sessions.

A special acknowledgment is due to many individuals who are not elsewhere mentioned. Dr. H. V. Hammarberg and her staff, R. W. Roth, Don Irwin, for planning and general arrangements, Alex Rossi, for photography, Wm. J. Schaefer and Sinclair Knapp, for work on these proceedings, Miss Mary J. Shank, Mrs. Vera Twist, for transcription and editing, and A. L. Elliott of the Elliott Printing Company for the production of the proceedings, are the principal among a host of others who by their enthusiasm and ideas have made the Institute a success.

In response to many requests, the motion picture films and loops presented at the Saturday morning session have been made available for purchase. Details may be obtained by writing Mr. J. Robertson, University Extension, University of California, Berkeley 4, California.

General Chairman

ADDRESS OF WELCOME

GEORGE A. PETTITT

Assistant to the President,

University of California.

The Third Industrial Engineering Institute was opened at 9:00 A. M. on Friday, February 2, 1951 by D. G. Malcolm, General Chairman of the Institute. Dr. George A. Pettitt, Assistant to the President, University of California welcomed the group to the campus. He expressed the thought that conferences such as this are one of the important developments in higher education of the last generation.

It used to be that we thought only of the loss to society which results from the lag in applying scientific discovery to the needs of the people. Lately, however, we have been realizing that there is just as much of a loss if there is a lag in applying the field experience of practitioners in the various professions to the problems of teaching and research. Meetings such as this facilitate that two-way flow from the laboratory and the classroom to the practical men in the field and from the practical men in the field back to the laboratory and the classroom. If we have only a one-way flow, the result eventually is a sort of sterility comparable to that which occurs when a piece of land is continually cropped and the products of that land never plowed back or the chemical equivalent thereof added. It follows then that such conferences and institutes serve as a catalytic agent to bring together theory and experience, as well as discovery and methods of application, and thus, to influence both the university and the practitioner in the field.

STANDARD DATA SYSTEMS SESSION

Chairman--E. L. SLAGLE, Works Industrial Engineer, Columbia Steel Corporation, Pittsburg, California

THE PRACTICAL ASPECTS OF WORK-FACTOR

Joseph H. Quick,

President of the Work-Factor Company,

New York.

Man, as an individual, has always survived by his ability to use his hands and feet. Half a million years ago, his life depended on the skill with which he could use them to run away, do battle, or catch his food. The greater his skill and swiftness, the greater his safety and comfort.

Today, he no longer battles savage beasts. Yet he is in constant danger from wars and depressions. Both World Wars have shown us that a nation's survival depends on its skill in production--its ability to use millions of hands and feet to the greatest advantage. After the war, we learned also that this same skill is needed to reduce costs, lower prices and ward off inflation. The economical use of hands and feet is so essential that man has developed all sorts of labor saving devices to enable him to do more in less time. The time required to make motions with hands and feet is becoming more and more significant as we progress. As you know, a large portion of the ECA effort has been directed at improving European efficiency to help save those countries from economic ruin and help them with self defense. Now, of course, the world appears on the brink of another crisis, and emphasis is again redoubled toward production--the use of people who move their hands and feet to run machines, assemble goods, and transport them for use.

Along with the great urgencies which periodically face the peoples of the world when wars are waged, or when depression and economic troubles set in, is an underlying and steadily growing trend which has made manual efficiency of permanent importance during war or peace. When men become free and can think for themselves, when their living standards provide some leisure and education, then their time becomes more valuable to them. Wages rise. The cost of labor becomes more significant, both in the cost of production and to the worker who does the producing.

There is nothing wrong with the concept that a worker's time shall become more and more valuable to him. I believe all fair-minded industrial people must be ready and willing to pay fair wages for a fair return in work. The great danger to our nation today is not high wages--the danger is low productivity. If we successfully combat this, we will have assured mankind of at least a chance at a sound economic future. Being realistic about it, our destiny resides in the ef-

ficiency with which we, the people of the world, choose to use millions and millions of manual motions to produce goods and services. In its broad economic and military aspects, this principle is not difficult to understand. The more we produce, the more we have, both for home consumption and for defense. When we get back to the workplace in offices or factory, however, the situation often becomes more personal. Except in times of desperation, the workaday world has a tendency to dim the big issues and bring out the employer-employee questions concerning work and wages.

The problem has always been the same and still remains the same--
1. How fast should a person work?
2. How can we set fair rates consistently?
3. How can we get an operator to understand and agree they are fair?

Failing to get good answers to these and similar questions has probably caused as much misunderstanding between labor and management as any other problem in industry. I do not suggest a cure-all for industrial personnel troubles. I would like to show that much can be done by using a sensible scientific approach to the measurement of work. To me, timestudy is one of the most difficult jobs there is. It deserves every possible attention.

FILM DISCUSSION

Four film sequences of actual performance in the manufacture of metal housing for the Oldsmobile Company were shown. The operation selected was the "first draw" and was performed on a 240 ton double action Bliss press. See Figure 2 for complete description of operation.

First Film Sequence - The operator works with obviously poor method and slow pace. He fumbles, hesitates, and makes unnecessary motions. The average time he requires for each piece produced is approximately .75 minutes or 80 pieces per hour. In this situation, if a stopwatch is used, the engineer making the timestudy must, by some means, estimate to what extent the worker is inefficient both in motion pattern and speed of motion, and then set a standard time based on this opinion.

Second Film Sequence - Here, the same operator improves his method to a reasonable degree. He also moves more rapidly and gets more work done. His average time for each piece is now only about .33 minutes. This means his output now has gone from 80 pieces per hour to 182 pieces per hour. Performance is better, but not necessarily correct. The timestudy engineer must still rely on his judgment.

Third Film Sequence - In this sequence, the operator looks good. His motions are smooth and accurate. He appears to lose little time and he manages to keep the press going rather steadily. He has reduced the average time for each piece to only .25 minutes. His output therefore

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has risen from 80 per hour in the first sequence, 182 in the second sequence, to 240 in this third sequence. There is no help from the stopwatch. It tells the engineer how fast the operator is producing, but it does not tell how fast he should produce.

Fourth Film Sequence - Now we see the operator "open up." He is quick, sure and clean in his movements. The bare machine time is .138 minutes. Working at this high level of productivity, the operator almost keeps the press "rolling over." His average time per piece now is reduced to about .17 minutes. This is 353 pieces per hour. An increase of more than 400% over the first film sequence. The question is--is this correct? Should the operator be expected to work this fast? Again, the engineer is on his own. He must estimate which, if any, of the four performances were fair and normal. Here is a recap of these four performances:

	Min. per Piece	Pieces per Hr.
FIRST SEQUENCE	.75	80
SECOND "	.33	182
THIRD "	.25	240
FOURTH "	.17	353

Obviously, it is an important problem. If the engineer estimates too low a time, then he is unfair to the operator and there may be trouble with his union. If he estimates too high a time, then there is high cost and loss of competitive position by the company. This, of course, eventually hurts the operator, the union, the engineer and everyone in the organization. It is apparent that the need here is to use as scientific an approach as possible.

Some arrangement is required whereby the operator's speed of performance will not affect the way the production rate is set. This brings us, then, to the subject of WORK-FACTOR analysis. The name WORK-FACTOR has come into use because it was by analyzing the factors involved in work that it has been possible to apply a scientific method to the measurement of work.

WORK-FACTOR, I believe, is one of the earliest published systems of motion times. Although revolutionary in its approach to timestudy, it follows the pattern which any good analyst, chemist, physicist, or other scientist would choose. An enormous amount of work has been done in research and actual application. There are certain arrangements which are original and perhaps clever, but, for the most part, WORK-FACTOR is just common sense.

It is simply a system of highly accurate time values for every conceivable individual finger, hand, arm, leg or body motion which a human being can make. These time values have been set into moving time tables (Figure 1) and rules have been written for their use.

When it is desired to use WORK-FACTOR to determine how long it should take to perform an operation, the procedure is simple:

1. List all of the individual motions which are required to perform the operation.
2. From the table of motion times, apply the time for each individual motion.
3. Add the individual motion times and the result will be the total time to perform the operation.

THE MECHANICS OF WORK-FACTOR

There is a fundamental concept required to apply successfully the WORK-FACTOR system. The engineer must think in terms of single motions. For example, in picking up a pencil, there are three separate motions--not just one:

First Motion - Move hand to pencil
Second Motion - Close fingers to grasp pencil
Third Motion - Move hand with pencil to paper

Later, after he has become thoroughly familiar with WORK-FACTOR, the engineer can use the simplified system which groups a series of motion times together for greater speed in rate setting.

In attempting to use science to solve the problem of setting a fair standard despite the widely differing performances we saw on the punch press, we must be able properly to describe and classify the motions required to operate the press.

Figure 1

Therefore, let us determine what it is about work motions which affects the time required for an operator to make them.

Although there are dozens of variable factors involved in motions, for practical purposes, the following major ones must be recognized in measuring them for rate setting purposes:

1. The body member used (arm, leg, finger, etc.)
2. The length of the motion (5", 10", etc.)
3. The kind of motion (WORK-FACTORS involved)
   (1) Does it carry weight or overcome friction (W)
   (2) Does it require control to steer it (S)
   (3) Does it require care or precaution (P)
   (4) Does the motion change direction (U)
   (5) Must it end at a definite stop point (D)
If each of these factors is known about a given motion,

that motion can be identified according to the amount of time required to make it. Examples of motions classified according to WORK-FACTOR analysis are:

No.	Description of Motion	WORK-FACTOR Classification	WORK-FACTOR in Minutes
1	Move finger 1"	F 1	.0016
2	Move hand 10" (arm)	A 10	.0042
3	Move hand 20" (arm)	A 20	.0058
4	Move hand 20" to wrench	A 20 D	.0080
5	Move hand 20" carrying wrench (3 lbs.) to place aside	A 20 WD	.0102
6	Move hand 20" carrying wrench (3 lbs.) to place on nut	A 20 WSD	.0124
7	Move hand 20" carrying wrench (3 lbs.) around and behind fixture To place on nut	A 20 WSUD	.0144
8	Move foot to depress machine pedal (leg)	L 10 W	.0070

The symbol before distance designates the body member and each symbol used after the distance represents a WORK-FACTOR.

The above examples show how time varies with the body member, the distance, or the type of motion.

It is apparent from these examples that if the motion can be described in words, it can be quickly put into its proper WORK-FACTOR classification. Using the WORK-FACTOR classification makes it possible to determine the time for the motion from the WORK-FACTOR table of motion times.

SETTING THE PUNCH PRESS RATE WITH WORK-FACTOR

We have previously observed the punch press operation running at four widely differing levels of performance. At this point, we do not know which (if any) is the correct speed on which to base a standard. By the use of the table in Figure 1 and the following type analysis, as shown in Figure 2, the correct time value can be established accurately and impartially without reference to the operator's actual rate of performance.

A point is chosen as the beginning of the cycle. In this instance, the first manual element following the disposal of the piece was·selected because both hands are together reaching for the blank. The characteristics of this first element, "Reach for Blank," are then determined:

(1) The body member involved - the arm
(2) The distance moved - 20 inches
(3) WORK-FACTORS required - definite stop

The WORK-FACTOR "D" is required inasmuch as the hand must be brought to a halt close to the edge of the blank before grasping. Using the WORK-FACTOR notation, the element is described as A20D. This then is a 20

inch arm motion, having one WORK-FACTOR (the symbol "D" after the distance denotes a WORK-FACTOR). The time value for this motion is taken from the (A) Arm section of the Moving Time Table (Figure 1) opposite 20 inches in the "1-WF" column, which is the second column of the section. The value appears as .0080 minutes.

The second element, "Grasp Blank," (See Figure 2) is described as a finger motion of 1 inch length having one WORK-FACTOR, a "W" which represents the application of pressure by the fingers because the blank is heavy and a firm grip is needed prior to the transport which follows. Using the WORK-FACTOR notation, the element is identified as F1W (or a 1" finger motion having 1 WORK-FACTOR "W") and the value taken from the (F) Finger section of the table (Figure 1) opposite one inch in the "1-WF" column is .0023 minutes.

In a similar manner, the third element, (Figure 2) "Carry Blank to Die," is analyzed as an arm motion of 40 inches, having three WORK-FACTORS, "W" - weight (weight of the blank is 4.04 lbs.) but since the two hands are carrying the piece, the effective weight per hand is 2.02 lbs. which, according to our table, requires one "W" factor, "S" - steer (to the die pins), and "D" - definite stop (at the pins). The motion is expressed as A40WSD; its time value taken from the (A) Arm section of the table (Figure 1) opposite 40 inches in the 3-WF column is .0159 minutes.

RESULTS OF THE STUDY

The WORK-FACTOR analysis of the punch press operation establishes a time value of .22 per piece or a rate of 272 pcs. per hour. Compare this time with the four times shown in the film, namely, .75, .33, .25 and .17 minutes per piece.

The important idea to be gained from the foregoing discussion and analysis is that if the WORK-FACTOR value is correct, then at no time did we see the operator performing at a rate of speed which could be used as a standard for setting a correct production rate.

Here the difference between stopwatch timestudy and WORK-FACTOR stands forth. Obviously, if at no time does an operator work at a correct speed for setting a standard, then the timestudy engineer must either use an actual time value which is incorrect or he must arbitrarily adjust the value to what he thinks is correct.

On the other hand, if we can accept the WORK-FACTOR time value as correct, then regardless of the operator's performance, the engineer can always establish a fair and accurate rate because he always has the same WORK-FACTOR table of elemental time values. His problem is simply to list the motions required for the job, apply the times from the table and strike a total.

LEVEL OF PERFORMANCE ESTABLISHED BY WORK-FACTOR

All values shown on the WORK-FACTOR table of motion times are known as "select times." They do not include any of the allowances for personal needs, fatigue, or miscellaneous minor delays. The select time represents the performance of an experienced operator working with good skill and good effort. It is equivalent to 25% above a "60" or base rate level of output. The following calculation illustrates how WORK-FACTOR select time is converted to standard time.

OPERATION NAME Oldsmobile Case : 1st Draw Operation (2 Pin Die)

EQUIPMENT Mach # 1031 : Buss Double Action Draw Press 240 Tons 72.5 RPM

MATERIAL CR Steel : Thk = .050 ± .003" Dia = 19.25" Wt = 4.04 lbs

H.B. Ameto   Sheet 1 of 1

No.	Elemental Description (LEFT HAND)	Motion Analysis	Elem. Time	Cumulative Time		Elem. Time	Motion Analysis	Elemental Description (RIGHT HAND)	MACH.
1	Reach For Blank	A20D	0080	0080	0080	0080	A20D	Reach For Blank	
2	Grasp Blank	F1W	0023	0103	0103	0023	F1W	Grasp Blank	
3	Carry Blank To Die	A40WSD	0159	0262	0262	0159	A40WSD	Carry Blank To Die	
4	Release & Clear Fingers	F3W	0028	0290	0290	0028	F3W	Release & Clear Fingers	
5	Place Fingers On Blank	F3D	0028	0318	0399	0109	A40D	Reach For Trip Lever	
6	Push Blank Against Pins	A2P	0029	0347	0415	0016	F1	Grasp Lever (No W Req'd)	
7	Withdraw Hand (Aid) & Wait		0146	0493	0493	0078	A10WW	Pull Lever To The Press (10 lbs)	
8	Move Hand To Hold Blank (Turn Slw)	A30D	0096	0589	0589	0096	A30D	Reach For Oil Rag (Turn 90°-Sim)	
9	Press Down To Hold Blank	A1W	0026	0615	0606	0017	F2	Grasp Rag	
10	Hold Blank At Center	-	-		0691	0085	A12UD	Carry Rag & Dip In Oil Pan	
11	" " " "	-	-		0723	0032	A6	Raise From Oil Pan	
12	" " " "	-	-		0749	0026	A4	Shake (Squeeze Sim°)	
13	" " " "	-	-		0804	0055	A18	Carry Rag To Stack Of Blanks	
14	" " " "	-	-	0913	0913	0139	A40U	Apply Oil (Circular Motion)	
15	Release Blank	A1W	0026	0939	0955	0042	A10	Raise Rag From Blank	
16	Withdraw Hand From Blank	A16	0052	0991	0997	0042	A10	Strike To Dislodge Blank	
17	Approach Blank	A3D	0032	1023	1048	0051	A15	Withdraw Rag To Side	
18	Grasp Blank	F1W	0023	1046		-	-	Hold Rag	
19	Turn Blank Over (Release Sim°)	2A14W	0138	1184		-	-	" "	
20	Move Hand To Blank Center	A13D	0067	1251		-	-	" "	
21	Press Down To Hold Blank	A1W	0026	1277	1277	0055	A18	Carry Rag To Blank	
22	Hold Blank At Center	-	-		1386	0109	A40U	Apply Oil (Circular Motion)	
23	Release Blank	A1W	0026	1412	1437	0051	A15	Toss Rag Near Pan	
24	Hand Idle (Turn 90° Sim°)	-	-		1517	0080	A20D	Reach For Trip Lever (Turn Sim°)	
25	" "	-	-		1533	0016	F1	Grasp Handle (No W Req'd)	
26	" "	-	-		1781	0248		Wait (.0443+.1100-.1333-.0032=.0248)	
27	Move Hand To Piece On Punch	A20D	0080	1873	1873	0092	A15WW	Push Lever To Stop Press (10 lbs)	
28	Catch Piece On Palm	React	0020	1893	1896	0023	F1W	Release Handle	
29	Carry Piece To Chute (Balance)	A40WPD	0159	2052		-	-	Hand Idle	
30	Toss To Chute Or Stack	A5W	0043	2095		-	-	" "	
31	Turn To Worktable	120°	0100	2195	2195	0100	120°	Turn To Worktable	

MACH. CYCLE • 0.1380 MIN.

Figure 2

If Select Time is	Production Incentive Jobs	Production Day Work Jobs
	1.000 Min.	1.000 Min.
Personal, Fatigue, Misc.	18%	18%
Incentive Allow.	25%	--
Standard Time	1.475 Min.	1.180 Min. (1)

(1) As a rule, the base rates on day work jobs are 25% or more higher than on comparable incentive jobs. Hence the standard should not include the 25% allowance.

THE VALIDITY OF WORK-FACTOR VALUES

The WORK-FACTOR motion time table is based on time data accumulated during the years 1934 to 1938, inclusive. During this period, more than 20,000 motions were measured using special watches, motion picture cameras, photo-electric relays and stroboscopic lighting units. All measurements were made at actual work-places. There are no laboratory time values in the WORK-FACTOR time table, although values were later double-checked with laboratory equipment. After the original table was compiled, many hundreds of rates were set with it but not used--they were for test purposes only. During succeeding years, up to the present, WORK-FACTOR has been used on most types of work ranging from small manual assembly to loading and unloading lumber from box cars. Throughout the past ten years, WORK-FACTOR has been modified and improved according to problems encountered in actual rate setting in the factory and office.

As most of us are well aware, the best proof of any technique or system involving people is whether or not it works. Many plants today do not use a watch at all--they measure entirely by WORK-FACTOR. We could spend many hours discussing the tremendous complexity involved in securing this apparently simple table of values. However, our concern is practical not theoretical. To the best of my knowledge, WORK-FACTOR is accurate, correct and practical. However, differing opinions are wholesome. I will consider it a privilege to receive comments and answer questions concerning the WORK-FACTOR values.

WHAT DOES ORGANIZED LABOR
THINK OF WORK-FACTOR

Of course, it is dangerous to try to speak for a body of men totaling in the millions. I want to say a few words about union viewpoints, however, because it is a vital question to all of us.

Here is what I have found during 17 years of working in factories:

1. A great many workers and their unions have little respect for the conventional stopwatch timestudy. They feel that only a few men are able to judge properly a worker's efficiency and do it consistently.

2. There is a great difference of opinion about whether incentives are desirable from the worker's standpoint. Many workers and their unions prefer day work. However, I believe that all workers recognize the need to measure the amount of work in a job. They know that a production standard should be set to determine a fair rate of output for the protection of both the company and the worker. Incentive vs. day work is a secondary consideration.

3. It is not likely that many unions will embrace and endorse officially any timestudy technique. In all of my experience, however, I have never found any worker or union representative who did not agree that the WORK-FACTOR approach is more scientific than the stopwatch. Several unions have set up WORK-FACTOR training courses for their stewards.

4. The usual comment about the WORK-FACTOR system is that it is beneficial because in cases of rate dispute, the worker or the union steward can check to see if the method is correct and if the time values have been properly applied. This, of course, cannot be done with the ordinary stopwatch study because the timestudy engineer must speed rate the operator's efficiency.

THE THREE SYSTEMS OF WORK-FACTOR

There are three distinct types or systems of WORK-FACTOR, each developed for a specific purpose. WORK-FACTOR had its origin in a large Philadelphia plant during a period of severe labor unrest. It was created as the result of a need to find a way to set rates more consistently and quickly than had been possible using the stopwatch. Because of this, it was designed to be a timestudy tool, and as a practical way to set rates. A practical and good rate setting technique must provide for consistency, accuracy, speed and assistance in methods improvement.

However, in providing these things, the practical system must do so in proportion to the importance of the job being measured. Hence, it is necessary to have three distinct WORK-FACTOR techniques:

1. Detailed--For mass production.
2. Simplified--For medium quantity production.
3. Abbreviated--For job shop and maintenance.

The principle is easily understood. If there are to be hundreds of thousands, or perhaps millions of parts to be produced, and if this production involves many workers, over long periods of time, then infinite care must be taken to set the correct rate. Obviously a rate set on an operation of this type must be extremely carefully analyzed, both for method and accuracy of time value. In such a case, the Detailed WORK-FACTOR System is used.

A good example of mass production is the pressing of phonograph records. Many presses, thirty years old or more, are in use today, with few changes in the motion patterns required for their operation.

Sharply contrasted to this is a job shop operation which may have a total expected production of ten pieces. If the engineer attempts too detailed a study, not only will he spend his time to poor advantage, but the job might be completed before his study is.

In the case of the mass production item a 5% error in the allowed time might result in the loss of many thousands of dollars and great loss of output. In the case of the job shop operation, there might be but a few hours of labor involved in producing the entire batch of ten pieces, a net loss of a few minutes if the error were as great as 10%.

Briefly then, a sound timestudy system must fit its accuracy to the job to be measured. A good simile is the use of a micrometer, 6" scale, or a yard stick--the accuracy required, determines which is to be used.

To provide a quick insight to the three WORK-FACTOR Systems, let us continue to discuss the same punch press operation.

Before discussing the three WORK-FACTOR Systems as they are applied to an actual operation in a factory, it may be illustrative to use a very simple operation for easy explanation.

Let us assume the following operation:

"Reach 13" to pick up dowel pin (1/4" x 3" long), carry to 1/4" diameter drilled hole and insert. "

From the comparison of the three systems shown in Figure 3, it is readily apparent that the Simplified and Abbreviated Systems require a great deal less timestudy effort than the Detailed System. This effort may be said to be reduced in approximate proportion to the number of time values involved; i.e.--Detailed 7, Simplified 3, and Abbreviated 1.

APPLICATION OF DETAILED WORK-FACTOR
TO THE PUNCH PRESS JOB

The analysis made of the punch press operation as shown in Figure 2 is an example of Detailed WORK-FACTOR. This is the most accurate of the three systems and is recommended for mass production and short cycle work.

APPLICATION OF SIMPLIFIED WORK-FACTOR
TO THE PUNCH PRESS JOB

This type of analysis usually does not employ the right and left hand chart, but merely indicates which hand is the controlling one from a time standpoint. Values established by simplified WORK-FACTOR are sometimes as much as 5% in excess of the detailed because they are averages and therefore cannot be as specific to each operation. It is the most widely used of the systems because it is quite accurate and is useful for quantities ranging from 500 up to 50,000. However, it should not be applied to operations with cycles less than .150 minutes. This point has been established through experience in using the data. It results from the fact that because it is composed of larger time elements, there are elemental highs and lows which cannot balance out unless there are sufficient of them for the purpose. A .150 cycle seems to accomplish this successfully.

APPLICATION OF ABBREVIATED
WORK-FACTOR TO THE PUNCH-PRESS JOB

Abbreviated WORK-FACTOR was developed to be quick and easy to apply. It is relatively new and has not had the extensive testing of the other two systems. To date it has proven very promising, however. It is extremely rapid, and if used appropriately, will provide very satisfactory time values. It is not recommended for quantities in excess of 500 or for cycles less than 1.00 minute.

If the punch press operation were a small quantity job, the Abbreviated analysis would look like this:

		Anal.	Time
1.	Turn to blanks on bench	180° Twist	100
2.	Pick up blank and place in die	40"-2	500
3.	Trip press	TR-2-3	250
4.	Machine time	MT	1380
5.	Aside housing to chute	TR-3-1MM	250
	Total units		2480
	Select time in minutes		.248
	No. values required		5

Figure 3: Comparison of the Three Work-Factor Systems

Operation: Reach 13" to Pick-Up Dowel Pin (1/4" dia. x 3" long), carry to 1/4" drilled hole & insert.

DETAILED SYSTEM			SIMPLIFIED SYSTEM			ABBREVIATED SYSTEM		
Description	Anal.	Time	Description	Anal.	Time	Description	Anal.	Time
1. Reach to Pin	A13D	67	1. Pick-Up Pin (10"-15")	P/U-M	190	1. Pick-Up Pin and assemble to hole 1/4"	15"-2	300 .
2. Grasp Pin	CYL	40						
3. Carry to Hole	A13DS	88						
4. Align to Hole	1½A1S	39	2. Assemble Pin to hole	2-E	90			
5. Upright	A1S	26						
6. Insert	A1	18						
7. Release Pin	½F1	8	3. Release	RL-G	10			
TOTAL UNITS		286	TOTAL UNITS		290	TOTAL UNITS		300
Select time in minutes		.0286	Select time in minutes		.029	Select time in minutes		.030
No. of time values required		7	No. of time values required		3	No. of time values required		1

Note that the Detailed System requires 7 time values, the Simplified System 3, and the Abbreviated System only one.

The reaching distance of 13" was selected because it is an average of one of the classifications in the Simplified System (10"-15").

Figure 3

WORK-FACTOR AND STANDARD DATA

After having compared the three WORK-FACTOR Systems, it becomes rather easy to see how WORK-FACTOR is applied to the construction of standard data. It is simply a matter of building large units of time by putting together the elemental motion times in the combinations which occur in the class of work for which the standards are being compiled.

One of the chief advantages of WORK-FACTOR in compiling standard data is that it often requires less than half the man-hours required when the stopwatch is used. This is because all part sizes, distances, and other variables can be analyzed at one time, whether they occur during the study or not. The use of the stopwatch usually requires many studies over long periods of time to cover all conditions. Compiling data this way is slow if all details are written into the studies, and sometimes highly inaccurate because of difficulty in interpreting the old stopwatch studies when the data is finally put together.

Taking a look at the results of the three systems side by side, and with standard data, they appear like this:

Punch Press Operation - 1st. Draw. on Olds Case
Comparison of Three WORK-FACTOR Systems

	Select Time	No. of Values	Approx. Quantity Range	Cycle Limitation
Detailed	.2195	43	All	None
Simplified	.2230	8	500-50000	.15 up
Abbreviated	.2480	5	1-499	1.00 up
Standard Data	.230	3	All	None

Note that, while both the Detailed System and standard data are adequate to measure all work quantities and cycles, it may not be practical to do so; hence, the simpler systems may be better suited for speed in rate setting, and, at the same time, providing satisfactory accuracy.

WORK-FACTOR AS AN AID IN INCREASING PRODUCTION

I think most of us are familiar with the fact that, whenever attention is focused on a problem, it is usually possible to find a way to solve it. We all know, too, that if we apply ourselves to the task, we can improve just about any operation we tackle. It is not so much the need for a knowledge of how to be more efficient, it is really a need for attention to the problem of being more efficient.

In applying WORK-FACTOR (or any motion time system), an inherent part of the rate setting procedure is paying attention to the motions used by the operator during the study. Hence, the timestudy engineer practically is forced to decide whether or not each motion is necessary. Hence, again, he finds himself automatically establishing an efficient motion pattern on which to base his WORK-FACTOR timestudy.

Speaking conservatively, based on our experiences during the past sixteen years in industry, we have found that on an average, when WORK-FACTOR replaces the stopwatch, the increase in productivity is about 20%. Of course, this varies with the plant's efficiency before the installation of WORK-FACTOR. Some plants increase by 30%, and some by less than 10%. This increase does not cause hardship to the workers. It is largely a result of establishing better motion patterns, better tools, and better work-places.

It is my sincere belief that, if all of our activities in this great country were subjected to a careful motion time analysis and rates of output established accordingly, we could step up national output by 20% without adding a single piece of new equipment!

Applied to government white collar activities, this could mean stupendous reductions in taxes. Applied to defense production, it could increase manufacturing

capacity by 1/5 without the addition of as much as one new plant. The possibilities for good are almost unlimited.

In 1947, I had the pleasure of speaking before the Industrial Management Society in Chicago. At that time, I expressed the belief that in ten years industry would look with disfavor on the stopwatch and that the use of standard motion times would be well on its way to being a necessity both from a labor and management standpoint. To the best of my knowledge, WORK-FACTOR was then the only commercially applied, published system of motion times. I believe it is the original and oldest such system now in existence. However, a text of motion times was published in 1948, articles are beginning to appear in periodicals, and many engineers today seem to accept the fact that the stopwatch needs a little bolstering. Three of the ten years are gone, but progress usually is slower in the early stages than in the later stages. Sizing up the trends and borrowing a phrase from Mr. Winchell--I predict that by 1957, your plant will be behind the parade if you have not installed or made plans to install a system of timestudy which does not require the stopwatch.

I sincerely urge that you give consideration to the use of standard moving times. If you are not ready yet for setting your rates with it, at least use the values to help you be consistent in your leveling and to help with improving your methods. Then when your confidence increases, perhaps you will want to set aside your stopwatch.

METHODS-TIME MEASUREMENT APPLICATION EXPERIENCES

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In May of 1948 a new book was launched by the McGraw-Hill Book Company. This book was called "Methods-Time Measurement," and it described the results of the researches of its authors, Maynard, Stegemerten, and Schwab, in the field of predetermined motion time standards. When the book was finally published, there was a brief period of calm, but then things began to happen at an accelerating tempo. Interest in the procedure began to mount, and we were increasingly asked to tell about it in talks like this one. Recently I made a check and found that over a period of five months our organization averaged better than one formal talk each week on the subject of methods-time measurement.

First of all, let us see why methods-time measurement or MTM was developed at all. Many, many people today are stressing the point that the human problems are the most important which we face at the present time in industry. Speaker after speaker calls on his audience to pay more attention to the human factors in our industrial life. They tell us that technical advancement has outstripped social advancement and that we must improve our human relationships if we are to be able to enjoy the material comforts which our advanced technology can bring us.

All this is fine, and certainly any thinking American who understands present-day industry would agree that such things need to be said. The only trouble is that most speakers talk to us in terms of generalities. They appeal to us on an emotional basis. They may get us all steamed up about improving human relations in industry, but most of them do not tell us specifically how to do it. As an inevitable result, our emotional urge to do something wears off for lack of a means of satisfying it, and very shortly we are right back where we started from.

Now I do not mean to imply that methods-time measurement is the answer to all human relations problems in industry. Obviously, that would be foolish. It is interesting to note, however, that the idea of methods-time measurement was originally conceived because of the recognition of a human problem. It was developed to solve this human problem rather than to solve a technical problem. As we shall see presently, it not only solved the problem it originally set out to solve, but several other technical problems as well.

Back in 1940, our firm conducted a methods improvement training program for a large group of methods engineers in one of our major corporations. We discussed such things as the questioning attitude, process charts, and operation analysis. We encouraged the trainees to make practical applications of these procedures in the shop. As a result of these applications by the time the program was finished, cost reductions had been made totalling well over one million dollars. Everyone was very much pleased.

Gratifying as this was, we were not too satisfied ourselves. We had the uneasy feeling that we were only accomplishing a fraction of what could be accomplished. In addition, we saw that we were creating human relations problems as a result of improving methods. At length it occurred to us that if "any method can be improved" perhaps it was time that we took a look at our own methods of improving methods to see if we could not find a better way.

When we analyzed what it is that the methods engineer does as he improves methods, we saw at once that he quite often does <u>methods correction</u> work instead of <u>methods engineering</u> work. He studies methods which are already in existence and seeks to improve them by correcting the inefficiencies which he finds. He is forced to do this because all too often he is not directed to do his methods work until after the method has been established and production has started. Thus he appears on the scene in the role of fault-finder, criticizing the method established by the foreman, the worker, or others.

It would be far better if he were to make his study of methods <u>before</u> the job is put into production. There is seldom any trouble introducing the first method which is used for doing a task. Therefore, if the first method is a good, efficient method so that subsequent methods correction is unnecessary, the human relations situation will be greatly improved.

Now, if the methods engineer is to be able to determine what the best method for doing any job is before it goes into production, obviously he needs a better tool than motion and time study. Motion study is a study of the motions used by an operator who is already doing the job. Time study is the measuring of the length of time it takes an operator to perform a task. In both cases, someone must be doing a job before the procedures can be applied. What the methods engineer needs, therefore, if he is to study and develop a method before production starts is a procedure which will tell him how long it will take to perform any motion sequence he may be able to think of without having first to train an operator to follow it and then to time it with a stop watch. With such a procedure, the methods engineer can at last get away from methods correction and begin to do true methods engineering. As a result, one of the causes for unrest in industry will be eliminated.

This was the line of reasoning which led to the development of the methods-time measurement procedure. It was developed with the basic objective of improving human relations on the job. Experience has shown that it accomplishes this objective. As a matter of fact, it succeeded beyond our original anticipation in a way that was to become so spectacular that it overshadowed our original objectives.

The methods-time measurement procedure has made it possible to establish production standards without using a stop watch. Now there is nothing particularly wrong about a stop watch. It is a perfectly good measuring device. However, the stop watch has been so abused by the self-styled efficiency experts, the speed-up people, and the fumblers who did not know how to use it properly that an emotional prejudice has been built up against it throughout the world which we cannot do otherwise than recognize. Stop watch time study is an extremely useful tool which gives excellent results when properly applied. It will always be used where machine or process time must be measured.

At the same time, it is readily apparent that any procedure which does away with the necessity for using a stop watch will bring about a marked improvement in human relations. If at the same time, the procedure can eliminate the necessity for rating the performance of the operator so that the engineer does not have to perform the controversial task of saying how fast or how slow in his judgment the operator is working, then indeed will one of the major causes of human relations problems in methods engineering have been eliminated.

This, of course, is just what the methods-time measurement procedure does. It is a technical thing to be sure, an engineering tool of management, but it is also a practical means of improving human relations in industry. It is the kind of development which is eventually going to bring us to a better human situation in our working lives.

The methods-time measurement procedure itself is quite simple, although a period of careful training is necessary before it can be applied properly. The procedure recognizes a few basic motions which are used over and over again in varying combinations and sequences to perform all manner of industrial work. The most important of these basic motions are

        REACH
        MOVE
        TURN
        GRASP
        POSITION
        RELEASE
        DISENGAGE
      – BODY MOTIONS

Time standards have been determined as the result of the extensive analysis of motion picture films of industrial operations for these basic motions under all of the variable conditions under which they are made.

To use these standards, the method of performing a given operation is analyzed to determine what motions are used. Each motion is then classified with respect to the variables which affect it. For example, the variables that affect a Reach motion are length of the motion, classification of motion, and whether or not the hand is in motion at the beginning and/or at the end of the Reach. When each motion has been classified, it is recorded so that it may be subjected to further study.

This analysis and classification may be accomplished in either of two ways. The methods engineer may observe the operation as it is being performed by an operator and thus determine the motions being used. If he is thoroughly familiar with the class of work under study, it is not necessary actually to observe the operation. Instead he may visualize the motions which would be employed to perform the task.

When all motions have been identified, classified, and recorded, the time value for each motion is determined from tables of predetermined methods-time data. These tables are quite compact and all fit on a small pocket size card. The sum of the individual motion-times gives the time required to perform the operation by an operator of average skill working with average effort under average conditions. It does not include allowances for fatigue or personal or unavoidable delays.

Perhaps the best way of explaining how MTM works is to consider how a simple element would be handled by time study and by methods-time measurement. Assume first that in making a time study the time study engineer describes the first element of a certain operation as "get part and move to assembly position." This is a typical time study element description, but it does not tell much about the method. To determine the time for performing

this element, the time study engineer would time a number of cycles and then perform a series of computations. He might eventually arrive at the fact that it should take .00062 hour to perform the element at the average performance level without allowances.

During the course of the time study, the study engineer would observe the method used to perform the element as closely as he could between the times that his eyes were focused on his stop watch and the observation sheet. As a result, he might be able to tell someone else within an hour or two after the study was taken just how the element was performed. After that, he might not be so sure. Certainly another time study engineer looking over the study later on and seeing only "Get part and move to assembly position, " .00062 hour, would have no accurate knowledge of the method employed.

Going a step further, let us assume that a month or two later the operator changes the method and begins to earn a 100% bonus when a 25% bonus is normal expectancy. A time study engineer is asked to look into the matter and determine the reasons. He observes the operation and checks against the original study. The operator is still performing the first element of "Get part and move to assembly position. " This sounds the same as before. The time study engineer makes a check study and finds that the time required to perform the element at the normal performance level is only .00034 hour. He finds this difficult to explain. The method seems the same but the time required is much less.

In such cases, the time study engineer is quite likely to decide that the operator may possess exceptional skill which the levelling factors are not large enough to compensate for or that the first time study engineer must have used different division points when he broke the operation down into its elements, or the most common example of vague thinking of all--that "conditions" must have been different.

The methods-time measurement procedure avoids all this inexactness. The procedure calls first for analyzing, classifying, and recording motions. Let us see how the element "Get part and move to assembly position" would be handled, using for the sake of simplicity, the quicker method mentioned before. The first step would be to observe the element accurately to determine the motions used to perform it. The observer finds that the element is performed entirely with the right hand. Starting from a point close to the front of his body, the operator reaches for the part which is by itself on the work bench. He grasps it, moves it to the assembly position, releases it, and returns his hand to a point which is approximately where he started from.

To facilitate the recording of motions, a set of conventions has been developed. The first motion used to perform this element is that of moving the hand to the part. Using the conventions the motion is described as R10B. The R signifies that it is a Reach. The 10 signifies that the Reach is ten inches long. The B signifies that it is a Case B Reach. The complete description of the element would be as follows:

TMU		Right Hand
11.5	R10B	Reach to part
1.7	G1A	Grasp part
8.9	M6B	Move part to assembly position
1.7	RL1	Release part
10.5	R10E	Return hand to starting position
34.3 = .000343 hour		

The chart indicates to those trained in the methods-time measurement procedure that the Reach was followed by a G1A Grasp which is a pick-up Grasp of a small, me-

dium, or large object by itself in an easy grasping position. M6B indicates that the object is moved six inches to an approximate location. RL1 shows that the part was released with a normal release performed by opening the fingers as an independent motion. R10E signifies that the hand was moved ten inches to an indefinite location to get hand in position for body balance or next motion or out of the way.

Knowing the exact nature of the motions required to perform the element "Get part and move to assembly position," the time required to perform the work may easily be determined. All that is necessary is to refer to the tables of methods-time data and pick out the proper times. All time values represent average or normal performance time without allowances. For convenience in handling and to avoid the necessity of writing a large number of zeros, time is expressed in arbitrary units of measurement known as Time Measurement Units. This is readily abbreviated to TMU. One TMU is equal to .00001 hour. Thus to convert TMU's to decimal hours it is necessary merely to multiply by .00001.

On the chart, the time for each motion is shown in TMU. The sum of the motion times is 34.3 TMU which is .000343 hour.

With a description of the method available such as is provided by the chart, it is quite easy to determine at any subsequent time whether or not the method has changed. All that is necessary to do is to observe the operation as it is being performed and analyze, classify, and record the motions. If the method has not changed, the descriptions will be just as they were before. If it has changed, they will be different.

For example, another method of performing the element "Get part and move to assembly position" might be as follows:

Left Hand	TMU	Right Hand
R14C	16.9	
G4B	9.1	
M10A	11.3	
	5.6	G3
	6.9	M4B
	1.7	RL1
	10.5	R10E
	62.0	

This signifies that the left hand reaches 14 inches to a group of objects; the part is selected from the group and grasped; it is then moved to the right hand and transferred to it; the right hand then moves it four inches to an approximate location, releases it, and finally returns 10 inches to an indefinite location. This is an entirely practical method of performing the element, but it requires nearly twice as long as the other.

Some of the practical uses of the methods-time measurement procedure should now be beginning to become apparent. The procedure provides an exact record of method. It permits the establishing of standards without stop watch time study. But perhaps most important of all, it permits a detailed study of methods which makes it possible to select with certainty the best known method of performing any task.

As a means of trying to maintain an objective viewpoint, I now discuss MTM by describing several different but typical experiences which others have had in the application of the procedure. Then I shall point out some of the conclusions which may be drawn from these experiences, so that we shall develop a picture of the way the MTM tool is being used at the present time.

Here is the first case. A manufacturer of thermostatic controls had been making a control for gas water heaters for several years by a job lot method. At length, the volume became sufficient to justify the installation of a progressive assembly line so they decided to set up the

The first step was to develop in a methods laboratory the various workplaces required. The motions that would be used to perform each operation were carefully studied and recorded. This gave the exact time required to perform each operation. These times were then compared with the balancing factor for the line, and work was either added to or taken from the operations until they were all balanced. At the same time, the motion patterns were analyzed from a work simplification standpoint, and the methods and workplaces were perfected.

Next, the line was completely set up and all of the workplaces were thoroughly tested and checked. From the motion patterns that were developed as a result of the MTM analyses, detailed operator instruction cards were prepared for each operation before the line was actually manned. The production standard for the line was also established in advance. This standard was announced to the operators the first day the line was started and, furthermore, was guaranteed not to be changed.

When completed, the line consisted of 19 stations. Previous experience with similar production lines in this plant indicated that it would normally take three to four weeks from the date it was put into operation to balance such a line and to arrive at a final production standard. It would then take an additional week or two to bring the line up to standard. The actual results were that the line was in perfect balance from the very first day. It required a total of only three days to train the operators to the point where they were meeting the production standards. In addition, practically all of the difficulties normally encountered in working out methods improvements, eliminating bottleneck operations, and in overcoming operation resistance to changes, were eliminated.

Productivity was increased by 50 per cent over the previous method of manufacture. This increase was largely due to the methods improvements developed by the use of MTM during the first step in the installation. At the present time, the line has been in operation for a year and a half. Only minor changes have been made in the original workplaces, no change has been made in the original production standards, and the operators are currently working at 18 per cent above standard.

The conclusions to be drawn from this case are several. The most important of those which we have not already discussed are:

1. MTM offers an improved tool for setting up progressive assembly lines.
2. MTM greatly improves human relations when installing progressive assembly lines.
3. MTM reduces the time required to attain the standard performance level and provides the opportunity of substantial but not runaway incentive earnings.
4. MTM is a tool which permits the development of good methods in advance of beginning production.

Case 2. An interesting case of the use of methods-time measurement for the development of time formulas occurred at the plant of a manufacturer of large industrial filtration equipment. Time formulas are compilations of time data which make it possible to establish accurate and consistent time standards without the necessity of studying each individual job. They provide the only practical means yet developed for establishing standards economically on low

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quantity work. Time formulas developed from time study data have been used by industry for years. Time formulas derived from MTM data are a new and important development.

The case I am about to describe is interesting for two reasons:

1. Each piece of equipment manufactured was individually engineered to meet the requirements of a specific installation, the manufacturing lot quantities were unusually small.

2. The operations consisted of large machine shop work of all kinds as well as of plate fabrication and erection work.

Three of the shop personnel were first trained in the theory and fundamentals of the MTM procedure. Then a time formula was developed to cover all operations that could be performed on a 42" engine lathe. The MTM analysts worked on this project as a group, and it was handled as a part of their application training. Following the completion of this formula, the remaining machine tools were assigned to the three individuals, and they worked up time formulas independently. It was soon discovered that the analyst who could themselves actually operate the machines they were studying were most proficient at applying the procedure to a battery of turret lathes, one analyst developed a complete time formula for a milling machine in exactly three days. Most of the elements were derived merely by visualizing the motions required to start and stop the machine, change milling cutters, place work on table, and so on without actually observing an operator. It has been our experience that it would require at least a month to develop the same formula with conventional time study techniques.

In less than four months this group developed time formulas that covered all machine shop work, including layout, half of the plate shop work, and a portion of the erection work. It would normally take close to two years to do this job in the conventional manner.

Some of the conclusions to be drawn from this case are as follows:

1. MTM is applicable to low quantity or jobbing work.

2. MTM reduces the time required to develop a time formula by 75% over the older methods, thus making the application of standards to low quantity work more attractive from an economic standpoint than it has been in the past.

Case 3. A company manufacturing air conditioning equipment decided several months ago to install a wage incentive plan in one of its storerooms. There were nine men in the storeroom at the time doing the kind of work that is typically done in a storeroom. The elements of the work were quite variable.

The methods engineers first determined the elements of work performed in the storeroom. Then either by observation or visualization--usually the latter--they determined the average or normal method which would be used to perform each element. The time required was determined by MTM and finally the formula was developed from these time data.

While this was being done the volume of production doubled. The storeroom work, however, is now being handled by 5 men instead of 9, partly due to methods improvements developed during the analysis and partly due to the more steady application to the work which the wage incentive plan encourages. Performance efficiency is about 25% above average and costs have been materially reduced.

This case confirms some of the conclusions previously drawn and offers an additional point: MTM is applicable to work of an irregular nature.

Case 4. A company manufacturing molded products had a number of very short cycle press operations. A good part of the operation consisted of raising both hands after placing parts in a die and pressing two control buttons which were attached to the front of the press. The operators on this job quite often became afflicted with tenosynovitis which is an inflammation of a tendon and its sheath due to excessive use. Excessive use causes the lubricating fluid normally present in the tendons to be consumed more rapidly than it is supplied. The tendons run dry, and one gets what is popularly called the "squeaks."

In the case we are considering, the "squeaks" occurred in the wrists of the operators. They were caused because the operators used a wrist motion to operate the controls of the press. MTM showed this to be the quickest way of doing the job, but obviously it was undesirable from a human standpoint. MTM also showed that the wrist motion could be avoided by keeping the wrists stiff and moving the arm in an arc to reach the controls. This required slightly more time, but it would eliminate the "squeaks." Therefore, all standards were based on the longer but less harmful method, and the operators were instructed to follow it, at least most of the time.

Possibly this condition could have been recognized by an alert time study man, but it was not. The cycle was quite short, and in all probability the time study man was too busy recording watch readings to notice the excessive use of the wrists. In any event, because the operators made only normal incentive earnings and because they suffered periodically from the "squeaks," it must be assumed that the time study standards were based on the harmful method. MTM brought this to light and enabled management to establish standards based on a method which it knew was a safe, harmless method. From this we may conclude: MTM can be helpful in establishing safe, non-fatiguing methods and hence can help improve the health of the workers.

Case 5. Cornell University has recently issued a report entitled "A Study of the Extent to which Methods-Time Measurement Application Data can be Reproduced." The object of this study was "to determine to what extent it is possible to reproduce by independent investigation, the time values for elemental motion times." Professor White took a number of motion pictures of operations being performed in plants in and around Ithaca, New York. He analyzed the resulting films, doing his own performance rating, working up his data independently, and arriving at his own conclusion. His conclusions, which shall be ours for this case, are in part as follows:

1. The data compiled from studies under this project indicate that time values for elemental motions, as defined in the Methods-Time Measurement system of predetermined elemental motion times, can be reproduced for a large majority of the elements within what are considered to be reasonable limits.

2. The time differences between check times and MTM times for all elements studied are distributed very nearly uniformly between positive and negative differences such that the mean of all check times for all elements analyzed is 2452.6 TMU's compared to 2459.2 TMU's for the corresponding MTM element times.

3. The operators on the operations analyzed were exceeding the levelled times established for the elements Reach and Move on the average

by approximately 10 to 20 per cent.

Slides prepared from Professor White's report on his findings were shown.

Figure 1. <u>Reach</u> -- <u>Case B</u> -- <u>Actual Data</u>

This slide shows the time vs. distance relationship for the actual data obtained on the Case B Reach. The time is the time actually taken by the operator and is not adjusted for performance.

The times were determined from motion picture film frame counts. In effect the camera is used as the measuring instrument. Most of the pictures were taken at 1,000 frames a minute. The small points represent data for a single operation. The circled points represent the mean time for all data at a given distance.
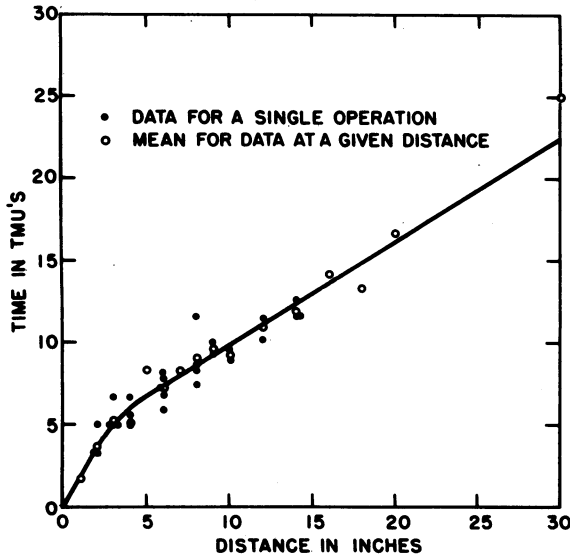
TIME vs DISTANCE FOR ACTUAL DATA

REACH - CASE B

"REACH TO SINGLE OBJECT IN LOCATION WHICH MAY VARY SLIGHTLY FROM CYCLE TO CYCLE."

Figure 1

Figure 2. <u>Reach</u> -- <u>Case B</u> -- <u>Levelled Data</u>

Here is the same set of data after they had been levelled for the performance of the operator. The levelling was done by Professor White at the time the film was taken. No supplementary lighting was used in taking the pictures, nor were the original workplaces changed in any respect. Those of you who have had any experience in plotting similar data for time study purposes will agree, I am sure, that the points line up remarkably well.

Figure 3. <u>Reach</u> -- <u>Case B</u> -- <u>Table</u>

Here are the same data in tabular form. Professor White's data are listed in the two columns labelled "Check Study." The first column lists the actual time in TMU's for various distances and the second column shows the same data after they have been levelled. The next column shows the MTM times for the same motions. The column that follows indicates the difference between the check

times and the MTM times. The differences range from 0 to .6 TMU. Since the value of one TMU is approximately 1/30 of a second, the maximum difference here is roughly 1/50 of a second.

The last column shows the ratio of the levelled time to the actual time, or in effect, the levelling factors. These range from 1.00 to 1.18.
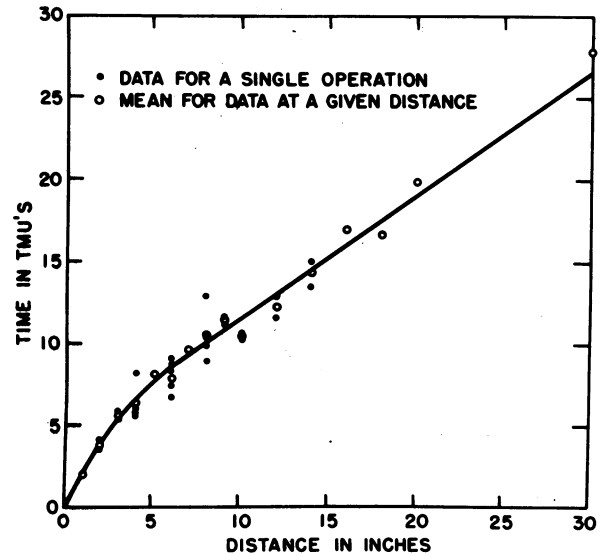
TIME vs DISTANCE FOR LEVELLED DATA

REACH - CASE B

"REACH TO SINGLE OBJECT IN LOCATION WHICH MAY VARY SLIGHTLY FROM CYCLE TO CYCLE."

Figure 2

	REACH - Case B				
"Reach to single object in location which may vary slightly from cycle to cycle."					
	Check Study				Ratio of
Distance	Actual Time in TMU's	Levelled Time in TMU's	MTM Time in TMU's	Difference Check-MTM	Levelled Time / Actual Time
1	1.9	1.9	2.1	-.2	1.00
2	3.7	3.9	4.3	-.4	1.05
3	5.1	5.4	5.9	-.5	1.06
4	6.0	6.6	7.1	-.5	1.10
5	6.8	7.6	7.8	-.2	1.12
6	7.4	8.5	8.6	-.1	1.15
7	8.0	9.3	9.3	0	1.16
8	8.7	10.1	10.1	0	1.16
9	9.3	10.8	10.8	0	1.16
10	9.9	11.6	11.6	0	1.17
12	11.2	13.0	12.9	.1	1.16
14	12.4	14.5	14.4	.1	1.17
16	13.7	16.0	15.8	.2	1.17
18	14.9	17.5	17.2	.3	1.17
20	16.2	19.0	18.6	.4	1.17
22	17.4	20.5	20.1	.4	1.18
24	18.7	22.0	21.5	.5	1.18
26	20.0	23.5	22.9	.6	1.18
28	21.2	24.9	24.4	.5	1.18
30	22.5	26.4	25.8	.6	1.17

Figure 3

Figure 4. <u>Check Data and MTM Data</u> -- <u>Reach</u> -- <u>Case B</u>

This figure is a graphical comparison of the check data and the original MTM data for the case B Reach. The solid line curve represents the check data and the broken line curve the MTM data. As you can see, the two curves are practically super-imposed and show remarkable correlation between Cornell's data and the original MTM data.
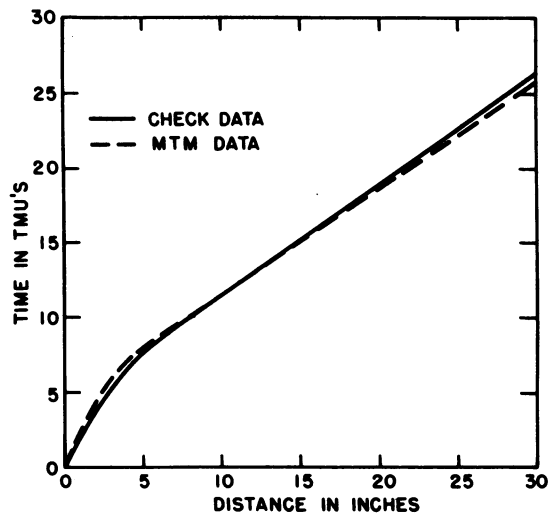
COMPARISON OF CHECK DATA WITH MTM DATA REACH-CASE B
"REACH TO SINGLE OBJECT IN LOCATION WHICH MAY VARY
SLIGHTLY FROM CYCLE TO CYCLE."

Figure 4

Figure 5. Move -- Case C -- Actual Data

Here we have another time vs. distance curve. This time it is for the Case C Move--which is the move employed in moving an object to an exact location. The data this time are the actual data before they were levelled.
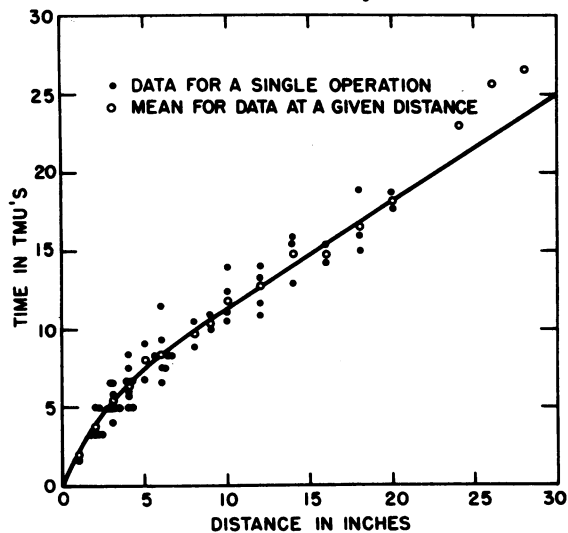
TIME vs DISTANCE FOR ACTUAL DATA
MOVE - CASE C
"MOVE OBJECT TO EXACT LOCATION."
Figure 5

Figure 6. Move -- Case C -- Levelled Data

This figure shows the same data after they have been levelled. In looking back at the previous figure you will notice that the levelling procedure tends to reduce the variation between the mean times and the individual studies.
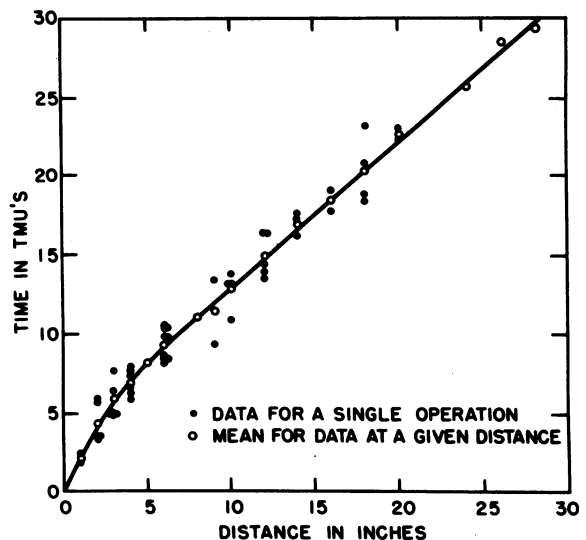
TIME vs DISTANCE FOR LEVELLED DATA
MOVE - CASE C
"MOVE OBJECT TO EXACT LOCATION."
Figure 6

Figure 7. Move -- Case C -- Table

Again we have a table showing the comparison of check data and the original MTM data. Here the differences range from 0 to .9 TMU. The ratio of levelled time to actual time ranges from 1.00 to 1.26.

	MOVE - Case C			
	"Move object to an exact location"			
Distance	Check Study		MTM Time in TMU's	Difference Check-MTM	Ratio of Levelled Time/Actual Time
	Actual Time in TMU's	Levelled Time in TMU's			
1	2.3	2.3	1.7	0.6	1.00
2	4.0	4.1	4.2	-.1	1.03
3	5.4	5.6	5.7	-.1	1.04
4	6.5	6.9	7.3	-.4	1.06
5	7.5	8.1	8.7	-.6	1.08
6	8.4	9.1	9.7	-.6	1.08
7	9.2	10.1	10.8	-.7	1.10
8	10.0	11.0	11.8	-.8	1.10
9	10.7	12.0	12.7	-.7	1.12
10	11.3	12.9	13.5	-.6	1.14
12	12.7	14.7	15.2	-.5	1.16
14	14.0	16.6	16.8	-.2	1.18
16	15.4	18.5	18.7	-.2	1.20
18	16.8	20.3	20.4	-.1	1.21
20	18.1	22.2	22.1	.1	1.22
22	19.5	24.1	23.8	.3	1.23
24	20.9	26.0	25.5	.5	1.24
26	22.3	27.9	27.3	.6	1.25
28	23.6	29.7	29.0	.7	1.26
30	25.0	31.6	30.7	.9	1.26

Figure 7

Figure 8. Check Data and MTM Data -- Move -- Case C

Here is the graphical relationship between the check data and the MTM data for the Case C Move. Again you will notice the close correlation between the two curves. The Cornell data are again represented by the solid line and the MTM data by the broken line.
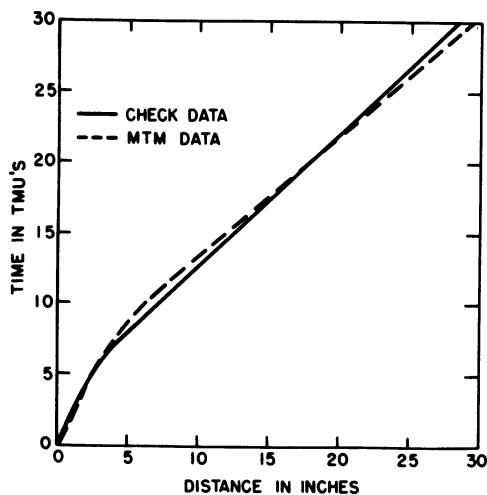
COMPARISON OF CHECK DATA WITH MTM DATA FOR MOVE - CASE C,
"MOVE OBJECT TO AN EXACT LOCATION."

Figure 8

The most significant conclusion to be drawn from Professor White's study seems to be the fact that the MTM data are basic in nature. There is such a thing as a constant basic time which any normal operator will take to perform a basic motion of work under a given set of conditions. This time can be reproduced independently by others from independent data providing they follow the systems of motion classification and methods of measurement which were followed when MTM was originally developed.

Furthermore, the evidence seems to be pointing to the fact that these basic motion times apply not only to American workers but to workers in other countries as well. At least we have up to the present time found by actual personal experience that they apply in Australia, Sweden, and Canada. Investigators trained by us have found the same to be true in Finland and Great Britain. Correspondence which we have had with people in Holland, Germany, and France who have tried to apply MTM on their own after reading the book, has indicated that the procedure works there satisfactorily too.

I could go on with numerous other case examples of different kinds of MTM applications, but I believe I have given enough to paint in broad outline at least a picture of the kind of things that are being accomplished by MTM. I would like to conclude, therefore, with a few remarks about the way the use of MTM is being spread at the present time.

It has been our policy from the very outset to make the methods-time measurement procedure freely available to anyone who may wish to use it. We feel that the approach to work measurement and methods improvement which the procedure represents is too valuable to the industrial engineering profession as a whole to warrant attempting to keep the procedure as the private property of those who developed it. If it is basic in nature--and there is growing evidence that it is--then the procedure must belong to everyone.

The first step in making the procedure available was to publish in 1948 the book, "Methods-Time Measurement." We set forth in that book all that we had learned about motions and motion times up to date of publication. We soon learned, however, that people were having difficulty in trying to apply the procedure after merely reading the book, no no matter how carefully they read it. It is difficult to describe in static words something as dynamic as a motion, and it became evident that more was needed to show others how to use MTM.

This led us to begin to undertake training work in the field of MTM. The training programs have ranged from comparatively brief three-week programs held at our Training Center at Pittsburgh to comprehensive in-plant programs complete with guided application practice for technicians and a supporting supervisory training program for foremen and other key non-technical personnel. We have included in our training programs professors from universities and colleges and men from other management consulting firms. And as a result the number of available sources of training is beginning to multiply. This I believe is desirable, for as we go into the all out production period which lies ahead, we shall need every tool for increasing productivity which is available. The MTM procedure has by this time demonstrated its value beyond question. We feel no hesitation in recommending its expanding use.

I hope that those of you who have not yet looked into the MTM procedure will do so. It is a tool of many uses not all of which I have covered here. Most of all, it is a tool of methods improvement, and methods improvements are vitally needed now to conserve our manpower and to increase our national productivity.

LUNCHEON SESSION

THE PLACE OF INDUSTRIAL ENGINEERING ON THE MANAGEMENT TEAM

R. Conrad Cooper, Vice-President,

Industrial Engineering, United States Steel Company,

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In my discussion of the place of industrial engineering on the management team I shall confine myself to one specific case history regarding which I have some first-hand information. Accordingly, we will confine our considerations to the subject as it is viewed in United States Steel. Whether the conclusions we have reached with respect to our problems are applicable or of assistance to you in relation to your problems will be left for you to judge.

Our views in United States Steel emerge from a number of searching inquiries and the process of evolution. One can scarcely begin to consider the question of the place of industrial engineering on the management team without encountering the collateral question of the place of other functions on the management team. To the uninitiated it might suffice to say that the members of the management team are those who perform management functions.

If this question is pursued, however, the further question of what are the functions of management is sure to arise. We have made an extensive inquiry into the subject of management functions. In part we concluded that accurate information as to the authority, responsibility and duties of each management position in the Company is essential to common understanding and maximum effectiveness in the discharge of management's obligations. Such information is required in clear and concise form, developed in full light of the following fundamentals.

It is the objective of the Company to make regularly and consistently the most effective use of its entire resources for the benefit of the owners, employees, customers and public by providing: (1) investment return sufficient to induce further investment; (2) employment opportunities and working conditions to attract and retain competent employees; (3) products and services of such merit as to secure and improve the Company's competitive position; and (4) a high standard of service to the Nation.

The Company's requirements, for the attainment of that objective, are: (1) adequate manufacturing facilities; (2) necessary supplies of raw materials; (3) qualified managing and technical personnel; (4) competent skilled, semi-skilled and non-skilled work force; (5) sufficient capital; (6) adequate markets; (7) the public good will; and (8) sound policies of administration under management's exclusive control.

Those who provide and control the Company's requirements, plan and regulate its operations, lead and direct its working forces, and perform related duties which are an inherent part of the Company's control are the Company's management. The president of the Company plans, establishes, authorizes and staffs the Company's executive management structure. Within the framework of the structure so established, the chief executive of each division of the Company's executive management plans, establishes, authorizes and staffs a subsection of the management structure for his respective area of authority and responsibility. The inter-relationship of those subsections of the management structure must be of such nature that in the exercise of their authorities and the discharge of their responsibilities, the occupants thereof may perform as a team of managers with the single dominant purpose of attaining the Company's objective. While performing as individual managers within their respective areas of authority and responsibility, the Company's managing personnel must perform as a single management entity in the common endeavor. That entity cannot be divided without destroying the unity that is essential to effective conduct of the business.

In the exercise of their requisite authorities and the discharge of their separate responsibilities the Company's managing personnel as a team must perform the overall management duties to:

1. Provide, maintain and effectively utilize the required force of qualified employees.
2. Provide, maintain and effectively utilize the required equipment and facilities.
3. Provide, maintain and effectively utilize the necessary supplies, materials and services.
4. Provide and maintain safe and sanitary working conditions.
5. Establish and maintain equitable compensation rates, procedures and practices.
6. Establish, determine, and enforce compliance with the required standards, controls, instructions and specifications.
7. Develop and improve products, processes, methods, practices and procedures.
8. Plan and direct the operations, effectively coordinating all related activities.
9. Maintain effective discipline and harmonious employee relations.
10. Market and supply the product required by customers.
11. Manage, control and protect the assets, finances and accounts of the Company.

Those eleven functions of management obviously are but major overall responsibilities stated in very broad terms. However, they serve to convey a general description of management. Also they form a good base from which to develop a description of industrial engineering. This we have done by considering the extent to which each of the eleven major functions of management contains factors related to one or more of the recognized branches of industrial engineering service.

First, let us look at management's responsibility to provide, maintain,and effectively utilize the required force of qualified employees. Measurement of the amount of work involved in the performance of each given job is the foundation of fact from which to determine the required force of employees. Regardless of whether such determinations are made by supervisors or by industrial engineers identified as such, the fact remains that if made in any systematic manner they are determinations of industrial engineering nature. We term this the field of labor measurement.

Effective utilization of the work force is contingent upon employee performance. The relationship of wage incentives to employee performance needs no emphasis. Clearly the determination of incentives is an industrial engineering action, no matter by whom performed.

Next let us examine management's responsibility to provide, maintain, and effectively utilize the required equipment and facilities. Measurements as to the capabilities or capacities of the tools of production are the foundations of fact from which to determine the required amounts of equipment and facilities. It is our experience that in one way or another the human equation is involved at the core of every operation. The machines do not operate themselves. They must be regulated by people. Thus measurements regarding capabilities of the tools of production involve not only the physical capacities of equipment, they are inseparably involved with the human matters of labor measurement and employee performance. Clearly, therefore, industrial engineering is involved in such determinations.

In like manner, management's responsibility to provide, maintain, and effectively utilize the necessary supplies, materials, and services involves industrial engineering work. We term the combined activities of measuring the required amounts of equipment and materials as the field of equipment and material utilization.

Industrial engineering determinations of labor measurement nature bear directly on management's responsibility to provide and maintain safe and sanitary working conditions. An example of the relationship is found in our labor agreements which specify that:

"The purpose of the Company and the Union.....
is.....to achieve the highest level of employee performance consistent with safety, good health, and sustained effort. "

We turn now to management's responsibility to establish and maintain equitable compensation rates, procedures, and practices. The inseparable relationship of this responsibility and the industrial engineering field of wage and salary evaluation needs no emphasis. To the extent that factual determinations as to the required amounts of equipment, materials, and personnel are involved, industrial engineering has a function in connection with management's obligation to establish, determine, and enforce compliance with the required standards, controls, instructions and specifications.

Let us now look at management's obligation to develop and improve products, processes, methods, practices, and procedures. The root of these activities rests in factual determinations and research. The connection between industrial engineering work and the development of improved methods is so well recognized that no further comment is required. We speak of the industrial engineering work in this field as methods and standard practices.

The work of industrial engineering has significant bearing on the management responsibility to plan and direct the operations, effectively correlating the related activities. The precision with which operations can be planned is directly measured by the accuracy of the available information as to the amounts of equipment, materials, and personnel that are required to do a given thing. The determinations of such information, as we have already seen, have aspects that are industrial engineering in character. Such determinations not only facilitate the planning of operations but they serve as the foundation of fact from which to measure and judge the effectiveness with which each operation is performed. Obviously, of course, the accuracy of such measurements and judgments of performance are no better and no worse than the accuracy of the factual basis from which they are drawn.

At first glance one might think that industrial engineering has no direct connection with management's responsibility to maintain effective discipline and harmonious employee relations. This erroneous idea can be dispelled quite readily by looking at one provision of our labor agreements which specifies that:

"The fundamental principle of the work and wage relationship is that the employee is entitled to a fair day's pay and the Company is entitled to a fair day's work. "

Thus with fair pay rates and fair performance standards being at one and the same time the foundation for harmonious employee relations and the essence of industrial engineering, the connection between the two subjects is inescapable.

One may wonder as to the relationship between industrial engineering and management's responsibility to market and supply the product required by customers. There is of course the possible connection of salary evaluation and related matters bearing on the Company's sales personnel. However, we recognize another connection of fundamental importance. Enlightened pricing schedules bespeak the necessity for a modern standard cost accounting system which in turn rests on basic standards expressing the amounts of equipment, materials, and personnel required: (a) to perform the necessary operations in the required time; (b) to manufacture a given unit of product; (c) under specified standard conditions. The development of such basic standards is industrial engineering work, and hence the connection with marketing functions.

This brings us to management's responsibility to manage, control, and protect the assets, finances, and accounts of the Company. The relationship between such matters and industrial engineering determinations of fact regarding the required amounts of men, machines, and materials speaks for itself.

This inquiry into the overall functions of the management team produced for us in United States Steel the conclusions that:

1. The subjects of labor measurement, incentives, wage and salary evaluation, methods and standard practices, equipment and material utilization, and basic standards are inter-related and inseparable. Therefore, they require coordinated handling. They combine to form the function of industrial engineering in United States Steel.

2. The factual determinations in such matters form the foundation of yardsticks by which to plan operations, judge performances, and regulate expenditures. Therefore, they are of fundamental importance to the immediate and long-term welfare of the enterprise.

3. The determination and application of such yardsticks involves difficult matters bearing on the direct responsibilities of various administrative

divisions of the Company's management. Therefore, they require a high degree of interdepartmental participation and cooperation.

4. The proper handling of this industrial engineering function requires: (a) full executive recognition of the necessities for such service; (b) assignment of authority and responsibility for the inter-related parts of industrial engineering to a single directing head with executive status; and (c) working arrangements within the management structure through which the industrial engineering executive may coordinate with, serve, and receive the assistance of the executive heads of the other management responsibilities having major related administrative interest, specifically operating, accounting, and industrial relations.

Thus you have a picture of the industrial engineering function in relation to the overall functions of management as we see it.

Let us digress for a moment from the management team to another kind of team. It is one thing to describe generally the position of center in football as it relates to the team as a whole. It is quite another matter to describe the specific actions the center must take in order to play his part of the game. Both descriptions are necessary to anyone proposing to be a successful center. Furthermore, a fairly complete knowledge of both descriptions is necessary to anyone proposing to play successfully at any other position on the team. Likewise the center must have more than a passing acquaintanceship with both the overall functions and the specific assignments of the other players on the team. Otherwise, when he should be in the line doing his own job, he may find himself in the backfield interfering with the ball carrier instead of interfering for him. Or more probably, he may soon find himself warming the bench. The same relationship is true with respect to the position of industrial engineer and all other positions on the management team.

Our discussion so far has touched only upon the function of industrial engineering as related to the overall functions of management. We have found that the industrial engineer's place on the management team cannot be described adequately without specific reference to the kinds of actions required of him, and of those with whom he is most closely associated in the performance of his work. Therefore, I propose to touch upon the kinds of actions required of the industrial engineer and the other management positions immediately at interest. Again we report conclusions that result from considerable inquiry.

We approach this inquiry by examining the component parts of the several subjects involved in the overall industrial engineering function. Let us relate the component parts of industrial engineering to a given operation in the manufacture of a specific product. Men, materials, and machines are involved. The inevitable initial problem is to determine what material on which machine with how many men performing in accordance with what method will produce the desired product at least cost. Once that problem is solved the next problem is to put those determinations into practice and produce the desired product at such minimum cost.

It would be nice if those actions could be taken as easily as they can be stated but such is not the case. Therefore, we must look a little further into the problems of the operation before us. In this examination we will proceed on the basis that:

1. It is management's obligation to develop the least cost way of producing the desired product.

2. It is management's obligation to produce the product in accordance with that least cost way, or such other lower cost way as might become possible at some subsequent date.

3. A development of the least cost way of performing the operation at any given time can come about only if the many problems involved therein are handled respectively by those of the management team best qualified to deal with the different kinds of problems, assuming of course that each member of the team is fully qualified and competent to perform within his assigned field.

This leads us to an examination of the different kinds of problems and to members of the management team best qualified to deal with each kind. First, there is the question of the material required to make the desired product. In our business the specialized knowledge possessed by those engaged in the field of metallurgy generally is best able to supply the necessary answer. Thus, the metallurgists are the members of the management team who normally describe and specify the material to be used. Next is the matter of equipment. Dependent upon the purpose to be accomplished by the operation in converting from material to product, the specialized knowledge of mechanical engineering, electrical engineering, and metallurgy, and the practical knowledge of the direct supervisors of the operation under consideration may all be required in balance to supply the right answer. Accordingly, the responsibility for specifying the machine and the purpose to be accomplished thereby rests between the engineers, metallurgists, and line operators. Those two actions dispose of the physical or inanimate parts of the operation for the moment.

Next is the animate or human part of the operation. The determination of what jobs, how many people, what duties shall each person perform, how much work shall they perform, how much shall they be paid, and a whole host of other collateral questions must be dealt with. Foremost among these for resolution, as the starting point from which to resolve the others, is the question of methods. In this field, those best qualified to develop the answer are the industrial engineer and the line operator. Their functions are inseparably involved and their success is dependent one upon the other.

As we see it the industrial engineer is best qualified to develop the facts with respect to each of the various alternate methods of doing the job. Once these determinations have been made the line operator is best qualified, in light of all of those facts, to determine the practicalities involved in accomplishing the purpose of the operation and to decide officially upon the method to be employed. In our opinion the industrial engineer in this endeavor who goes beyond the functions of factual determination and the presentation thereof in understandable and usable form is like the center playing in the backfield. Also we believe that the operator who is unable or unwilling to make skillful use of those facts imposes a handicap upon the management team as would the ball carrier on a football team who thinks it well to play the game minus a center. No matter how good the individual player may be in his own right as a ball carrier, the team has a better chance to win the game with a full complement of players, each performing his respective assignment and relying upon his teammates to perform their part of the work. Likewise, as we see it, no matter how good an operator may be, he can do a better job when proceeding on the basis of accurate facts, properly and objectively developed through sound industrial engineering procedures, than he can

when proceeding by rule-of-thumb guides. We conclude that the primary role of the industrial engineer in the determination of methods is that of the fact-finder to do the leg work and provide a skillful service to the operator. It then becomes the responsibility of the operator to weigh all elements of the problem and determine the specific method to be employed.

As previously noted, this determination of methods paves the way for a number of subsequent determinations of major importance. It follows logically that the best-known method having been adopted, the statement of such method in written description or specification form, will serve the added endeavors and conserve the time of other members of the management team. Some of you may term such records as manufacturing specifications, standard practice specifications, or other variations. For simplicity we term them operating practice descriptions. The preparation of these descriptions of methods is clearly a procedural and service job which we believe is best handled by the industrial engineer.

At this point in our hypothetical operation the material, the equipment, the crew and the method by which the crew shall use the specified material and equipment to produce the stated product have all been determined. In short, we have passed through the methods and standard practice phase of the development.

A number of further determinations are now in order, most of which are largely technical or procedural and for which industrial engineers or other staff personnel are best qualified. The jobs require description, classification, and appropriate standard wage scale assignment to determine the applicable rates of pay. In our organization the preparation of job descriptions and classifications is looked upon as a technical function to be handled by the industrial engineer. Thereafter, the job descriptions and classifications require negotiation with the union representatives of the employees. The member of the management team best qualified to handle such matters is the industrial relations executive or his designated representative.

We have now passed through the job evaluation phase of the development, and are ready to take up the next determination, namely the rate at which the operation shall be performed. Such determination requires measurement of the work required per unit of product. Thus the industrial engineering determination of labor measurement and the establishment of an appropriate incentive to induce capacity operation of the facility is now in order. In this test tube development we now have the facts from which to calculate the amounts of equipment, material, and personnel required: (a) to perform the necessary operation in the required time; (b) to manufacture a given unit of product; (c) under specified standard conditions. In other words, the industrial engineering function of calculating the basic standards for incorporation into operating controls, production planning, standard costs, pricing schedules and other related management activities can proceed.

From this point forward the real job is to put the foregoing determinations into practice and thereafter produce the desired product at the standard minimum cost. I hardly need point out that the burden of responsibility to produce the product at minimum cost falls upon the line operator, the ball carrier of our team. He must be aided and abetted by the administrative assistance of the other management functions, particularly accounting, industrial relations, and industrial engineering in ways which we will endeavor to describe.

The inquiry we have just been through produces a number of conclusions. It is clear to us that:

1. The common denominator in each action to be taken by the industrial engineer is that he makes determinations of fact for someone else to apply and use. Therefore, his job is to provide a technical service to those who perform the functions of direct line administration.
2. These determinations of fact run to the heart and the blood stream of the enterprise. Therefore, they must be developed objectively and impartially; they must be accurate and hence reliable; and they must be practical and usable.
3. The other members of the management team have a great deal at stake in the activities of industrial engineering. All of their interests are fully protected only when the industrial engineering determinations are both correctly made and properly applied. In some degree the other members of management are in much the same position as the crew members of a bomber whose night flying course is guided by the reckonings of a navigator. All members of the crew are in trouble if the navigator makes a mistake in his calculations or if the pilot mistrusts the navigator's determinations and chooses to ignore his guidance.

To those of you who are engaged in the practice of industrial engineering these observations may seem elementary discussion of self-evident truths. You know the industrial engineer's place on the management team and I can tell you nothing new about it. The important question is whether the other members of the management team are equally conversant with the industrial engineering function.

In my opinion this is the key to the situation. I believe that the chance for effective discharge of the industrial engineering function is contingent upon establishment of the following conditions:

1. The function of industrial engineering must be recognized in the Company and have the full backing of the Company's chief executive. No management function that bears so intimately upon the administrative affairs of other management functions and involves matters of such importance to the enterprise can be discharged effectively without full participation and support of the Company's chief executive. In the absence of such recognition and backing various undesirable tendencies may develop. The industrial engineer is apt to spend too much time securing acceptance and adoption of his findings, thus leaving too little time for the legitimate function of developing the findings. Not enough of the management people come to realize that the importance of sound industrial engineering increases directly as competition in the business increases. Under such circumstances too many of the management people, whose participation and support is essential to successful discharge of the industrial engineering function, fall into a frame of mind somewhat like the individual who couldn't put a roof on his house when it rained and concluded that he didn't need the roof when it didn't rain. The fact is that industrial engineering is an essential part of the management function at all times and is particularly important in difficult times.
2. The line operators who direct the operations and are called upon to produce the products at minimum cost must understand that such results can be accomplished only through their skillful use of sound industrial engineering determinations. They must be able to see the benefits to be derived by such

service. They must be convinced of their ability to do a better job when proceeding on the basis of fact than when by rule-of-thumb. They must realize that such improvements as are made or not made are the direct responsibility of the operator--not the industrial engineer.

3. The accounting people who must apply the results of the industrial engineer's factual determinations in the daily records and transactions of the business must participate fully in the development of policy and procedure through which those determinations are made. Their participation is needed to insure that the results thereof are subject to practical application and accurate adjustment for new or changed conditions.

4. The industrial relations people who are called upon to negotiate the industrial engineering findings that affect the daily lives of employees likewise must participate fully in the development of policy and procedure through which those findings are made. Otherwise the findings may not be fully negotiable or the negotiators may not be properly equipped for the discharge of their responsibility.

5. And last but by no means least, the industrial engineer must be qualified and willing to perform the work at hand. He must understand his function as that of technical service to facilitate the handling of other people's problems and therefore, must approach those problems with complete sympathy for the point of view held by those people. He must perform his own job well, run interference for the ball carriers, and stay out of the backfield.

These expressions reflect the fundamental cornerstones of our industrial engineering endeavor in United States Steel. The industrial engineering function I have described fits within my officially stated responsibility. The objectives I have described are fully known and supported by our chief executives. The participating arrangement that was outlined is in practice. The executives of Operating, Accounting, Industrial Relations, and Industrial Engineering participate fully in the development of all industrial engineering policies, procedures, and decisions of major significance.

We leave it to you to judge whether our description of the industrial engineer's place on the management team, as developed for our problem, is of assistance to you in relation to your problems. Whether or not we all agree as to the industrial engineer's exact place on the management team, I am sure we do all agree that wherever he may be his purpose is always the same. It is to enable the production of more goods and services at less cost and hence to facilitate wider distribution of the benefits of industry.

[1] Mr. Edward W. Estes
Assistant Vice President
Industrial Engineering
United States Steel Company
Pittsburgh, Pennsylvania
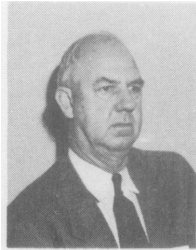presented Mr. Cooper's address

PRODUCTION ENGINEERING SESSION

Chairman--Walter Kassebohm, Factory Manager, The Marchant Calculating Machine Company, Emeryville

ESTIMATING FOR PRODUCTION

W. A. Nordhoff, Chief Machine Shop Estimator,

Douglas Aircraft Co., Inc.,

Santa Monica, California.

The field in which I have somewhat more than a speaking acquaintance is estimating for production of machined parts. The illustrations and examples I will use to amplify my remarks will be drawn exclusively from my experiences in the machine shop. By taking some license with my subject, it could be "Estimating for Production in the Machine Shop." However, the principles of estimating applying to the machine shop will also apply to other spheres of production endeavor.

Were you ever in a machine shop? Let me describe it to you if I can. It is a noisy place. Out of its throat comes a cadence of squeaks, squeals, howls, wheezes, rattles and bangs which blend into the crescendo of a great symphony. There is also smoke. It hovers prophetically for a while and momentarily blurs the vision. When it clears away, out steps a genie in the form of a masterpiece of art--a beautiful, shiny, useful part; the product of a master craftsman. I know you do not believe in fairies carrying paint brushes and palettes of gaudy color around the shop. Do you? Then tell me who paints the metal chips from chrome molybdenum steel their iridescent blues and purples; chrome nickle iron chips their pastel yellows, blues and greens; low carbon steel chips their reds and somber browns. Their colors are matched only by the rainbow and the setting sun. What Thor or Vulcan hurls those million miniature thunderbolts in brilliant display when the grinder disturbs his slumber? This apparently incoherent noise, this arrogant show of brute force, this restless surge of power, this pandemonium of confusion, this endless mery-go-round of men and machines at last comes to rest in order, harmony and beauty. Believe me, the machine shop is truly a fairyland of music, magic and color.

Let us walk into this fairyland and note how soon we come down to earth. We do not go far before we meet the estimator. He is being greeted by the shopmen with such salutations as "Good Morning, Mr. Simon Legree." A turret lathe operator yells to his neighbor, "Here comes the Sultan of the Salt Mine." "Double-O-Four (.004)" Nordhoff they call me, referring to an estimate I made anticipating the production rate of four parts per minute. However, they all have smiles on their faces when they say those things, I know they are just making fun of me.

Seriously, let us turn to the business of "Estimating for Production." Industry is interested in the relative merits of various alternatives in operation. These alternatives are expressed in terms of production costs, man-hours, investment in new machinery and equipment, efficiencies, etc. Knowledge of the efficiency of labor, the evaluation of various methods of manufacture, and an analysis of machinery capacity are fundamental to a stable economy in any industry. The ability to forecast future costs with a fair degree of accuracy is the keystone of intelligent planning.

The proprietor of the small job shop is responsible for decisions affecting the cost of a product. He must think in terms of time and operator efficiency if he is to bid effectively on work. To overestimate a job means that the shop loses it to a competitor. To underestimate a job means financial loss to the shop. Too many losses mean shop failure.

Larger industries employ persons trained in the knowledge of shop methods, machine efficiencies, and the principles of motion and time study. At Douglas these persons are called "estimators" and are qualified to make time and motion studies, rate the operator, evaluate methods of operation, outline from blueprints all the necessary steps in the manufacture of a product, recommend proper tooling and production aids, and place a reasonable time value, or cost, on the job. The estimator's function is to convert time data into operation standards. Where standard data do not exist, he must be qualified to gather this information from time-study observations or draw heavily upon his own shop experience. His function is limited as an estimator without this experience.

An estimate is the length of time calculated by an estimator to be necessary for a normal operator to perform a given task. The estimator bases his opinion upon established or standard data and upon his experiences with observations of similar or identical operations. The difference between standard data and experience is that standard data are information arrived at scientifically by time-study observation, the statistical analysis of identical elements of operation, and the logical organization of this information in a manual for ready reference while experience is those data which are recorded only in the mind of the estimator.

Estimates are individual opinions. How closely these opinions reflect true shop operating conditions indicates the quality of the estimator. Estimators with different shop experiences will make different estimates on the same job. The estimator who can make the most reliable estimates for a shop is usually the one who has had the most experience in that shop.

The basis upon which reliable estimates are made is standard data. Standard data are derived from time study. They include all tables, charts, curves, and miscellaneous information necessary for the setting of standards synthetically. An estimate is the recognition of all the elements of operation which are necessary to perform that operation, with a time value fixed for each element. An

operation is the sum of its elements. Therefore, the time to perform an operation is the sum of its element times. It is the business of the estimator to know what elements make up any given operation and the time value of each element.

Does estimating for production have any advantages over time study? I am sure it has several. One advantage is an estimator can set a reasonable standard on a job in a fraction of the time required by a time-study observer to study it.

A time study depends upon the physical presence of the work operation. The blueprint, the stock, the machine, tooling, and the operator are present when a time study is taken. This is not the case when an estimate is made. Only a blueprint or a sketch of the part is available to the estimator. He must see in his mind's eye all the processes involved in the fabrication of the part, he must postulate suitable tooling, he must know the best equipment available in the shop for the various operations, and he must antici-pate every move of each person who will be engaged in the manufacture of the part in order to arrive at a dependable time estimate on the part. Standard setting for production under these conditions is not possible by time study. This is true also of small job-lot sizes. The estimator can set standards on these small lots before they get into the shop, but it would not be possible to get a representative time study of the job in the shop because of the limited number of parts involved.

One of the nightmares of my existence is to know when and how much an operator is "kidding" me when taking a time-study observation on a job. Many times have I felt that my production estimate was more correct than the on-the-spot observation. The only rule I have to evaluate the elements of my time-study observation is my standard data. When I resort to this to "rate" the time study, I am merely reestimating the job and the new answer will closely approximate the original estimate. When you rate an operator anywhere under normal the time study takes on the aspect of an opinion and is subject to the same criticism as is an estimate. Although it may be the "opinion" of a man trained in time study, it is still rather difficult to convince the shop that an operator who has been running a particular machine for ten years was operating below the accepted normal when the time-study observa-tion was made.

No production job goes into the machine shop or any other fabrication or assembly department of the Douglas Aircraft Company, Santa Monica Plant, without an es-timated production standard set on it. An accurate time-keeping record is also kept of the time spent in the various production departments and the number of parts completed on each operation by each direct employee is recorded. Shop performances are then statistically computed using the production estimate as the measure of shop effort and efficiency. Performance is based on 100% being normal. These records are management's tools used to determine the effectiveness of its shop and supervisory personnel, and they reflect immediately any decline in performance. When conditions warrant management can take immediate corrective action where any trouble spot appears. These performance reports not only reflect the condition, they are tailored also to pin-point the source of trouble.

Just how are production estimates made? To start with, remember the estimator knows approximately every element of operation that goes into the production of a part. He also has his standard data which give him the time values of these elements. He knows the various methods which will be employed to fabricate a part.

The machines in a machine shop lead, in the main,

rather prosaic and monotonous lives. The elements of their operations are limited and usually can be counted on the fingers of two hands. The more generalized and adaptable the machine, the greater the number of elements necessary completely to describe its varied operation functions. The more highly specialized a machine, the fewer the elements required to describe its functions. Some elements are common to most machines; other ele-ments are usable only with machines of a special class.

For example, the following elements of operation will describe the operation of a milling machine, and they will repeat themselves without variation on the bulk of the work done on the milling machine.

1. Pick up part and install in some holding device for work.
2. Start machine and advance work to cutter or cutters.
3. Mill dimension or dimensions.
4. Back work from cutter and stop machine.
5. Release part from holding device.
6. Aside with part to tote pan.

If one knows the time values for the elements de-scribed and refers to cutting tables for the time to mill, he can estimate rather accurately the time required to perform the operation.

Let us take time here to estimate the unit time re-quired to fabricate a simple bolt made from 3/8 diameter steel bar. The bolt has a 1/4 dimension head, a 1-1/2 shank and a 1-1/2 length of thread. The shank thread diameters are 1/4 and the thread is 1/4-28. We know this is a number one or a number two turret lathe job so we use the elements of the turret lathe to build up our estimate of the time required to make one bolt. The ele-ments of operation and their time values are as follows:

Elements of Operation

1. Advance material to stock stop.
2. Index hexagon turret and advance tool to work.
3. Point material for box mill and chamfer.
4. Index hexagon turret and advance tool to work.
5. Turn 1/4 diameter (length of cut, 3 inches) (1480 RPM .005 FEED).
6. Index hexagon turret and advance tool to work.
7. Machine 1/4-28 thread (Length of Cut, 1-1/2").
8. Clear hexagon turret.
9. Advance cross slide tool to work.
10. Cut off part (740 RPM .003 FEED)
11. Aside with part to tote pan.

Adding these elemental times together, we arrive at the bare minimum time to make one bolt. In this case it would be .0165 hour.

This, however, does not complete the estimate. The personal needs of the operator must be taken into consider-ation, the factor of fatigue must be allowed, and an al-lowance must be made for tool sharpening and adjustment from time to time. The personal allowance depends on several factors. We use 5 per cent. Fatigue is a var-iable factor and an allowance is made based upon the judg-ment of the estimator as to the amount of fatigue developed by running the job. Tool allowance is based upon the life of the tool operating continuously in metal in perform-ing its work. To arrive at the estimated unit production time to fabricate one bolt, the estimator places a unit time value for these allowances and adds this to the unit time to make a part. Multiply this by the number of parts you wish to produce and you have the total run time for the job exclusive of the make ready or setup time.

The setup time is arrived at in a similar manner to that used in arriving at the run time. Setups can also be

broken down into well defined elements, although we use the element in a much broader and looser term than when applied to an operation. The changing of a collet in the turret lathe spindle is considered one element although it involves the removing of the spindle guard, removing the collet hood, removing the collet, storing the collet in its proper place, selecting another collet for the job, inserting the collet in the spindle, securing it in place with the collet hood and reinstalling the spindle guard. This can be done in approximately 1.5 minutes. Installation of the stock stop, box mill turning tools, threading dies, cutoff tools, and so on, each carry a time value. Time for the setting of longitudinal feed stops, added time values for close tolerance work, time for boring chucks with soft jaws, etc., all go into the estimate of the setup. No necessary function of the operator is omitted when making the estimate of his job.

The production estimate not only gives the company a measuring stick to determine the effectiveness of its production departments, it also gives the company a basis for evaluating bids on subcontract work. A company which subcontracts a large part of its work can save many thousands of dollars annually by utilizing the services of its estimating staff.

The Douglas Aircraft Company is such a concern. Many manufacturing plants in the Los Angeles area are or have been engaged in doing subcontract work for it. The Douglas Aircraft Company maintains a very effective Estimating Department. It is doubtful in my mind if any manufacturer in the West maintains as efficient, well equipped and as alert a group as this one. Very few decisions are made concerning the purchasing of new capital equipment, the laying out of new fabricating and assembling areas, the erecting of new buildings without first consulting the estimating staff.

For example: The supervisor of the machine shop makes a request for new capital equipment. This request is turned over immediately to the machine shop estimator for his analysis of the need for such new equipment. If, after carefully weighing the facts, the estimator finds the new machine will make a better part, produce it more economically, and production requirements warrant it, he will approve its purchase. If he cannot justify it, he recommends that the equipment not be purchased at that time.

Let us get back to the Purchasing Department. We were handed the blueprint of a large nut some four inches in diameter to estimate the cost of manufacture. The order called for 8,000 of these nuts to be made. We wrote an outline of the manufacturing processes involved and estimated that the part should cost the Company seventy-five cents a piece. This information was given to a buyer for the Company who was to be responsible for purchasing this part outside of the plant. The next day he came to us very upset and said that if this part could be produced in the time we said it could, he would eat the part. "Without pepper and salt," he added. The best bid he had been able to receive up to this time was $2.25 per part. He was so sure our estimate was wrong that the part was given to another estimator for his opinion. A re-evaluation of the estimate left the picture the same. The second estimator said the original estimate was all right or, if anything, a little on the high side.

The buyer was told to try again and to see how near seventy-five cents he could get the job done. He finally was able to subcontract the part to an outside shop for a price that was close to the estimate. The Company saved $10,000.00 on this one order by making use of its estimating department.

There is a sequel to this story. We asked the buyer later if it were possible for him to visit this vendor's plant to find out how he was making out on his bid. To make a long story short, the buyer found out that the vendor was not doing the job; he had in turn subcontracted it to another machine shop; and, both parties were making a comfortable margin of profit out of it.

Hardly a day passes without some one from the purchasing department calling us to learn our production estimates on a list of parts.

Estimates are made with production in mind. Sooner or later the part will come into the shop to be fabricated accompanied by an outline of its processes. Each operation of the process will carry an estimate. The estimate will be used to measure the performance of the worker. The estimator always has some definite method in mind when he sets the production standard for a job. This is where he gets into trouble. He usually makes the estimate before production tools are in existence. He postulates a "reasonable tool" for the operation and what does he find? The shop contends that his estimate on a profile operation is too low. He investigates and finds that his time is based upon processing four parts simultaneously. The fixture supplied is designed to handle only one part at a time. The result, a temporary adjustment of the estimate and a request to have the tool redesigned to accommodate four parts. This usually calls for only a minor change in the tool design.

On the other hand the opposite condition also occurs. The estimator sees a tricky little operation and estimates accordingly. One day, while walking through the shop, he sees the job. The tool designer had thought of and fashioned an ingenious device for holding four parts to be machined simultaneously. No wonder the operator's performance reaches an all time high on that day. The shop seldom tells him his estimate is too high due to change in methods. He must find this out for himself. When he does find such a case, he drops his role as an estimator, gets his stop watch and observation board, and time studies the job. He records the better method for posterity. The operator laughs and says, "Well, it took you a long time to catch this one." It is like a good-natured game of hide-and-go-seek. They treat it as great sport--"putting one over" on the estimator. While taking the time study the operator gets a superficial scratch on his finger but it does not bleed. "See," he says, "No more blood."

Another time an estimate was made on a turret lathe operation on an arrester hook end. The estimate was rounded out to one hour per part. The shop said the best it could do was six parts in eight hours. It complained that the estimator had failed to take into consideration all the factors consuming time on the job. We were sure we had considered everything but were asked (just to keep peace in the family) to time study the job for a full eight hours and learn where we had miscalculated the job. I was selected to make the time study. At the end of eight hours, I was completely dissatisfied with the job, both in sequence of operations and approval of the operator.

The next day I made up a simo chart of the operation. The operator had made no attempt to use cutting tools simultaneously. This is basic and fundamental to good turret lathe operating--doing work with the cross slide tools while the hexagon turret tools are working.

My simo chart of the operation listed the possible integration of the elements of operation. My answer--still an estimate--was the job could be done in approximately thirty-six minutes per part exclusive of allowances. This chart was submitted as proof that the original estimate was liberal.

The supervisor of the machine shop removed the operator from the machine, brought in another operator who had never worked on this job, told him to follow the instructions of the estimator, that I was to be his "boss" for the day. After the operator had mastered the method, we time studied the operation. Adding necessary allowances, we set the standard at .667 hour per part. In less than a week, the operator had stepped up production on this part to fourteen parts per day (116.7% performance) and maintained that rate to the end of the job which lasted for over a month longer.

The machine shop supervisor some time later made a statement before a managers' meeting in the plant that without the estimator he would require fifteen more production workers to maintain his present level of production. Production estimates when published are silent foremen. No production worker at the Douglas Aircraft Santa Monica Plant works on a job without a known target at which to shoot. Every foreman can tell each of his operators the time he is expected to complete a task because he knows in advance what the production estimate is.

As we mentioned before, the production estimator always has a method in mind when he makes an estimate. He is always available to assist the shop in finding the correct method for doing a job. On the other hand, do not sell the operator short for finding better and more economical ways of doing a job. Lacking a formal training in the field of industrial engineering, my professors and instructors have been the machine shop operator. I have learned by observing him. I have found him to be quite resourceful in his sphere of activity.

You make the estimate and set the standard. The operator will always try to go you one better if he feels it necessary. Let me illustrate. I time studied a job where the fixture would hold only one part and set the standard accordingly. The operator felt my standard was unfair. Some time later I returned to the shop and found the operator had discarded the fixture for a vise and was doing five parts simultaneously. Under the guise of "a change of method" I restudied the job. His reaction was that of a challenge. The next time I saw the job, the operator had added a C-clamp to his setup and was doing fifteen parts simultaneously. I gave up. He still runs the job when it comes into the shop fifteen parts at a time on a standard set for five. His increased productivity was a result of a challenge to find a better method.

Another time I was going through the milling section of the shop. I stopped to look at a job. The operator noticed my pondering over the job. Operators get curious when I stop to watch a job for any length of time and say nothing.

"Well, out with it! What's wrong with the way I'm doing this?" he asked.

"I didn't say anything was wrong."

"But there must be. You just don't get a kick out of just watching chips fly. You've been around too long for that."

"Well," I said, "I was thinking that ten inches per minute feed might be a little low. Really, however, I am in a very charitable mood today."

"What would you suggest?" he inquired.

"How about forty inches per minute."

"O. K."

The job was run at forty inches per minute and nothing happened.

He put another part on his machine and said, "If it will run at forty inches it will do sixty." The part was run at sixty inches per minute and still nothing happened.

Another part was put on the machine. "Sixty inches per minute is the best this machine will do, unless....."

"Unless what?" I inquired.

"Unless I use the rapid traverse."

"Well!"

So he used the rapid traverse (approximately 100 inches per minute). The machine still did not leave the floor nor throw the part across the shop.

Again I say, do not sell the shop operator short.

Sometime ago we set a production estimate on a small external grinding job of 600 parts per eight hours. The day shift operator turned in 600 parts daily until one day he stopped to inform me he had produced 1200 parts that day. "There ain't no night shift man can make a fool out of me." I was at a loss to say anything because I was not aware of any constructive rivalry between the two work shifts over their respective rates of production.

I made an investigation and found the answer to the 1200-part production of the night shift. I just did not have the heart to tell this grinder operator that the night the 1200 parts were produced, two operators had worked on the job.

How did the day man produce 1200 parts in one shift? That was what I wished to learn. Here was his method. He acquired another tapered mandrel, loaded and unloaded the parts from the mandrel while the machine (semi-automatic) was working. This idea alone doubled his production on this operation.

So again I say, "Do not sell the shop man short." He can teach us much.

The production estimator is always concerned with methods. Each time he makes an estimate he has some method in mind.

The aircraft industry has been constantly beset with small lot orders. The flow of 5-, 10-, 25- and 50-part orders into the shop is heartbreaking to its personnel. The setting up and the tearing down of jobs all day long is almost nightmarish. A job shop is all it is to some members of the organization.

Let an order for a thousand parts come through and the whole complexion of things change. Now here is our chance. A few months ago we saw a truck load of 1/4" aluminum plate six inches square come into the shop. It was like Santa Claus coming to town. It was the fulfilment of an analyst's dream. We immediately herded this job under our wing, took it into protective custody, and immediately began re-evaluating our estimates in terms of a 7200-part order. Briefly describing the design of this part, it was a disc-shaped part having a pulley groove on its edge, six lightening holes around the center, and a center hole having a plus or minus .0005" tolerance. The design which complicated these parts for high production was due to their being three similar parts having different diameters varying by increments of 1/4". The lightening holes were also designed proportionately to their outside diameters.

We felt if we could only get the design engineers to give us the same diameter of lightening holes for the three different sizes of pulleys and also get them to loosen up the tolerances on a slot just a wee bit, that we could greatly increase the productibility of the job. We submitted our proposal showing our present method of doing the job and the proposed method. We presented, side-by-

side, estimates for both methods including the added cost of tooling for the new method. Old tooling was to be scrapped. We showed that for the expenditure of seventy-five hours for tooling and a slight redesign of the parts, we could effect a saving of some 1400 hours in production time on this one order.

A few days later engineering gave us its o. k. to the changes for which we asked and the machinery was set in motion to have the new tools designed at once and to install the new method in the shop. Instead of drilling the lightening and center holes one at a time, we punched them in one stroke of the punch press. We did not trepan the outside diameter singly on a lathe, but blanked them on a punch press. We ganged the parts on an arbor and formed the pulley groove on several parts simultaneously on the lathe using a gang of form tools. We broached them--five at a time--to a plus or minus .0005" tolerance. Nor were the parts deburred by hand. They were deburred 300 at one loading in a tumbling barrel--at the rate of 750 parts per hour. After the parts were in production, we time studied every operation. As a result of the time studies, every estimate except one was found to be slightly high. Our original estimate of the saving of 1400 man hours by a change of method was really a conservative one.

Let me give another example of the production estimator at work as a methods analyst. From time to time orders would dribble into the shop to fabricate an elbow pipe fitting which was made from a heavy chrome molybdenum forging. One of its features was an internal 1-1/4" pipe thread. In the past we had found it impossible to thread this part with a large tap on the conventional type. This was due to the tearing action of the metal which produced an unsatisfactory thread. We were obliged to do this part on the conventional lathe with a single-point threading tool. The time for this operation alone was approximately 24 minutes per part. In spite of all the care taken to produce a good thread, the inspection rejection rate was relatively high. We could not justify a better method because the number of parts needed was never great enough. Suppose we could show a saving of twenty minutes per part and there were twenty parts on the shop order. This would be a saving of 400 minutes on the job or less than four hours. How impractical to even discuss a better method! Why, we could not have even a tool designed in four hours, let alone have it made. Therefore, we continually consigned this part to the limbo of forgotten, neglected parts until . . . .

It happened again. An order for several hundred parts crossed our desk and it stopped right there for revaluation. Here was the chance for which we had been waiting to bring this part out of disgrace and make it a respectable member in our family of economically produced parts and gain for it the affection it so deserved. Now we could go to the small tools purchasing department and present its case. We conservatively estimated the part could be threaded in less than four minutes on our thread mill if we had a special thread hob and the necessary special cams and hobs and to air express them to us as soon as possible. (The Douglas Aircraft Company is a great believer in air mail and air express, in fact, in any form of air transport.) The tooling department made a minor change in the lathe fixture to adapt it for use on the thread mill. In less than two weeks we were threading this part on the thread mill at a saving of twenty-two minutes per part.

A time study was made of the new method and what formerly took us twenty-four minutes to do we now did in a little less than two minutes. Also the inspection rejections on this part dropped to zero. Furthermore, a nice little adjustment in the selling price was made in favor of the customer.

When production estimates are used in the manner they are in the Douglas Aircraft Company, they must be highly refined. They must be as near the correct answer as is humanly possible to make them. The aircraft company is unique among the producers of consumers' goods. It is not a production agent like the manufacturer of hobby horses and hair pins, ribbons and razors, or toys and trinkets. It cannot stack its wares upon a shelf for the customer to come and buy. The customer's order precedes production.

The aircraft company is always working against time-- the schedule. The schedule is set by a customer always anxious to receive his airplane. We tell the customer we can make delivery of his plane in June. He says he wants delivery several weeks earlier. This ultimatum is tossed into the laps of the company's various staffs to determine if this is possible. Rest assured every effort is made to comply with the customer's wishes. After mulling over many details that go into the manufacture of a plane, Douglas decides the customer can receive delivery of the plane as he requested. When Douglas has the assurance from his staff that the plane can be delivered as scheduled he tells the customer so. And when he promises a delivery date, rest assured that commitment will be kept. His ability to do this depends much upon the accuracy of his staffs' estimates. As a result every DC-6 airplane in the past two years has been delivered in the contractual month, some of them ahead of schedule.

We have already mentioned the use of the estimate as a measure of shop performance. When it is so used as it is in the Douglas Aircraft Company, it is paramount that weight be given to every time consuming factor. Men are judged and rated by them. It would be manifestly unfair to the operator if little thought were given to the estimate. We have found that the most accurate method of estimating is to make as fine an elemental breakdown of the job as possible and to place time values upon these elements. The time on any single element will be small. Therefore, any error on the part of the estimator in giving it a time value will be small. Errors in judgment will be made on both sides of the ledger in normal estimating. Some elements will be overestimated; others will be underestimated. The errors on the plus side and those on the minus side will tend to offset each other. This makes it possible for the overall estimate to be near right.

When estimates are used to measure individual effort, I see no other than this method of making the estimate. The estimate not only tells the worker what is expected of him for the wages he receives but also tells the company what it has a right to expect. The estimator thus keeps alive the principle of fair play between employee and employer. The company pays for a day's work and has a right to expect a reasonable day's effort for that pay. The worker also believes in fair play. He wants to do a fair day's work for the wages he receives. The estimate tells him what his employer feels to be a standard of fair play. The estimator in this respect acts as the balance between the employee and the employer and sets that standard. The estimator, at all times, should be observing and critical of method. His position in the plant affords him the greatest opportunity for constructive, creative work. The shop is the analyst's paradise.

The estimate must be a production standard for the average normal worker. It must be readily attainable by him. The first-class worker will better the estimate by a considerable margin. The estimate should not be something arbitrary and mysterious. It should be open at all

times to review. Any operator who charges the standard of being too low is entitled to a review of that standard and to an immediate revision in his favor should the facts warrant it. One justified revised standard in favor of the worker is worth a thousand protestations of interest in fair play.

In conclusion, let me state that the estimator occupies a position of unparalleled importance in a functional going organization. He has no prejudices, no axes to grind to cloud his thinking. No department of activity in an industrial organization can approximate the tangible results obtained by its estimating department. The estimator is a front line soldier in the battle against waste and lost time. He is the balance wheel of industry. The company's ledger is in a more healthy condition because of his fight. The struggle never ends.

SIMO CHART OF TURRET-LATHE OPERATIONS

SHADED AREAS REPRESENT IDLE TIME.   NUMBERS IN PARENTHESES REPRESENT "FREE TIME"

SEQUENCE	DESCRIPTION SQUARE TURRET & OTHER ELEMENTS	CROSS SLIDE TIME	HEX. TURRET TIME	SEQUENCE	DESCRIPTION HEX. TURRET & CROSS SLIDE	ALLOWED TIME
1	MATERIAL TO STOCK STOP	.0178				.0178
2	SET CROSS SLIDE TOOL	.0042				.0042
3	ROUGH TURN 1.578 DIA. (367 RPM .007 FEED)	.0400				.0400
4	CLEAR CHIPS	.0067				.0067
5	REPOSITION CROSS SLIDE TOOL .	.0037				.0037
	SECOND ROUGH TURN (367 RPM .007 FEED)	.0360				.0360
7	CLEAR CHIPS	.0057				.0057
8	REPOSITION CROSS SLIDE TOOL	.0031				.0031
9	THIRD ROUGH TURN (521 RPM .007 FEED)	.0250				.0250
10	CHECK FOR STOCK SLIPPAGE	.0033				.0033
11	REPOSITION CROSS SLIDE TOOL	.0033	(.0033)	17	ADVANCE HEX. TURRET TOOL	.0033
12	FACE END OF PART (521 RPM HAND FEED)	.0040	(.0025)	18	CENTER DRILL	.0040
13	REPOSITION CROSS SLIDE TOOL	.0033				.0033
14	TURN 3 3/4 STOCK DIA. (367 RPM .007 FEED)	.0017	(.0033)	19	CLEAR HEX. TURRET	.0017
15	INDEX SQ. TURRET & TOOL TO WORK	.0067				.0067
16	FORM 3/4 R. & 50° ANGLE (89/45)RPM .005 FEED)	.0250				.0250
20	WATER CUT 3/4 R. & 50° ANGLE	.0185	(.0040)	27	HEX. TURRET TOOL TO WORK	.0185
21	R. TURN 1.531 DIA. (521 RPM .007 FEED)	.0133	(.0500)	28	DRILL 1.312 DIA. HOLE (89 RPM .015 FEED)	.0133
22	HAND FEED TO DEPTH OF CUT	.0085	(.0033)	29	INDEX TURRET TOOL TO WORK	.0085
23	F. TURN 1.531 DIA. (521 RPM .007 FEED)	.0150				.0150
24	CHECKING TIME	.0083	(.0133)	30		.0083
25	ADV. BACK CROSS SLIDE TOOL	.0070				.0070
26	PARTIAL CUTOFF 89/127 } RPM .005 FEED	.0670				.0670
26A	CROSS SLIDE TOOL IDLE	.0067				.0067
31	CLEAR BACK CROSS SLIDE TOOL					
	INDEX SQ. TURRET TOOL TO WORK	.0067				.0067
32	C' BORE FOR REAMER (367 RPM .007 FEED)	.0065	(.0050)	35	ADVANCE HEX. TURRET TOOL	.0065
33	INDEX & ADVANCE TOOL	.0067	(.0400)	36	REAM 1.312± .005 (127/62 } RPM .022 FEED).	.0067
34	FORM 47 1/2° ANGLE (127/62/15]RPM .005 FEED)	.0670	(.0050)	37	CLEAR HEX. TURRET	.0670
			.0067	38	ADVANCE HEX. TURRET TOOL	.0067
			.0042	39	SPOTFACE END OF PART (89 RPM HAND FEED)	.0042
			.0050	40	CLEAR HEX. TURRET	.0050
41	BREAK EDGES, FILE, POLISH & CHECK (HAND OPERATION, NO TOOLS WORKING)	.1000				.1000
44	ADV. CROSS SLIDE TOOL	.0067	(.0033)	42	ADVANCE HEX. TURRET TOOL	.0067
45	CUT OFF PART (89/127 } RPM .005 FEED)	.0500	(.0250)	43	FORM 2" INTERNAL RADIUS (89 RPM .007 FEED)	.0500
			(.0050)	46	CLEAR HEX. TURRET	
47	ASIDE WITH PART	.0060				.0060

31

ENGINEERING DEVELOPMENTS IN PRODUCTION PROCESSES
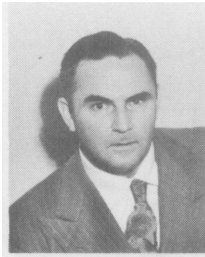
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INTRODUCTION

During the World War II period considerable advancement was made in the development of new production processes and tools for the aircraft industry. The cream of these tools and processes has been retained on the basis of economic efficiency for the production of a small number of identical parts with a rapid change from production of one part to another. Since the war, production processes and tooling have continued to develop and improve. This continued development and improvement is due in part to ever increasing performance characteristics of aircraft and, on the other hand, due to the competitive need to use more efficient airframe manufacturing methods.

Numerous factors affect production engineering methods, processes and tools. Some of the major factors are:

Increased smoothness requirements of high speed aircraft require closer tolerances of skin contours and connecting sub-structure. Increased smoothness affects production design, and jigging, forming and assembly methods.

Space limitations are ever present in the aircraft industry and in some cases are increasing, e. g., thinner airfoil sections of the modern high speed aircraft. When space is critical, the design of a part is often restricted because of this limitation. As a result, it may be necessary to devise new or modified production methods, or at least form, fabricate or tool to more difficult conditions.

Because of the ever increasing performance characteristics of aircraft, materials with greater mechanical design properties, i. e., increased U. T. S., Y. S., etc., and/or lower weight-strength ratios continually are being sought and designed. It has been found that the stronger materials require advanced process and tooling techniques. More efficient designs of welding, forming and fabrication tools are needed and a greater degree of tool rigidity and strength is required. Materials of lower elongation or ductility are being used to a greater extent where they also exhibit high strength or light weight, since high ductility and elongation usually are not important attributes to a successful design. These materials must be formed, fabricated, and/or welded in spite of their limited elongation and ductility. Welding, forming and fabricating design, processes and tools different from those normally used with the more ductile materials are often necessary.

The necessity to design production military aircraft in a manner compatible with the military requirements for interchangeability and replaceability, i. e., sectionalizing the aircraft for field service breaks and producing such field service joints with sufficient accuracy to allow direct interchangeability of any replacement part or assembly for the original part or assembly, imposes many engineering and production problems and limitations.

Since the last war, the quantity of aircraft produced has been small as compared to the quantity during the war. This has resulted in smaller individual contracts and a relatively small number of any one part being made. This trend has necessitated the development of processes and tooling that will produce economically a small number of identical parts with a rapid changeover from one part to another.

All of the above factors have affected the trend in aircraft production engineering developments since the last war. The following discussion gives concrete examples of specific trends and developments in tooling, forming, fabricating, and welding to amplify further the above general remarks.

TOOLING

In discussing tooling, one at once also discusses welding, forming, fabricating, etc., for the tools are but the holding jigs, fixtures and instruments which perform the actual forming, welding, fabricating, machining, and other operations. In general, tools and tooling methods can be divided into three types: experimental or job-shop tools; limited production tools; and mass production tools.

Experimental or job-shop tools are most economical in producing one to several of a given part. This type of tool figures largely in manufacturing experimental aircraft.

With limited production tools greatest economy is in producing a small number of a given part, i. e., approximately 20 to 500 parts. Further economy is introduced by tooling methods allowing a rapid changeover from production of one part to production of another. This type of tooling is used extensively at present in production of military aircraft.

Mass production tooling methods have been developed largely by the automotive industry. The aircraft industry has borrowed from this source to fill many of its needs, however. In general, mass production tools are most applicable for production of thousands of identical parts or for performing and repeating a given operation rapidly, efficiently and for a long period of sustained or intermittent operation. In many cases they are but specialized limited production tools.

The largest and most notable recent tooling development has been in limited production tools. Forming equipment, for example, has been increased in size, capacity and versatility to allow forming of stronger materials, heavier gages, and more complex shapes. Most of the recent developments that follow are of the limited production type tool and embrace the forming, fabricating, and welding fields.

Plastics as Tools

Plastics are being used more and more extensively, not only for light weight aircraft parts but also as a material for limited production and experimental type tooling. Their advantages in tooling are: lightness and fabrication simplicity as compared to equally strong or rigid metallic tools; short labor and shop time involved during fabrication (see Figure 1); low cost for many applications; good stability and strength, i. e. great resistance to dimensional changes; ready detection of excessive abuse (e. g. a plastic template if dropped will not bend or distort without noticeable "crazing" or crushing); and a non-priority source of material in time of emergency. A good example of their strength, rigidity and resistance to impact was shown sev-

eral years ago in an issue of "LIFE" magazine; you may have seen it. A photograph showed a large man hitting a laminated plastic fender with a 16 lb. sledge hammer. No damage or dimensional change was evident on the fender after this treatment. A disadvantage of plastic tools is that they are more easily abraded than metal. This is compensated by metallic facings of thin sheet metal on areas subject to great wear.

THERMOSETTING DIE FABRICATION PROCEDURE	ZINC ALLOY DIE FABRICATION PROCEDURE
1. Make plaster splash from "mockup."	1. Make plaster splash from "mockup."
2. Apply sealing compound and releasing agent (e. g.,silicone grease) to surface of splash.	2. Make plaster pattern from splash.
	3. Make sand mold using plaster pattern.
3. Pour in casting resin. Let set at room temperature for 8 hours.	4. Cast in zinc alloy.
	5. Finish grind surface to fit blue block.
4. Bake at 180° F. for 8 hrs.	
Man-hours - 8	Man-hours 24
Total time - 24 hours	Total time - 48 hours

Figure 1

Drill and trim templates can be made with laminated glass fiber cloth plastics. Plastic or metallic parts may be drilled and trimmed to size by use of this type template. Tools are produced by laying glass fiber cloth over a part or die, impregnating each layer of glass fiber cloth with a polyester resin, covering with a pressure bag when necessary, and allowing to air harden. The cold method of curing is used more extensively at Northrop than heat curing methods in order to prevent warpage during curing. After curing the laminated glass fiber plastic template is removed, drill bushings attached for drilling, edges cut to the desired trim line, and metal facings added, if necessary. This type of laminated glass fiber plastic is now being used also for assembly trim and drill templates and welding fixtures, and new uses will no doubt be found by extension of its current use.

Another type of plastic, thermosetting cast phenolic resin, is used for many tooling applications, e. g. pin router jigs, holding fixtures, mill fixtures, duplicating masters, matrix molds for electroform process, postforming dies, trim and drill fixtures, stretch press dies, duplicating patterns, etc. Mechanical properties of dies produced are in the order of: 5, 000 to 9, 000 psi U. T. S., 14, 000 to 20, 000 psi U. C. S., and 5, 000 to 7, 000 psi shear strength can be obtained. From this brief description it can be seen that plastics are a very versatile tooling material capable of further "use" expansion.

Costwise, plastic type dies are desirable in many applications. Figure 1 compares the steps and time in producing a thermosetting plastic die and an equivalent Kirksite (zinc alloy) die. In this table the die making steps are generalized as much as possible so that some variation in procedure, depending on the application, should be expected. The simplicity and speed of fabricating the plastic die are apparent.

Materials for Welding Fixtures

Welding fixtures have shown an interesting trend in recent years. The use of magnesium for jigs and fixtures in the welding of aluminum and magnesium parts has reduced warpage problems considerably. Steel jigs and fixtures were standard for years; however, when welding aluminum and magnesium in these steel jigs a certain amount of warpage of the parts occurred. This warpage was found to be caused by the difference in thermal expansion between the steel jigs and the aluminum or magnesium part during preheating and welding. The result is that the parts are under compression stress in areas held by steel jigs and if the stress is severe enough permanent deformation occurs.

Currently magnesium is replacing steel in welding jigs and fixtures. Steel is used only when necessary to give strength, rigidity and stability against jig deflection. As a result, warpage of welded parts has been greatly reduced. In connection with warpage it might also be asked, "What can be done about eliminating warpage during the strain-relieving treatment which is given every aluminum and magnesium welded part?" Warpage is prevented during strain-relieving at Northrop by leaving the welded parts in their jigs during the strain-relieving heat treatment, whenever possible.

Another question that may occur is, "Why is magnesium and not aluminum used in welding fixtures and jigs?" The primary reason is that magnesium is easier and less costly to fabricate. In addition the expansion characteristics of aluminum and magnesium are very similar, thus allowing the use of magnesium fixtures and jigs in the welding of both aluminum and magnesium parts.

Forming Tools

Recent forming tools and methods are following the trends to be expected in view of the higher strength materials being used and the competitive necessity to form more efficiently and economically a relatively small number of identical parts.

A limited production forming method recently developed at Northrop for stretch forming the leading edges of the F-89 all-weather fighter aptly demonstrates these trends. The leading edges are stretch formed from 75S aluminum tapered sheet varying in thickness from .081 (outboard) to .156 (inboard) gauge. The elevator and rudder leading edges are formed in one section and the wings in three sections. To form high strength 75S aluminum sheet into sections of this width--4 to 12 feet--requires considerable pressure. A 500 ton hydraulic press brake is being used to develop this required forming pressure. A stretch form die is mounted on the vertically movable ram of the press brake and a set of pivoting clamping jaws are mounted on the fixed bed of the press. The sheet to be formed is inserted in the clamping jaws, air pressure applied to the pneumatic jaws, and the stretch form die (punch) lowered until it is in contact with sheet.

The stretch form die is lowered and the sheet clamping and holding fixture is pivoted up (the fixture has a hinge joint at press bed), until the sheet is snug against the sides of the stretch form die. The stretch forming cycle then starts. Microstops are set on the hydraulic brake to limit and control the amount of stretch forming (a 5-6% stretch is being used in forming 75S A. Q. tapered sheet). At the press of a button the hydraulic press performs the required forming stroke and returns the stretch form block to some preset position to allow easy

removal of the formed part. Forming by this method provides a saving over the previous method (i. e. approximating the contour by a series of bends in 75S-T6 sheet along the contour with regular bending punch and die and heat) of approximately $60,000 for 100 ship sets of parts. This is the most obvious but not the only saving. By being able to design the leading edges with a reduced number of joints engineering design problems were simplified, the number of joints and fasteners reduced, a weight saving introduced, and overall fabrication and assembly time decreased.

Another recent forming tool development has shown this same trend toward increased efficiency and economy of forming. This tool is a flexible form block for the contour stretch forming of extrusions and preformed sheet or plate sections of similar shapes. In its present stage of development this method is particularly adapted and is being used almost exclusively to form contours common to the wing and empennage curve or to the longitudinal curve of the fuselage, (i. e. contours of 50" radius or greater). However, further development is anticipated to allow use of this method with sharper contours.

Previously a solid stretch form block of Masonite, cast aluminum alloy, or cast Zn alloy was required for each individual part to be formed. With the current method one flexible cavity snake is required for each shape and size of extrusion or formed section but can be used over and over again for stretch forming to any particular contour. These "snakes" are cast from cerro-matrix (low melting alloy) in one rectangular section using a straight length of the actual extrusion or formed section during casting to produce the desired cavity. This long casting is then cut transversely into segments sufficiently narrow to produce the desired contour within the tolerances required. For example a 2" segment will produce contour of radii 100 inches or greater within $\pm$ .005 of the desired contour. Before use the segments are connected by two long coil springs to permit the desired flexibility and ease of handling.

The other piece of equipment necessary with the current method is a set of adjustable angle blocks for backing up the snake and a base plate. Only one set of this equipment is necessary with current production for all extrusions and formed sections. However, in the future stronger angle blocks for sections with greater than about a two inch area and thinner angle blocks for small contour radii may have to be designed.

In practice, the adjustable angle blocks are adjusted to the desired part length and contour with a suitable template; the flexible snake is positioned on the angle blocks with the cavity up or outward, depending on plane of contour required with respect to extrusion cross-sectional shape; the straight extrusion or formed section is placed in the cavity of the flexible snake; ends of section are gripped by the stretch jaws; and the forming cycle then started. Stretch forming is discussed more fully below and the practicality of this tool, I believe, will become more evident then.

FORMING

With World War II, several important developments in metal working tools and methods were introduced. The Hufford Stretch-Wrap Forming Machine is one. It was used by a few aircraft manufacturers during the war, but since has become a necessity in all shops where sheet and extrusions must be contoured.

A Hufford Stretch-Wrap Forming Machine consists essentially of a fixed table for rigidly mounting a die of the required part contour; two pivotable arms at opposite extremities of the table with a hydraulic cylinder for gripping and stretching the sheet or extrusion located on each arm; and a hydraulic actuating cylinder located at the rear of the table and linked to the two arms so as to pivot the arms and wrap the extrusion or sheet around the contoured die. Present Hufford Stretch-Wrap Machines for sheet and extrusion vary from ten to 350 tons.

The theory of stretch-wrap forming takes into consideration two fundamental mechanical characteristics of metals and alloys, i. e. elasticity and plasticity. This can be readily explained by Figure 2.
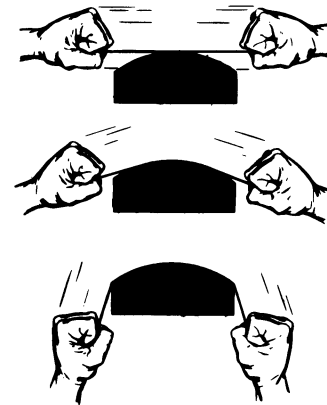

Figure 2
Theory of Stretch-Wrap Forming

When an aluminum alloy test sample is placed under tension, for example, a stretch takes place. As long as the elastic limit is not exceeded, the degree of stretch remains in direct proportion to the tonnage applied. When the piece is released, it returns to normal size and shape.

Suppose, however, that tonnage is increased sufficiently to exceed the elastic limit--a condition indicated by the fact that the degree of stretch is no longer proportional to tonnage applied. Upon release the test piece will not return to its original size as it did before; it remains deformed. When metal is under sufficient tension to deform permanently it obviously is in a semi-plastic condition. It is only logical to believe this plasticity would permit the workpiece to form more readily to the desired curves if suitable means were available.

Also during this experiment an important transformation has taken place. We find thereafter, upon reapplying tension, that the metal no longer elongates at the original yield point but resists until a factor several percent higher is applied. Thus, by the simple expedient of stretching to the proper degree, yield strength is materially raised! The Hufford system of stretch-wrap forming takes advantage of these phenomena. Its principle of operation is easily understood by the illustrations in Figure 2.

A die possessing the desired contour is securely mounted and remains immovable during the forming process. The work is held in tangency to the front of the die and stretched almost to its yield point (see A). With tension maintained, the work is wrapped around the die, accurately molding itself into and around each die configuration (see B). Upon completion of the wrap, another stretch is applied which slightly exceeds the elastic limit of the workpiece. This second stretch "sets" the contour shape and simultaneously raises the yield strength of the material (see C). Upon release, the part retains the shape imparted by the die curves. The process is simple, fast and effective.

Marform Process

An increase in the economy and efficiency of draw forming metals is achieved by the new Marform process, shown in Figure 3. This process produces deep drawn parts which are uniform in wall thickness and free from wrinkles, as compared to steel die drawing (thinning of wall) or Guerin Press rubber drawing (forms wrinkles). Developed by the Glenn L. Martin Company, the method employs a solid male punch and a rubber pressure pad in a hydraulic press. The pressure is controllable throughout the forming stroke of the press. Attached to the press and moved with the die is a cam which controls a valve to adjust the pressure.
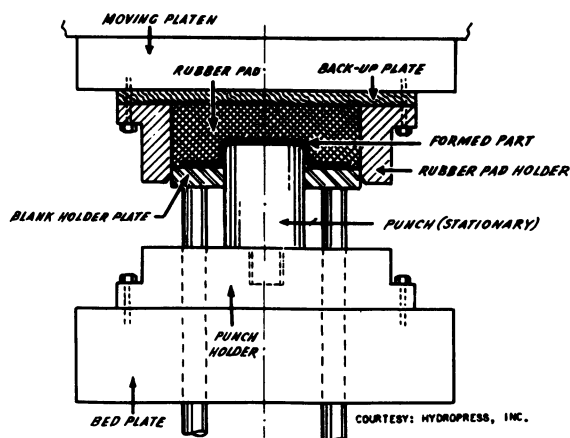

Figure 3
The Marform Process

The principle of the forming operation is illustrated in Figure 3. The Marform process eliminates the necessity for a female die, pressure plate or draw ring. The punch must be made only to tolerances necessary for finished part. The clearance between punch and blank holder is not critical, thus allowing economical fabrication methods. Elimination of the female die saves over 500% of the die cost and also makes possible forming the same shape from different thicknesses without changing the dies.

Reduction in cross-sectional area of 57% for deep drawn aluminum alloys is considered normal with the Marform process and figures as high as 70% have been obtained, whereas 40 to 50% is the maximum draw for the same materials when formed on steel dies. Likewise a cup depth equal to 1-1/2 times the radius is normally expected in the Marform process, about 50% more than that for a steel die. Material as thin as 0.010 inch thick has been successfully formed and a 0.012 cup was drawn to the point where the depth of the cup was 0.9 of its diameter. Gages as thick as 0.675 in aluminum alloys and 0.102 in 1010 steel have been formed.

Hot Forming

Hot forming (or elevated temperature forming) is an old art but relatively new to the airframe manufacturers. In the last five years the trend has been toward the use of high strength aluminum and magnesium alloys. Often when a gain is made by an increase in strength, a reduction in some other property, and in this case the formability, is affected. Thus, in the case of 75S-T6 aluminum and FS-1h magnesium alloys, hot forming is a necessity in order to fabricate aircraft component parts. The 75S is a heat treatable aluminum alloy which allows fabrication to be performed in the annealed ("O" condition), but in complicated shaped parts the subsequent heat treatment to the "T6" condition develops excessive warpage and check and straightening is prohibitive. Thus a saving in the order of 60 to one can be realized by hot forming in the "T6" condition. FS-1h is a work-hardenable magnesium alloy so, in order to maintain the high strength and form to tight limits, hot forming solves the problem.

All extrusions at Northrop are ordered in the full hard condition and formed as such by the hot forming method. This method produces closer tolerances in the parts and prevents the necessity of straightening after the heat treating operation as compared to forming in the soft or SO condition.

FABRICATION

"Why use 75S aluminum or magnesium when the production problems encountered are greater than with the 24S alloys?" This question was asked by aircraft production engineers in 1944. The answer was just as straight forward: "Metals with the highest possible weight-strength ratios must be used if we are to obtain the high performance characteristics necessary in the modern military aircraft." This answer, of course, still leaves the production problems to be answered. One of the major fabrication problems was dimpling of these higher strength alloys. Dimpling is necessary so that flush rivets may be used and smooth airfoil surfaces obtained. 75S-T6 material does not have sufficient ductility to satisfactorily cold dimple by natural forming. At room temperature the local elongation at fracture for 24S-T is 40-50% and for 75S-T 24-35%. This means that cold dimpling is impossible.

It was found by introducing a thickness direction stress (coining action) that the cold formability was raised sufficiently to eliminate radial cracks in rivet dimples (over forming method). Heat was necessary, however, to avoid internal shear cracks in some gages when excessive sidewall coining was used. It was also found that hot, natural formed dimples were up to 15% stronger than cold dimples with the same configuration. By dimpling 75S-T at elevated temperatures, the work hardening is reduced so that the dimples retain their original thickness and thus their strength.

Thus, today severe dimples are all made at elevated temperatures. There are three different methods used:

1. Natural Forming. This method is based on a minimum movement of material, i.e. a female die and rubber pressure are used to flow metal into the die cavity. Some thinning of the metal occurs in the dimpled area. Advantages are (a) a minimum of pressure required; (b) good structure with no regions of high internal shear. Disadvantages are (a) poor definition when used over a wide range of sheet gages; (b) poor nesting in multiple stacked sheets; (c) necessity of maintaining both 100°

and 105° countersinks for use in shop; (d) need for generous female die radius to avoid circumferential cracking in screw dimples.

2. Over Forming. This method is based on a coining action to raise the formability of the metal. The male and female die used have matching 100° angles and the diameter of the female die is equal to or less than the diameter of the male die. Advantages are (a)provides sharp definition; (b) permits multiple stacking; (c) permits 100° countersinking; (d) reduces tendency to circumferential cracks. Disadvantages are (a) requires greater tonnage; (b) produces critical shear deformation in heavier gages.

3. Optimum Forming. This method reduces shear deformation to a negligible value and retains good definition throughout the full range of gages. Shear deformation is reduced by increasing female die diameter so that it is greater than the male die diameter. Multiple stacked, 100° angle dimpled sheets produce the best possible nesting with no loose dimples. This method provides the best balance of high strength, definition (superior to previous methods), and suitability for all materials, i. e. 75S-T hot, 24S-T cold, and stainless steel cold.

Blind Riveting

The principle of blind riveting and the basic methods of blind riveting are not new. Patents were issued on many types of blind rivets in this country and other countries as far back as the late 19th century. Many additional features have been patented since that time. Nevertheless, it was not until the recent expansion of the aircraft industry that blind rivets became used to any appreciable extent. There has been considerable hesitancy on the part of many aircraft designers to employ blind rivets in any manner. This has arisen, probably in part at least, because of the lack of service performance information. Many designers have deliberately refused to accept the "easy way out" by the use of blind fasteners, even though a design employing them would result in appreciable simplification over the design employing non-blind fasteners.

Since 1940, there has been a steadily increasing acceptance of blind rivets and increasing confidence in and appreciation of the value of a blind rivet in aircraft structures. Today, there is little question among designers as to the important place which blind fasteners have in aircraft design. This has been brought about to a considerable extent by the satisfactory service life which rivets have exhibited in commercial and in combat planes over the recent years.

All those experienced in riveting problems of any type will appreciate the necessity, in all riveting applications, of having the members which are being riveted drawn tightly together. Unless care is exercised in the removal of chips and in drilling procedures, as well as in the riveting procedures, riveted joints may be unsatisfactory because of gaps between the sheets. In squeeze riveting and buck riveting of solid rivets, the chance of gaps is minimized due to the high forces involved. In blind riveting, however, more caution must be exercised in obtaining proper joints. This caution is necessary because of the lack of clinching ability of blind rivets. In those designs which do exhibit clinching ability there is either a deficiency of hole-filling ability or a complete lack of it.

In order to obtain both of the essential rivet characteristics, clinching force and hole-filling quality, some work was begun as early as 1940 to develop a rivet which would impart both qualities. This work was done by the Cherry Rivet Company and a patent was issued in 1945 on a fastener which would not only clinch the sheets together but would also completely fill up the holes in the sheets. This fastener consisted of two pieces, a hollow rivet and a multi-diameter mandrel passing through this rivet. The mandrel consisted of a stem portion substantially the same size as the rivet bore, an enlarged plus portion somewhat larger than the rivet bore, a head on the end of the plus section, and a collar portion approximately equal to the external diameter of the rivet. In operation this collar was drawn into the end of the rivet expanding the rivet and imparting an indirect force against the sheets, tending to pull them together. Considerable work has been done on this rivet from 1945 to the present and many improvements have been made in its performance. It has been only recently, however, that fasteners of this type have been introduced to the aircraft industry because it has not been until recently that economical methods of manufacture have been developed. It now appears likely that industry can be provided with this greatly improved type of blind rivet at a cost not appreciably greater than the cost of the blind rivets currently being used by industry.

Confidence in this easy method of assembly has been brought about by the satisfactory service life which assembled parts have exhibited in commercial and combat planes.

High Strength Fasteners. Fasteners to replace high strength alloy steel and aluminum bolts have been sought for a number of years. The prime requirements for this type fastener are adaptability to high volume production methods, shorter time and greater ease of installation, and reduced fastener weight.

The Huck Lockbolt, designed in recent years, has fulfilled the need for a high strength fastener meeting the above requirements. The Huck Lockbolt installation is shown in Figure 4. Lockbolts are quickly and easily installed with a minimum amount of effort using a pneumatic driving tool. The driving operation is continuous, in the following sequence:
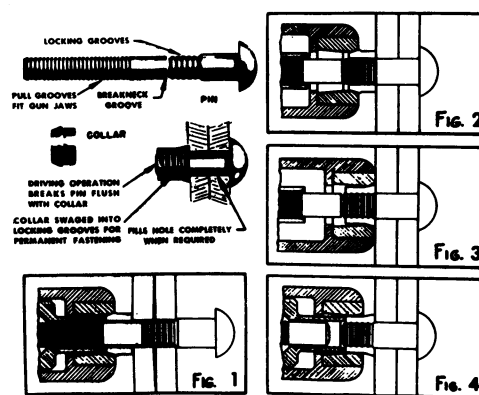

Figure 4
Huck Lockbolt Installation

1. The pin is inserted from one side of the work; the locking collar is then inserted over the lockbolt pin tail extending through the hole. The gun is then applied as illustrated in View 1. After the gun has been installed on the lockbolt pin tail, the jaws automatically engage the pull grooves.

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2. Depressing the gun trigger exerts the pull on the pin. The reaction on the pull is taken against the collar by the swaging anvil. This pull draws the work tightly together and, after the faying surfaces are in intimate contact, the pin is wire-drawn into an interference fit hole, simulating a bolting-up operation. See View 2.

3. As the pull on the pin increases, the anvil of the tool is drawn over the locking collar, swaging the collar into the locking grooves of the pin to form a rigid, permanent lock. See View 3.

4. Continued build-up of pressure automatically breaks the lockbolt pin in tension at the breakneck groove. When the gun piston returns to its initial forward position, the ejector advances to disengage the anvil from the swaged collar. See View 4.

Lockbolts are especially designed as a replacement for high strength alloy steel and aluminum fastenings and are readily adaptable to high volume production methods. Shear and tension design allowables equal or exceed the values of equivalent AN bolts. Liberal hole tolerances for an interference fit exceed those of AN bolts. No reaming operation is required. Lockbolts are available in 75S-T6 aluminum alloy as a standard item. Simplicity of operation requires only the gun operator. Installed lockbolts effect a weight saving of approximately 50% over an equivalent AN steel bolt and nut. High tensile preload and excellent sealing qualities are inherent in both steel and aluminum alloy lockbolts. Lockbolts under repeated loads in shear are stronger than aluminum alloy sheet materials in normal joints.

Tension fatigue tests indicate that lockbolts last many times as long as AN bolts (due to the uniformly high preload) when tested at any specified tension load.

The lockbolt clamps the work tightly together with sufficient force to pre-stress the pin in tension comparable to a highly torqued bolt but with much greater uniformity. This high tensile preload insures excellent tension fatigue strength. The clamping action is sufficient to pull together a total gap between sheets of 3/16 of an inch, thus the lockbolt does the work of clamps or fitting-up bolts, however, it remains permanently installed.

Lockbolts may be installed in from 1/3 to 1/4 the time to install AN bolts and nuts of comparable size. In cases where close tolerance holes are required, the time saving is much greater and the fit obtained with the lockbolt is tighter.

WELDING

Fusion Welding.

Progress and advancement of fusion welding processes has been more rapid since 1946 than in the previous years of the welding industry. Some of the development work began during the war, but it has expanded and broadened in use since that time. This is clearly shown by the Heliarc process which has made possible the welding of practically all alloys and is employed in hundreds of industries. At the same time various other welding processes have been developed from the original idea. The most recent developments of this nature are the Heliarc spot welder and the continuous wire feed Heliarc process.

Another very important development has been the introduction of low hydrogen type electrodes for welding steels of higher harden-ability and steel with chemical and physical variations from the mills. It is also applicable to high sulphur bearing steels and has become of increasing value when it is desirable to eliminate preheat or employ a low local preheat.

A new joining process has been introduced which requires no heat but welds and produces fusion entirely through pressure. This process is employed to weld aluminum to aluminum and aluminum to copper. It is applicable for thin aluminum sheets .010 and less and for electrical contacts or conductors. Commercial copper, beryllium copper, brass, silver, aluminum, lead, nickel, and monel can be pressure welded to each other.

An example of the advantages of Heliarc welding is shown in the fabrication of chrome plated steel kitchen chairs with the Heliarc spot welder. Material is 1010 steel. Initially chairs were arc welded, leaving spatter and flux on the surface. With the use of the spot welder, welding time is reduced and weld quality is improved.

Spot Welding.

From the time that spot welding was first employed as a means of joining metal parts in the manufacture of aircraft, process control of weld quality has been a factor of the greatest importance. Welding engineers have always been aware of this and in recent years have done a great deal in improving welding machine performance, adjustment technique, material cleaning processes, personnel training, etc. At the present time spot welding in the aircraft industry is well established.

Some design engineers, however, seem to lack confidence in this method and prefer to use mechanical attachments where spot welding would be advantageous. Therefore, to insure the confidence of the designers, as well as inspection and process control departments, a system of statistical analysis of weld quality has been set up that has worked very well. This system of quality control can best be explained by tracing through a typical example, as shown in Figure 5.

Figure 5

When a new weld application is brought to the welding department to become a regular production item, it is examined immediately by the department supervisor and the welding engineer to determine which machine or machines are best suited to the welding job. After this has been decided, a welding schedule is set up and a group of thirty-five standard type single spot weld shear specimens are made. The weld material for these specimens is arranged so as to correspond exactly in thickness, alloy type and condition of heat treat, to that of the weld application. The weld machine control dial settings as used are all accurately recorded on a form provided for this purpose. Five of these specimens are selected at random, cross-sectioned through the center of the weld, polished, etched and metallurgically analyzed. The remaining thirty specimens are individually tested to their ultimate shear strength. The values thus obtained are recorded on the Process Control Chart and are averaged, first in groups of three, and these results averaged to give a general average for the ten groups. This general average value is checked against a table of "Minimum Average Strength Values Acceptable." If satisfactory, the figure is "rounded off" to the nearest zero, and the strength spread range determined from the "10% Tables Rounded" column. These levels are established on the Process Control Chart, the averages in blue and the limiting boundaries in red. The shear strength values of the thirty welds tested (each figure represents an average of three welds) are plotted on the Process Control Chart.

The Process Control Charts, as shown in Figure 6, are signed off by the Process Engineering representative and the schedule is available for production use. During production, the machine operator is required to keep his machine adjusted according to the machine adjustment schedule, and he is further required to make and furnish to the inspection department three shear test specimens at thirty minute intervals.
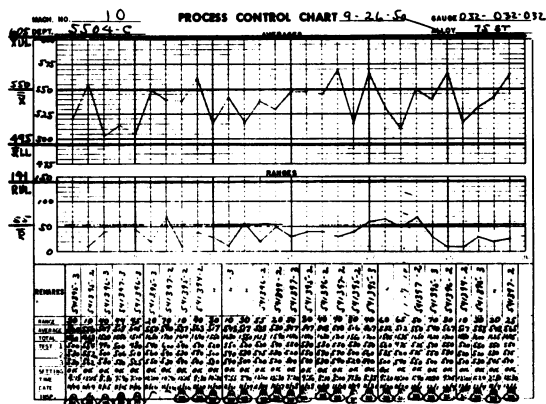
The inspector tests the specimens, notes their values on the Process Control Chart, averages them and plots the average value. As long as the tests show that welds of the desired strength are being obtained, and are passable in all other respects, the operator continues in production. When the test shows a value not conforming to the established Control Chart limitations, the work is stopped until the cause can be determined and corrections made.

Figure 7 shows reverse contour spot welding. While the foregoing procedure has been satisfactory as far as producing individual spot welds is concerned, an occasional assembly problem still remains. For example, stringer to skin spot welding is a common application but also is inclined to leave waviness in the panels between the stringers. One method of assembly that has been used successfully to overcome this condition has been the introduction of a reversed contour into the panel while it is being spot welded. This seems to have the effect of relieving, or at least equalizing, the local stresses so that when the panel is permitted to flatten out to its normal position, all evidence of waviness is gone.

Northrop engineers have chosen resistance welding as a means of joining metals in the fabrication of their wing tip tanks. Principally, this consists of spot welding of skin to the bulkhead rings and a combination of spot welding and seam welding at skin splice joints. By choosing resistance welding as a preferred method of joining, the use of high strength 75S-T Alclad is possible. Also, resistance welded joints are higher in joint strength efficiency since resistance welding does not anneal the surrounding area to the extent that is common to fusion welding.
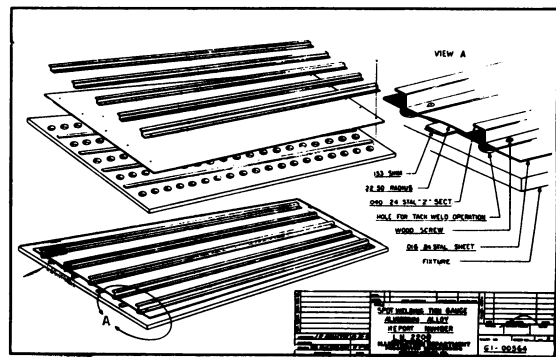

Figure 6

Figure 7

ACKNOWLEDGEMENT

TIME STUDY SESSION

Chairman--Ralph Barnes, Professor of Production Management and Engineering,
University of California, Los Angeles

OBJECTIVE TIME STUDY RATING

M. E. Mundel
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The Industrial Engineering group at Purdue has felt, for a long time, that the accurate determination of work standards is one of our crucial industrial engineering tasks. We think of a time study, as "a procedure for determining the amount of time required under certain standard conditions of measurement, for tasks involving some human activity."[1] As part of our research program in this area we hold an annual work session devoted to the development of factual data in this area. These have been held annually (with one war year missing) since 1944.

The typical performance of people taking time studies may be inferred from the ratings shown in Figure 1. These data are from a group consisting of the production manager, the three methods engineers, the three shift superintendents and their assistants, from a medium sized Lafayette manufacturing concern. It is to be noted that in such circumstances, a large number of the rates set in this manner would be outside of reasonable limits of accuracy.

Figure 1

Figure 2, for instance, shows the data from three of our work sessions, 1945,[2] 1949[3] and 1950.[4] This chart is based on an analysis of the ratings assigned performances of various jobs at these work sessions and leaves us with the inescapable conclusion that time study is in a grievous state.
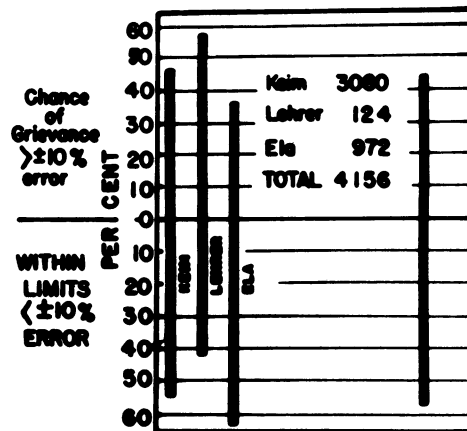
Figure 2

With these data in mind, it would seem appropriate to review rapidly the field of time study, determine our areas of agreement and those areas in which we have adequate control, and then examine that which the Purdue research program and the resulting "objective rating" has to offer.

Figure 3 gives the steps in time study. I believe we can all agree on the need for step 1, which requires our

I- Determination of objective

2- Recording the method

3- Timing

4- Adjustments
Rating
Allowances

Figure 3

stating, "What is the measurement supposed to represent," but stating this is another problem. I shall never forget the union-management dispute I arbitrated, concerning a

time standard, where the objective was defined only as "A fair day's work for a fair day's pay."

It is also interesting to note that the work session of 1950 revealed that of the 70 plants attending, only 44 had union contracts and of these about 13 per cent defined "the incentive gap" but 62 per cent had a clause concerning "time study grievance procedure." Also, 12 plants had no statement of objective, even as a matter of company policy, and in 10 other cases, men from the same plant gave different definitions.[5] No matter what rating procedure we use, this must be corrected.

There are many possible definitions and we suggest the use of:

"The standard time for a job will be 130/100 of the amount of time that will be necessary to accomplish a unit of work, using a given method, under given conditions, by a worker possessing sufficient skill to do the job properly, as physically fit for the job, after adjustment to it, as the average person who can be expected to be put on the job, and working at the maximum pace that can be maintained on such a job, day after day, without harmful physical effects."[6]

The fraction in the definition may be altered to suit company policy concerning the incentive gap.

Step 2, recording the method, is an obvious one. It would be impossible to give a standard time for a task unless that task was standardized and recorded. This is being done more fully in industry as time goes on and I think definite progress is being made in this phase.

Step 3, timing, has from time to time raised arguments concerning the relative accuracy of snap-back and continuous timing. Our data indicate that in competent hands, both methods are relatively suitable. These data were obtained by one of our graduate students, a Mr. Lazarus.[7] (Mr. Lazarus provided, by means of a modified telegraph code signal generator, a series of warning and reading stimuli, one series auditory and one series visual, so as to provide controlled situations that approximated actual time study situations. The data on which these statements are based were obtained with experienced time study men, using their own watches, in their own plants, using the method they were accustomed to, but reading visual signals from Mr. Lazarus' equipment.) Indiana, Ohio and Illinois plants cooperated.

Step 4, adjustments, or ratings, is the area where the controversy rages hot and heavy. As shown in Figure 4, there are two basic types of ratings of which the judgment

A - MATHEMATICAL

Morrow "Synthetic"

Statistical

B - JUDGEMENT

Multi- factor
Single factor

Figure 4

types are in most common use. The mathematical types have certain inherent fallacies, the discussion of which is beyond the scope of this paper.

The judgment procedures in use may be classified into three subgroups, as shown in Figure 5, depending on the

B- JUDGEMENT
(TYPES OF STANDARDS)
I- Fully subjective
2-Semi subjective
3- Objective

Figure 5

standard of reference used in the measurement. I wish to discuss primarily types 1 and 3 of Figure 5 to best illustrate what we have determined concerning what we call "objective rating."

Let us first discuss "fully subjective rating." Rating is defined by the Society for the Advancement of Management as "Rating is that process during which the time study man compares the performance of the operator under observation with the observer's own concept of normal performance."[8]

This, as usually interpreted, involves a two-step procedure as follows:

1. The time study man must observe the job and judge the difficulty of the job in order to form a mental concept of what the performance of the job under observation would look like if it met the requirements of standard performance as defined by the definition the observer is working with.

2. The observer must appraise the actual performance under observation as compared with the concept formed in step 1 and place a numerical value on this appraisal.

To our way of thinking, this produces the cloudy situation shown in Figure 6. The results obtained in such a situation have been previously detailed in this paper.
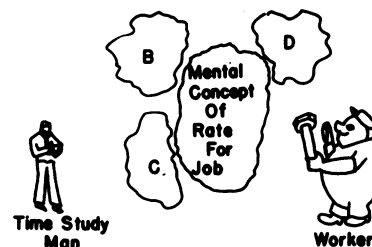
Figure 6

We postulated that the situation and the ensuing results could be improved by the three items shown in Figure 7. We further decided that the primary objective

I-Must have objective standard
2-An observable phenomenon
3-A concrete simple embodiment.

Figure 7

phenomena from which all inferences concerning performance (ratings) are made is the rapidity with which the parts of the task are performed. However, as will be explained later, it is rate of acceleration and deceleration rather than velocity which must be watched. In short, we decided to use an objective standard based on pace, meaning rate of acceleration and use one standard of reference for all tasks.

Objective rating also involves a two-step procedure, but the steps are in the reverse of the usual order.

1. We compare the observed pace to a film (or concept of a film) of pace, using the same standard of reference for all jobs. This is our "objective standard."

2. We adjust afterwards for the difficulty of the job being studied by means of an experimentally determined table showing the effect of various objective factors on the maximum possible pace.

We feel we are then in a situation such as shown in Figure 8, where an objective frame of reference replaces the former cloudy procedure.
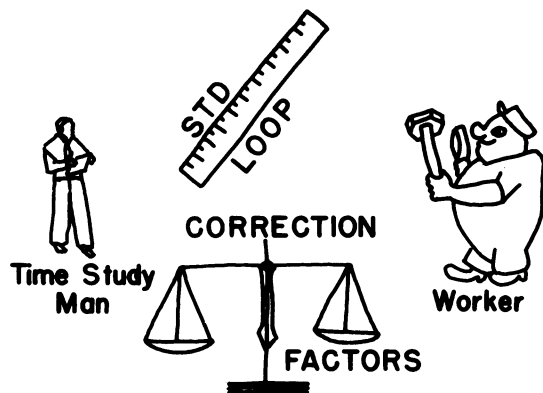

Figure 8

Now let us examine these proposals both from the viewpoint of the theory involved and the results obtainable.

Data obtained at the University of Iowa indicates that a constant per cent of the time for a movement is spent in accelerating, travelling at constant velocity and decelerating regardless of the distance, muscle group, or speed of action.[9, 10] Hence, if we rated rate of acceleration we would be expecting the time for double a given distance of movement to take only 1.41 the original time or, in general: the ratio of the times for two movements is the square root of the ratio of the distances. This, our theory
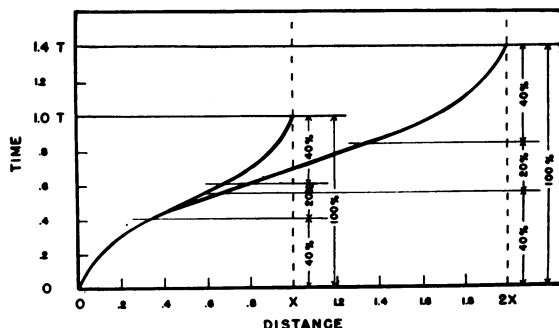
Fig 9 —Distance vs. time curves for movements of X and 2X distance at a given pace.

dictates, means similar pace or equal performance. This is shown in Figure 9.

This consequence of our theory was tested by setting up a series of movements of different distances, (in all cases involving the same muscle group) and measured the metabolic consumption of the operator performing each motion as the truest measure of the actual work involved. The theory was shown to be correct. At a given rate of acceleration, regardless of the length of movement, the work content, as measured metabolically with the setup shown in Figure 10, was constant.[11]
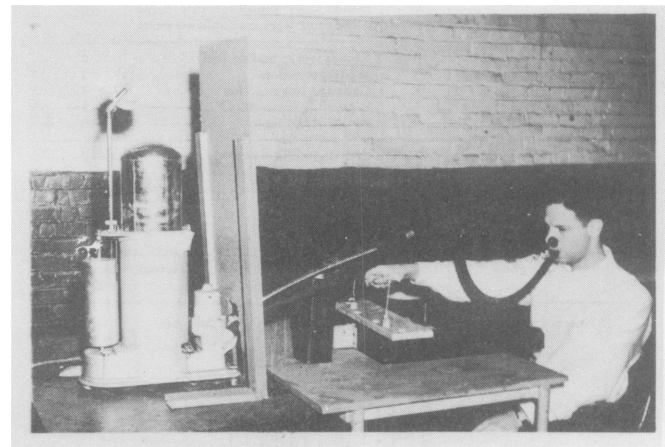
Figure 10

Thus, we could set up a film to give us a standard rate of acceleration for comparison. This film is used for all jobs. (A 16 mm loop was shown.) It shows 12 paces ranging from 156 per cent to 79 per cent. These values were determined by a large group of industrial engineers and are in correct relationship to each other. Twelve steps in the scale of pace are presented simultaneously in order to give a complete standard to which the task being studied may be compared.

Now for the correction factors to adjust for the difficulty of the job. Let us examine, for an example, the effect of using both hands. An M.S. Thesis by E. Ishinger approached this situation as follows: Laboratory data indicated that the use of two hands was slower per cycle than the use of one hand; although, of course, more work was produced per unit of time. To examine the use of one and two hands in a situation wherein neither condition was unduly favored by training, Ishinger timed two-handed simultaneous tasks in industrial situations (with experienced industrial operators). He later timed the same operators doing the tasks with only one hand. This was done with the cooperation of various Indiana plants on whose facilities the data were gathered. An average of 18 per cent slower for two-handed simultaneous work was obtained with very little variation from task to task.[12]

In a similar fashion, numerous experiments have been conducted to obtain the table shown in Figure 11.

These adjustments are added separately for each element after the element is rated and adjusted against the pace standard.

Now as to the results. Figure 12 shows the results obtained with objective rating (as compared to conventional subjective rating) with a group from the Indianapolis Society for the Advancement of Management.[13] Note the

Category No.	Description	Reference Letter	Condition	Per Cent Adjustment
1	Amount of body used	A	Fingers used loosely.	0
		B	Wrist and fingers.	1
		C	Elbow, wrist, and fingers.	2
		D	Arm, etc.	5
		E	Trunk, etc.	8
2	Foot pedals	F	No pedals or one pedal with fulcrum under foot.	0
		G	Pedal or pedals with fulcrum outside of foot.	5
3	Bimanualness	H	Hands help each other or alternate.	0
		G	Hands work simultaneously doing the same work on duplicate parts.	10
4	Eye-hand co-ordination*	I	Rough work, mainly feel.	0
		J	Moderate vision.	2
		K	Constant but not close.	4
		L	Watchful, fairly close.	7
		M	Within 1/64 inch.	10
5	Handling re-quirements*	N	Can be handled roughly.	0
		O	Only gross control.	1
		P	Must be controlled, but may be squeezed.	2
		Q	Handle carefully.	3
		R	Fragile.	5
6	Weight		Identify by the letter W followed by actual weight or resistance.	Use Curve Below

* Note: These scales could possibly go much higher in some cases.
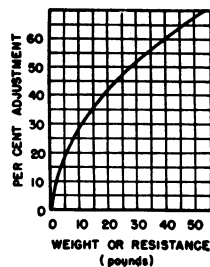

Figure 11
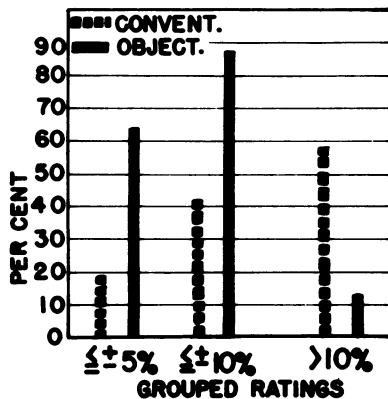
From thesis by LEHRER with INDIANAPOLIS S.A.M.

Figure 12

majority of objective ratings are well within the limits of acceptability in contrast to the subjective ratings. Further, note that this was this group's first experience with objective rating and all the members of the group had at least a year or more experience with conventional rating procedures.

Figure 13 shows a second characteristic of objective ratings. The lines shown in Figure 13 are the trend lines

for groups of 972 ratings made at the 5th Annual Purdue Work Session using three different rating techniques.[14] Figure 12 shows the improvement in accuracy; Figure 13 explains part of the source of this as more accurate separation of high and low paces through the use of a multi-image objective standard.
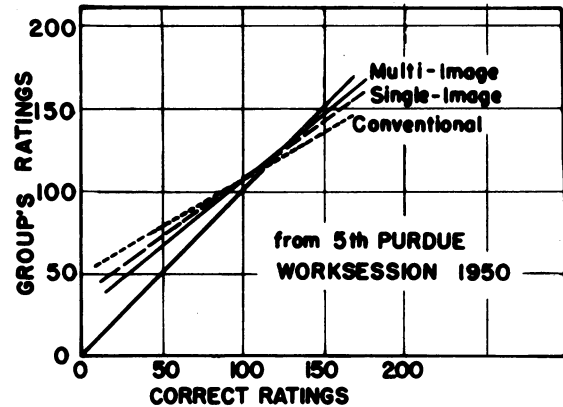
Figure 13

This paper has necessarily been a brief treatment of the results of a ten year research program. It is an attempt to describe objective rating, show its advantages and perhaps encourage time study men to take advantage of this improved tool for the determination of work standards.

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Discussion following the subject

Question: How do you determine whether 30% is the increment above standard that we expect? Why not 25% or 50% or 10%? Answer: I have seen 10-1/2%, 17-1/2% or 33-1/2% used; it is a matter of company policy. If you have a wage incentive and if you have a union contract, it is of course a matter for negotiation. We feel that the only figure that we can tie down on a scientific basis is "of what is the typical human organism capable." If your policy dictates that you want to set standards below that, then you move down the proper amount from that. Conversely, you could set your standards at a hypothetical maximum of what a person could do in 8 hours. This would be a perfectly acceptable standard, provided that nobody expected work to be done in that time, but perhaps only 1/3 as fast. Can you say whether a foot is too long? It depends on its use. It may be entirely too long if it is a spoon, or it may be too short if it is a shoe. Any measuring unit is acceptable, provided it is of somewhat the same order of magnitude as what you are measuring. The only requirement for a usable measuring unit in time study is to have a unit which more or less represents the type of function you expect to get.

Question: On that basis then are you implying that, rationally, we cannot establish one concept of normal pace? Answer: At the present my answer is no. We do not have enough evidence at the present time to determine the exact relationship of the rates of activity I showed you to any anthropologically determined distribution of human capacity. Hence it is not a hard scientific fact; it is a somewhat soft one. I offered this particular definition of normal pace to you because it is objective. The loop of film represents the considered judgment of the group we are working with and is fixed and available for review. By use of such a film loop in negotiation between union and management you produce a frame of reference which will bring more consistency to the standards typically obtained. Negotiation is necessary because it will be a long time before we have rates of activity tied down to an anthropological distribution. Some day, now that we have started this metabolic activity at Purdue, we will be able to produce data that will give us an accurate way to measure the work inherent to the job. In the meantime, the film loop certainly represents a more fixable point than imaginary mental concepts.

Question: Has any work been done to determine whether there is any difference in rating live operators and rating motion pictures of operators? Answer: In 1948, with the help of the Belden Manufacturing Co., a truck-load of production machinery, a truck-load of production material, and a bus-load of operators were brought to Purdue. We had previously visited the plants and photographed these operators on these machines doing the same jobs. Consequently, we had a series of films of this group of people doing their jobs, and we also had available the identical machines cemented to the floor. The workers took their turns doing the same jobs as in the films under as near a production setup as we could get. We found that the ratings made of the film were superior to the ratings made of the live operators. Results were unaffected by location of the rater with respect to the screen. Those in the front row did no worse or better than those on the side or in back. This

justified our experimental procedure and the conclusion was that ratings made of films are more accurate and more consistent than those made of live operators performing the job.

Question: Haven't you in effect merely refined the Westinghouse method of rating? Answer: The Westinghouse method of rating is a four factor rating system wherein an adjustment is applied to the skill, effort, conditions and consistency of the operator. If you examine the definitions of skill and effort, you will find that they also include method and are all appraisals. They refer to no really objective phenomena, except some peculiar inferences that this worker appears to like his job or appears to be trying to kill himself, etc. They are judgments or ratings. The secondary adjustments we were talking about are not ratings. These are, as near as we can make out, a mathematical evaluation of the factors which make for difficulties in different elements of the job. With these adjustments we can all start from the same point, rating only the rate of activity of the operator and not also the difficulty of the particular element.

Question: Tell us how you apply the objective rating method on the job. Do you take the projector and multiimage film to the job? Answer: There are three ways in which we do it, depending on the particular peculiarities of circumstances.
1) If it is a task under grievance we will take a motion picture at 1000 frames per minute. Then the film is developed quickly (with the growth of developing houses to supply TV, 16 mm film can be processed in one hour) and shown side by side with the 12 image film loop. All those who were parties would then attempt to discuss the relationship existing between the job and the loop.
2) Familiarize yourself with the appearance of the 12 images and the scale they represent by constant and repeated exposure to the film loop. Then when going to the job, you are relieved of the infinite multiplicity of mental concepts, one for each job. You also have a standard that can be reviewed and is constant once agreed upon. This is the most common procedure we have used.
3) Sometimes we take out a small portable shadow box and project the loop nearby the operation being studied.

Question: I have often thought a small device might be designed which could be called a "rating scope." This instrument could be taken to the job and used to aid the rating process. Answer: Undoubtedly such a device could be designed. We have had students propose the idea but drop it when the enormity of the task becomes evident. Professor Malcolm is working on such a device here at the University of California. However, such a device is merely the physical embodiment of the basic concept we are developing. The main thing I am trying to get across is that we have turned the time study procedure upside down. Instead of evaluating difficulty and then comparing it with your preconceived rate of activity, you can start out with a fixed pace and then adjust backwards to the difficulty.

Question: How does the speed of the projector affect accuracy of rating? Answer: Increasing the speed of projection of motion pictures may distort live operations. Because people are used to music and are very

accurate discriminators of pitch, the projector has to be soundproof. As you change the speed of projection, the picture changes in its apparent stability because the flicker fusion is reached at various points. Motions in a job do not exist as individual units apart from everything else. They are always integrated into a pattern. When a job speeds up in a live operation every motion in it does not change its velocity equally. This is most obvious when parts are being made. If you turn a projector up in speed, therefore, you will get a very false impression of performance.

Question: Can the same film loop be used for varying types of jobs: Answer: That is precisely what we are attempting to propose. That is why the loop shown covers the huge range it does, 79% to 156%. We have several such loops. One, I recall, we had to develop for a prefabricated house company where we found many performances to fall off the scale at the low end. Such a film is still a part of the same continuum of pace. It starts theoretically with a job of the minimum difficulty at which a job can be constituted, that is a free motion between indefinite ending points.

Figure 9 from Motion and Time Study Principles and Practice, M.E. Mundel, Copyright 1950, Prentice-Hall, New York.
Figure 11 from Motion and Time Study Principles and Practice, M. E. Mundel, Copyright 1950, Prentice-Hall, New York.

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and E. S. Valfer, Graduate Student,
University of California,
Berkeley, California.

The Industrial Engineering Laboratory of the University of California is engaged in faculty and graduate research in the design, development and use of time study rating films. In general the research program is exploring the following areas:

1. The Design of Time Study Rating Films
   a) The effect of the pace of the previous sequence shown upon the rater's judgment in the present sequence being rated.
   b) The optimum length or number of sequences to be rated in a rating film.
   c) The type of operation most satisfactorily lending itself to accurate, measurable changes in pace necessary in rating films.
   d) The effect of the above items upon the validity of comparing results from different rating films.
   e) The accuracy of the camera as a timing device.
2. The development of Films for Training in Time Study Rating
   a) Evaluation of multi-image films as a device for more quickly teaching the complicated judgment process of expressing observed performances in percentage terms.
   b) The optimum number of images in such a film in relation to human ability to perceive differences.
   c) Factors in evaluating improvement of rating ability such as memorization of rating films upon subsequent viewings.
3. Methods of Increasing the Accuracy and Consistency of On-the-Job Ratings.
   a) Development of portable film showing and time recording device incorporating a multiple-image film loop.
   b) Industrial testing and evaluation of this device.

Two motion picture films were developed as a part of this program. One film, which will be referred to as IE-1, consists of thirty sequences of various rates of activity of an operator inserting steel bearings into holes in an indexing dial plate. This device was positively driven by a synchronous motor and gave completely accurate speeds. (See paper by G. L. Marshall "The Human Factor in the Design of Indexing Machines, " for a more complete description of this operation.) The film in turn was taken by a camera which was synchronously driven. The second film, IE-2, consists of six images per frame of the same operation being performed at different rates of activity,

Figure 1. This film is in two parts. The first part shows the six images with their appropriate ratings in per cent. The trainee uses this portion to familiarize himself with rates of activity over a range of 70-145% of an established normal. The second part then shown has only code letters and the trainee is asked to rate and record his rating in percentage for each of the six images.
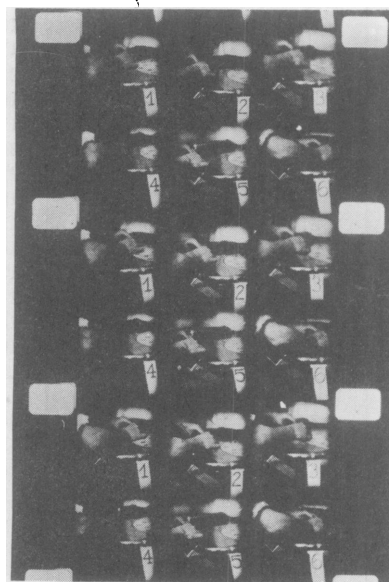
Figure 1
Three Frames of Multi-Image Film No. IE-2

The participants in the Third Industrial Engineering Institute were divided into two groups of equivalent experience and company representation for the showing of the above films. This was done in the attempt to get group data to be used in answering questions posed in 1a, 1b and 2a of the above outline. Group 1 consisting of 112 members was shown the multiple-image film IE-2 first and the correct ratings were given at the end of the film. Then the 30 sequence film IE-1 was shown and the participants recorded their ratings. Group 2, consisting of 75 members, was shown the same films but in reverse order.

For the purposes of this presentation, only the data obtained from both groups on the thirty sequence film IE-1 has been worked. Table I gives the average and the standard deviation (a measure of variability) of each group for each of the sequences rated.

The following charts have been constructed from the data in Table I and graphically portray the preliminary results of this group experiment. Figure 2 depicts the average rating of each group. Statistical tests of these data indicate that there is no significant difference between the results of the groups as far as mean is concerned. From this it may be inferred that the showing of Film IE-2 to group 1 prior to the showing of Film IE-1 had no effect on the group's accuracy.

The data plotted in Figures 3 and 4 show an estimated group consistency and do give significant results. Comparing each of the $\frac{\sigma_1^2}{\sigma_2^2}$ by the F test as given on page 145 in Kenney "Mathematics of Statistics" it is found that 22 of the 29 sequences tested show a significant difference at the 5%, or better, level. Eighteen of these 22 ratios were significant at the 1% level. From this it may be inferred

Seq. No.	Actual Rating	Group 1 Average	σ	Group 2 Average	σ	$F = \dfrac{\sigma_2^2{}^*}{\sigma_1^2}$
1	100	-	-	-	-	-
2	115	115.0	7.9	110.4	10.8	1.87
3	66	65.8	12.7	65.2	12.7	-
4	108	115.2	8.8	112.1	13.5	2.36
5	126	133.4	10.7	129.9	16.9	2.44
6	73	72.6	10.6	66.1	17.4	2.68
7	44	47.3	11.1	43.1	13.8	1.54
8	98	109.0	11.3	103.8	11.8	1.09
9	142	144.5	11.8	146.0	23.8	4.05
10	84	89.2	10.3	86.3	16.4	2.53
11	59	62.8	13.0	58.8	17.5	1.81
12	139	140.3	12.8	145.7	26.5	4.28
13	162	153.1	13.3	156.1	25.8	3.76
14	62	64.4	14.7	54.0	18.3	1.55
15	102	102.9	9.9	99.0	15.3	2.39
16	36	43.2	13.5	37.1	14.9	1.21
17	91	99.9	10.4	96.3	13.8	1.76
18	113	115.6	10.6	114.8	14.2	1.79
19	135	132.6	10.4	134.7	18.5	3.16
20	76	79.9	12.2	78.4	16.1	1.74
21	52	61.3	14.5	54.6	17.3	1.43
22	111	114.9	11.6	113.7	14.9	1.65
23	196	167.8	17.0	183.3	30.9	3.31
24	112	103.1	12.3	99.5	13.0	1.14
25	89	86.8	11.5	83.1	16.0	1.93
26	121	114.9	11.9	111.5	13.3	1.25
27	37	38.3	13.4	33.8	14.8	1.21
28	108	109.5	10.4	105.8	14.2	1.86
29	104	101.7	10.3	100.3	13.5	1.71
30	132	126.7	13.2	125.8	15.5	1.37

*Values of F greater than 1.66 are significant at the 1% level or better.

Values of F between 1.03 and 1.66 are significant at the 5% level or better.

GROUP σ vs FILM SEQUENCE
FILM IE-1

Figure 3

with confidence that the multiple image film seems to have a considerable effect in developing more consistent ratings quickly. Thus it appears that the multiple-image film is an excellent training device for instruction in rating. Figure 4 shows that inconsistency in rating becomes greater the further the rate of activity is from the 100% point. The inference here is that more consistent time studies will be made if more nearly normal performers are studied.

PLOT OF AVERAGE RATINGS OF EACH GROUP
± 10% ERROR LINES SHOWN

Figure 2

GROUP σ vs ACTUAL RATING
FILM IE-1
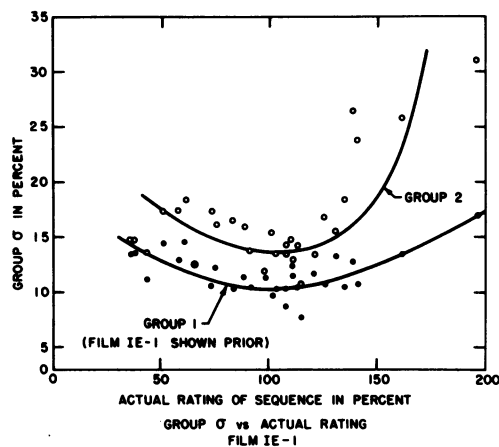
Figure 4

Figure 5 depicts the design of the Rating Film IE-1 and shows the attempt made to have consistent and equivalent variations in the rate of activity presented throughout the entire film. While this is a most important factor in the design of rating films, further analysis of the results has not yet been attempted. In regard to the optimum number of sequences in a rating film, subjective reaction of the participants would indicate that thirty sequences is
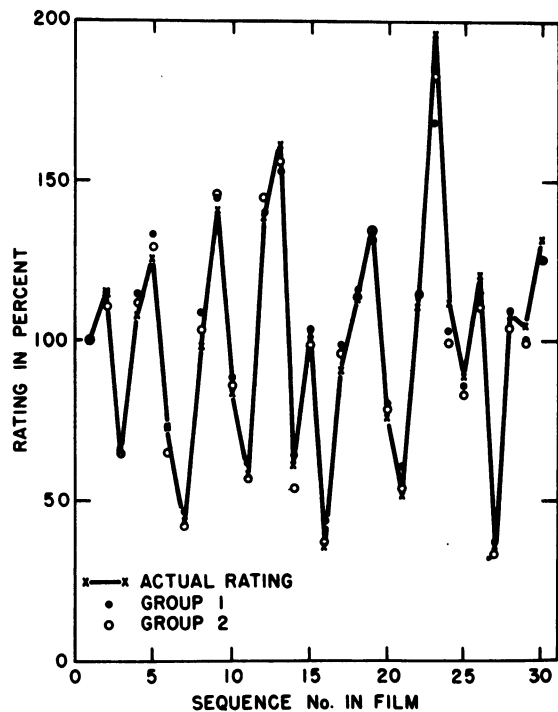
RATING vs FILM SEQUENCE
FILM IE-1

Figure 5

too many. Inspection of Figure 3 seems to indicate a trend towards more inconsistent ratings in the later part of the film. More detailed analysis of this problem will be made at a later date.

In conclusion, it should be pointed out that these films purposely make use of a very simple operation. The grasp and positioning portions of the work cycle have been made as easy to learn and perform as possible. This was done in order to eliminate the effect of false starts, fumbles and the resulting increase in·speed often noted in rating films where the operator has to meet a definite time schedule during each cycle.

The films IE-1 and IE-2 may be rented or purchased from the University Extension, University of California, Berkeley.

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WHY USE STATISTICS?

A chain is no stronger than its weakest link. This old proverb is obviously true, but it can be misleading in its inapplicability. For it may be length not strength in which we are more vitally interested. The process of making a time study--that is, of determining a standard time for an operation--consists of a series of many steps not unlike the links of a chain. However, the accuracy of the process, unlike the strength of the chain, is not determined by the least accurate step. Rather, it is more nearly comparable to the length of the chain, which is affected by the length of each link.

In a time study there are still certain numerical steps which are subjective, resting on the judgment of the observing engineer--for example, the rating step. Many have argued that since one step is subjective and thus only relatively accurate, there is no point to the expenditure of time, effort, or money in increasing the accuracy of the other steps. Yet consider a chain of ten links, each one centimeter long to an accuracy of five per cent; the chain will be 10 $\pm$ .5 cm. long or an accuracy of 5%. Now consider an improved chain in which, to use an extreme illustration, two links are accurate to 5% but the remaining eight links are perfect. This improved chain will be 10 $\pm$ 1 cm. long or an accuracy of 1%. While it is not anticipated that some steps in the time study process can be made perfect, it is true that an improvement in accuracy of any steps will favorably affect the final answer.

What are some of the steps involved in a time study? First a select time must be determined; to do this the engineer must:

(1) Choose a representative operator.
(2) Choose a representative period for making the study.
(3) Decide how many cycles to observe.
(4) Make and record the observations.
(5) Choose a select time for each element.

Each of these steps requires the exercise of good judgment. If an objective method of doing one or more of them is available, the engineer can better apply his judgment to the remaining steps. Furthermore, the objective statistical steps provide demonstrable evidence for management, union, or any other reviewing agency; the answers are reproducible; and, poor judgment is eliminated.

CHOOSING A REPRESENTATIVE TIME

Consider in detail how the fifth step listed above may be made objective, using for illustration twenty observations of the element "smooth surface with trowel." If the result is .06 minutes for every observation, there is no difficulty in choosing a representative time. If the results, expressed in hundredths of a minute, are 6, 6, 5, 7, 6, 6, 6, 6, 5, 6, 5, 6, 6, 6, 6, 7, 6, 7, 6, 6 then there is still little need for an objective criterion. If the results are 5, 7, 4, 8, 7, 6, 7, 6, 5, 6, 5, 6, 7, 8, 6, 11, 6, 9, 7, 6 it is not certain that every observer would pick the same representative time; it is not even certain that the same observer would repeat his choice if confronted with the same problem some weeks hence. Once picked, how accurate would the choice be? In order to answer that question it is necessary to know what one is after. What should this select time be or do?

The worker-machine-conditions combination which you have observed is going to perform that element often in the course of production. The time required to perform the element will vary--vary around some average figure so that while sometimes it will be performed faster, sometimes slower, the deviations will average out. What is more reasonable then than to use the average of the observations? Just add them up and divide by the number of observations. The rule is simple, objective, and it has been shown to be the most accurate method available for estimating that long-run average for future production from a given set of normal data. In the second set of results for the element "smooth surface with trowel" shown above, you would therefore have as select time 132/20 = 6.6 hundredths of a minute.

HOW ACCURATE IS IT?

It was asked previously how accurate a select time would be if it were chosen without objective aid. You quite properly might now ask how accurate you will be with such aid; that is, how close to that long-run average will you come with your observed average. For one thing, it obviously depends on the number of cycles you observe. If you were to observe all of the production run you would get a perfect answer. Naturally you will not do so, but the more cycles you observe, the more information you will have, and the better your select time will be.

The accuracy also depends on the consistency of the worker-machine-conditions combination. If the element is performed in .06 minutes every time, the consistency is perfect and the select time will be perfect. If the element is performed in from .05 to .07 minutes, a few observations will establish the fact. If the times vary from .04 to .11 minutes, many more observations will be needed to find the proper select time. Thus the more variable the element times, the more observations are required to establish the desired accuracy. Furthermore, you can measure this variability and compute the accuracy of a set of observations of an element by either of the following simple procedures.

Procedure A:

(1) Add the observed times and call the result ΣX.
(2) Square the result of (1).
(3) Add the squares of the observed times and call the result ΣX^2.
(4) Multiply (3) by the number N of observations.
(5) Subtract (2) from (4).
(6) Multiply the square of the number of observations by one less than the number of observations.
(7) Take square root of (6).
(8) Multiply (7) by the L factor from Table (A).

Expressed in a formula, procedure A may be written:

(A)
$$E = L \sqrt{\frac{N \Sigma x^2 - (\Sigma x)^2}{N^2 (N - 1)}}$$

where E represents the possible error in the observed mean: 95 times in 100, the observed average will be within E units of the long-run average.

Table (A)								
No. of observations 10	15	20	25	30	40	50	75	100
Factor L 1.85	1.90	1.92	1.94	1.95	1.96	1.97	1.98	1.99

For the twenty observations of the element "smooth surface with trowel" previously recorded, the formula (A) gives:

$$E = 1.92 \sqrt{\frac{20(918) - (132)^2}{400(19)}} = .67$$

hundredths of a minute.

Thus it is 95% certain that the long-run average lies somewhere in the interval 6.6 ± .67--that is, somewhere between 5.93 and 7.27 hundredths of a minute. This procedure A is essentially the same as has been suggested by Elmer B. Royer in Personnel in May, 1937, differing only in the use of "2 limits" rather than "3 limits" in the terminology of statistical quality control; it is slightly more accurate than the very similar procedure suggested by Professor Mundel in Modern Management in August, 1949. Royer's early article did not, however, conceive of a rating and allowance being applied to the result.

Procedure A is based on a normal distribution; the formula consists of the sample standard deviation, a factor of $\sqrt{N}$ in the denominator since the standard error of the mean is being estimated, and the factor L which includes a factor 2 to allow for 2σ limits and a factor to correct for the biased character of the small-sample standard deviation as an estimate of the population standard deviation.

Not all of us have the calculating machine or the time to use procedure A effectively. Fortunately, there is a simpler method for estimating E which is not only almost as efficient in theory but has been shown to be very practical in similar quality control applications. This procedure B makes use of a very obvious measure of variability called the range. Consider again the set of observations of the element "smooth surface with trowel":

5, 7, 4, 8, 7,	6, 7, 6, 5, 6,
5, 6, 7, 8, 6,	11, 6, 9, 7, 6.

The twenty observations have been broken up into subgroups of five observations each in the order in which they occurred. The range $\bar{R}$, or difference between highest and lowest, in the first five is 4 hundredths of a minute. For the other three subgroups, the ranges are 2, 3, and 5 hundredths of a minute respectively. The average range $\bar{R}$ is then one-fourth of 4+2+3+5, or 3.5 hundredths of a minute. Now multiply by the factor .192 from table (B) to get E = (3.5) (.192) = .67 hundredths of a minute, an excellent agreement with the previous result. Procedure B may thus be described by the steps

(1) Break observations into consecutive subgroups of five (the form on which the observations are recorded will facilitate this step.)

(2) Determine the range R for each subgroup.
(3) Compute the average range $\bar{R}$: the sum of the ranges R divided by the number of subgroups.
(4) Multiply $\bar{R}$ by the appropriate K factor from Table (B).

Table (B)								
No. of subgroups of 5 2	3	4	5	6	7	8	9	10
Factor K .272	.222	.192	.172	.157	.145	.136	.128	.122

For larger numbers, the factor K may be computed from the formula K = .860/N where N is the total number of observations. The formula for the error is:

(B)
$$E = K \bar{R}$$

and again there is 95% assurance that the observed average is within E units of the long-run average.

It should be noted that although the values of E from the two different procedures are identical to two decimal places in the numerical illustration cited, in general Procedure B is slightly less accurate than Procedure A.

The subgroup size was chosen arbitrarily as five because the efficiency of the range begins to drop off rapidly for larger subgroup sizes. Thus, the value .860 in the formula for K is just twice the reciprocal of the expected value of the range in terms of the long-range standard deviation; corresponding values could easily be computed for other subgroup sizes from the formula $2/d_2$ by taking d_2 out of any set of quality control tables.

HOW MANY OBSERVATIONS?

Turning the problem around, it is one simple step further to calculate how many observations are required for a specified accuracy. If the value of E calculated by Procedure A or by Procedure B is smaller than the specified tolerance, then the chances are 95 out of 100 that the number of observations already taken is satisfactory. If, however, E is larger than the specified allowable error, E*, it will be necessary to make more observations--and the number required may be calculated by the following method.

Procedure C:
(1) Compute the ratio of the calculated value E to the specified value E*.
(2) Square the ratio (1).
(3) Multiply by the number N of observations from which E was calculated.

The result of these three steps is the total number M of observations required for the specified allowable error E*; thus M-N additional observations need to be taken. Expressed as a formula:

(C)
$$M = (E/E*)^2 N.$$

Thus, if it is desired to be within .5 hundredths of a minute of the long-run average for the element "smooth surface with trowel," we have E* = .5 and

$$M = (.67/.5)^2 \cdot 20 = 36$$

whence thirty-six observations are indicated. When the additional sixteen observations have been made, they will

be averaged in to obtain the desired accurate estimate of the long-run average. This may be done by adding all 36 observations and dividing by 36; or it may be done by adding the sum of the additional times to the sum of the original times and dividing by the total number of observations.

Obviously, the additional observations must be made on the same worker-machine-conditions combination as the original observations. It is this fact which gives impetus to the search for quick methods of determining the number required. If the combination is different, M new observations are needed--in the illustration 36 more. If there is some doubt as to whether or not the conditions are different, the control chart technique described under "Are Observations Stable" will be a useful aid.

The additional observations contain additional information about the variability; it is always well to recompute E to verify that sufficient observations have indeed been taken. For example, suppose the additional observations of the element "smooth surface with trowel" are found to be

    5,9,6,8,6   7,6,6,7,4   7,5,6,5,6   5

hundredths of a minute in that order. The select value then would be (132 + 98) / 36 = 6.4 hundredths of a minute, with 95% chance of being within

$$E = 1.96 \sqrt{\frac{36(1542) - (230)^2}{1296(35)}} = .47$$

hundredths of a minute, satisfying the specifications.

The foregoing illustration follows Procedure A then Procedure C. It is possible to calculate directly the required number M of observations without first ascertaining E for the original observations. Such a procedure has the advantage of not requiring the extraction of a square root.

Procedure D:
(1) Add the observed times and call the result ΣX.
(2) Square (1).
(3) Add the squares of the observed times and call the result ΣX^2.
(4) Multiply (3) by the number N of observations.
(5) Subtract (2) from (4).
(6) Multiply (5) by the square of L.
(7) Multiply the number of observations by one less than the number of observations.
(8) Square the desired or allowed error E*.
(9) Multiply (7) by (8).
(10) Divide (6) by (9).

Reduced to a formula, Procedure D is:

(D) $$M = \frac{L^2 \left[N \Sigma X^2 - (\Sigma X)^2 \right]}{E*^2 N(N-1)} .$$

Procedure D, applied to the entire 36 observations of the foregoing illustration, gives:

$$M = \frac{(1.96)^2 \left[36(1542)-(230)^2 \right]}{(.5)^2 \, 36(35)} = 31.9$$

indicating that the 36 observations are ample to insure that the observed average of 36 has a 95% chance of being within .5 hundredths of a minute of the long-run average.

It is possible, as before, to avoid the summation of squares by using Procedure B and then Procedure C. Applied to the illustration, we would have

$$M = (.67/.5)^2 \cdot 20 = 36$$

as before.

Since the range method as described here is applicable to subgroups of five, suppose only 15 additional observations are made. The value of $\bar{R}$ from all observations is then $(4+2+3+5+4+3+2)/7 = 3.3$ and a new value of E is $(3.3)(.145) = .48$ for the 35 observations.

Also with the range procedure it is possible to calculate the number of observations required without first calculating E--by using the formula

(E)   , $$M = (.740) \, \bar{R}^2/E*^2.$$

It would be well to emphasize that the procedures based on sums of squares and the procedures based on ranges are alternatives; it is not necessary to use both. The latter are simpler to compute. It would be desirable to have these methods adapted so as to be used by the observer while making the time study, thus obtaining the necessary number of observations consecutively or almost so if such is deemed desirable. To that end, there is presented herewith a graph which may well be used by the observer on his clipboard, requiring only the calculation of the average range $\bar{R}$ for subgroup size 5. Figure (F) may be used for any units of time provided $\bar{R}$ and E are expressed in the same units.
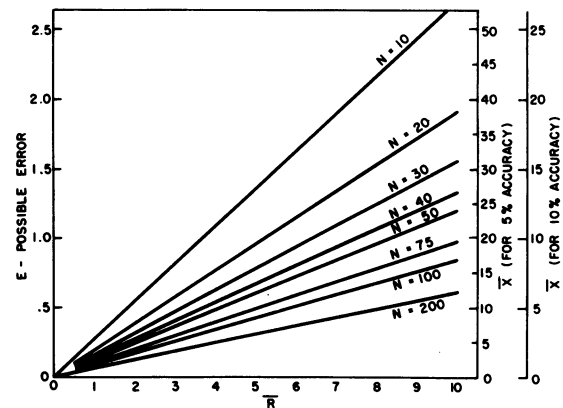
FIG. (F) POSSIBLE ERROR FOR GIVEN AVERAGE RANGE OF 5 ELEMENTS

In any particular operation where the same value of E is used for many elements a heavy horizontal line at that value will be found helpful--or a table may be made up of the values of $\bar{R}$ corresponding to various values of N. The graph may be used for determining the accuracy of a given set of observations or for determining the number of observations required for a specified value of E.

Occasionally, the accuracy desired is specified as a percentage of the average--within five per cent, for example. If this were so for the original observations of the element "smooth surface with trowel," you would enter figure (F) with $\bar{R}$ = 3.5 and E = (.05) (6.6) = .33 to get a required number of observations 85 so that 65 additional observations are necessary. To avoid the multiplication, two extra scales have been added to read off directly in terms of the observed average, expressed in the same time units as $\bar{R}$. You may easily construct scales for other accuracy percentages proportionately.

ARE THE OBSERVATIONS STABLE?

In determining a selected time, the objective aid of statistics has been described for the third of five steps previously listed. All the procedures proposed rest on the assumption that the second step has been properly carried out. That is, all the foregoing procedures assume that the worker-machine-conditions combination has settled down to a steady production in which the variation is random but consistent in size--a condition known in quality control departments as being "in control." Thus, it is assumed that the worker is adjusted to the job and the machine so that a week or month later under the same conditions his production would be variable to the same degree and with the same long-run average. Variations due to time of day or increase in skill will presumably be accounted for in rating, but if the operation has not "settled down" there is no reason to assume that future production can be properly forecast from the values observed and recorded. If there is a run of non-typical material, the time study will be incorrect through no fault of the observer or rater. If the machine is in exceptionally good or exceptionally poor adjustment, the study will not apply to production on the machine in average condition. The quality of product produced during the time study should be in accord with the quality of later production. You can make use of experienced judgment with respect to all these requirements, but along with subjective opinions there are objective methods available and in use today for verifying the stability of the operation before and during a time study. One outstanding example is the control chart.

In the September, 1947 issue of Industrial Quality Control Roy W. Good of the Robertshaw Thermostat Company has described six specific studies made by his Quality Control Department either preliminary to or concurrent with a time study by the Time Study Department. Some studies indicated the need for a change in design, some indicated the need for a change in the operation, some were satisfactory, and some were reported unsatisfactory as to quality without analysis of the reason. Various kinds of control charts are in current use, but all are basically a running plot of some dimension or of the proportion of defectives per lot or per sample, plus a center line and an upper control line and a lower control line. The center line represents the long-run average as best it is known and the control lines are chosen so that as long as the process or operation is stable there is very, very little chance that an observation will fall outside the control lines. A point outside thus indicates a lack of stability known as an out-of-control situation.

A control chart for quality before a time study will determine if the process has "settled down" in that respect. A control chart for quality during a time study will verify that production during the study is consistent with previous and subsequent production. It will also reflect poor machine condition by unfavorable comparison with the spread of previous control charts run on the same machine though perhaps not on exactly the same product. It will also reflect undue variation in the incoming material, depending on the quality measurement used. A control chart for times per element or per cycle will determine the stability of the times--or the instability due to any of the aforementioned factors.

There are several advantages to the control chart-- it is simple to maintain and easy to interpret. The control lines are easily obtained from tables in any work on Statistical Quality Control such as that by E. L. Grant. To illustrate one usage, consider an X chart for the first twenty observations of the element "smooth surface

with trowel, " shown in Figure (G). This chart indicates a stable, in-control condition.
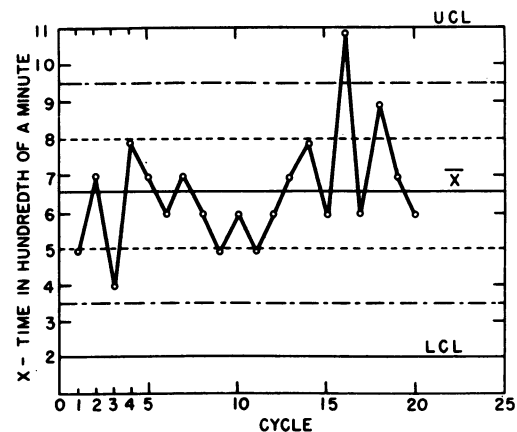
FIG. (G) X-CHART OF TWENTY OBSERVATIONS OF THE ELEMENT

Furthermore, counting outward from the center line we can expect roughly two-thirds of the points within one-third of the distance to the control lines, and 95% of the points within two-thirds that distance. To illustrate this property, dashed and dotted lines have been added to Figure G which are not ordinarily present. Fourteen out of 20 points lie within the dotted lines and 19 out of 20 lie within the dashed lines. The agreement with theory is not always so good but is close for a normal distribution. Increasing evidence is available that the observations of an element have a skewed rather than symmetrical distribution; if a sufficient number are obtained an $\overline{X}$ chart may be used on subgroups of five since $\overline{X}$ tends to be normal even when X is skewed. For further inquiry into such details and the construction of the various charts I refer you to a book on Quality Control.

For a single illustration of the small amount of work involved in control chart construction, consider the X chart in Figure G. The center line is placed at the observed average; the upper control line is placed at a distance of 1.5 E $\sqrt{N}$ above the center line and the lower control line is placed at a distance of 1.5 E$\sqrt{N}$ below the center line, where E may be calculated from Procedure A or Procedure B and N, as before, is the number of observations. In this case E = .67, N = 20, so the control lines are at $6.6 \pm \sqrt{20} = 6.6 \pm 4.5 = 2.1$ and 11.1 hundredths of a minute. For an $\overline{X}$ chart, the center line would again be at the observed average, but the control lines would be spaced a distance of 1.5 E$\sqrt{N/5}$ from the center line and only the mean of each subgroup of 5 observations would be plotted instead of each observation.

SHOULD AN OBSERVATION BE DISCARDED?

Two principal reasons have been advanced for discarding an observation--that is, for ignoring it in all subjective and objective treatment of the data. First, an observation is discarded because something is observed to occur which is not ordinarily a part of that element. For example, in a bottle-filling operation, one observation of the element "place bottle rack in slide" was .10 minutes

while all other observations of the same element were from .03 to .04 minutes. In this case it was noted that the operator hit the shake tray with the bottle rack; a skilled operator would not hit the shake tray and therefore on the basis of a very low skill rating that observation is legitimately discarded. In a time study of single-bottle packing into a carton, one element was "form one end of carton and invert." For this element, several observations were longer than the rest because the characteristics of the carton caused a flap to stick; there was no lack of skill or effort on the part of the operator. Such occurrences are quite possible in average production and cannot be ignored if the increased time is more than .04 or .05 minutes; they must enter either through the selected time or through an allowance. One possible way to provide for them is to introduce an additional intermittent element such as "unstick flap" and analyze it according to suggestions given later.

Observations are frequently discarded also when no particular deviation from ordinary is observed except the increased time taken. Even though no cause has been observed, and the skill and effort are still about the same, an observer will throw out an observation because-- and this is the second principal reason referred to above--it just seems to him to be too large and out of line with the other observations. Here is a subjective decision. Besides the fact that some other observer might disagree, there is the established fact that in a stable, typical system we still expect variation up to the control lines. Thus, the control lines may be used as an objective criterion for determining when an observation is too large, and hence not typical. For example, Figure G demonstrates that the .11 minute observation is normally expected to occur in twenty cycles and therefore should not be discarded. On the other hand, if an observation does fall outside the control lines, there is evidence that even though the observer did not note it, some extraneous occurrence may have taken place.

HOW PROFICIENT ARE YOU IN YOUR RATING?

The control chart technique finds usefulness also in connection with the fifth or rating step. The accuracy of the rating depends on your obtaining and maintaining proficiency--on training and refresher checks. By periodically rating film loops of various percents of standard effort, you may check your ratings against the calculated ratings of the loop. You expect to be within a certain percent of the correct rating-- by plotting the size of your errors, positive and negative, as an X chart or $\bar{X}$ chart, you may demonstrate graphically to yourself--and to others if it seems advisable--the consistency of your ratings and an objective assurance of their dependability. Such a chart may be continued over a period of many refresher checks. It shows three things--the average size of error, maximum size of error to be expected, and consistency of ratings within these limits.

OBSERVING FOR ALLOWANCES

After the select time has been determined and modified by the rating factor to give a base time for the element--an average time for an average worker--there remains the final problem of allowances for justifiable nonproductive time. For example, there is an allowance for those periods where the machine is down for maintenance. By observing many such periods, you could get an average

value for down-time per week or down-time per day. Despite the fact that such an analysis could probably be used for many different operations on the same machine so that a new study would not be required nearly so often as a time study--despite this fact, such an investigation would consume an unduly large amount of your time. It is possible by means of brief repeated samplings to obtain a good value for the proportion of down-time and carry on your other work too. One such method is known as a ratio-delay study and is treated elsewhere.

INTERMITTENT ELEMENTS

In making a time study, an operation is divided into component elements, base times obtained for each, and the sum of the base times used as a base time for the operation. Occasionally, there is an element which appears in one cycle but not in another, and the appearance is random. For example, in loading two bottles at a time into a bottle-washing machine with capacity of twelve bottles, it is quite simple to divide the loading element by two and the "wait on machine" element by twelve to get an average time per bottle. However, an intermittent element would be one which occurs frequently but not regularly, such as "trim core as necessary" in a core-making operation. By its very description one infers that in some cycles it occurs, some cycles it does not and there is a tendency to say "one never knows" if it will occur or not. This is true of any particular cycle you might choose to watch, but there is a certain proportion of the time it will occur. If it occurs 50% of the time, half the select time for that element can be added into the time for the whole cycle; if it occurs 10% of the time, 10% of the select time for that element can be added into the time for the whole cycle.

To allow for this intermittent element then, it is necessary to determine how frequently it occurs. The obvious and best method is to assume that the observed relative frequency of occurrence p (= number cycles occurred/number cycles observed) is the long-run frequency. The accuracy of such an estimate is given by the formula $E = 2\sqrt{p(1-p)/N}$ where N is the number of cycles observed and the chances are approximately 95 in 100 that the long run frequency of occurrence will lie between p - E and p + E. This is less accurate with small numbers of cycles than with large, but it points up the possible lack of accuracy in p for short studies.

THE OVER-ALL PICTURE

Statistics offer a helping hand as an objective supplement to the exercise of good judgment and experience. Wherever consistent variation exists, statistical experience will aid in proper planning for the taking of data, and in forecasting results from that data. It provides a measure of the accuracy of an estimate in a stable situation and provides tools for determining when that stable situation exists. Each of the foregoing specific applications illustrates one of these statistical functions. In addition, there are some statistical techniques which are applicable more to the never-ceasing search for improved methods of time study. One such technique for example provides an objective criterion for answering the question "Is method A more accurate than method B." An example of another technique--correlation analysis--appears elsewhere in these Proceedings.

Thus far only those situations have been stressed for which tested statistical techniques already exist. In the statistical laboratories are being developed new statistical

methods, techniques, and aids for the future. What will come forth for engineers' use only that future can say. However, it seems quite possible that we may soon see in practice improved methods of handling the apparently skewed distributions of time study, improved methods of handling the irregularities in timing of very short elements, and further information on the smallest practicable length of an element. Such improvements will not come from the statisticians alone but through the leavening procedures of cooperative testing in practice--the statistician melding his numbers and variability experience with the engineer's men, machine and materials experience.

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One of the more frequently recurring problems in the study of industrial operations and in the management of such operations is to determine the proportions in which the time of a worker or a machine is divided between different categories of activity. This type of data, for example, is essential in estimating appropriate allowance for delays in connection with time standards and is useful in studies of plant efficiency in which it is necessary to know how effectively various elements of a production process are integrated. For either purpose the proportions determined must be reasonably accurate and should be obtainable at a reasonable cost.

Depending on his particular purpose, the analyst or manager of a plant operation may seek answers to three types of questions as to how worker or machine time is utilized. He may wish to know the proportions in which the total time in a working status is divided between "working time" and "delay time." He may seek the correct allocation of total working time to different tasks, or the allocation of total delay time to various types of delay. Or, he may want the "flow pattern" in materials handling. In any event, he obtains his answer in terms of some measure of past performance. Three principal methods of study are currently in use:

Time Study, in which the study is designed to measure both normal and irregular delays and is conducted for a period presumed long enough to provide a representative sample of delays; or, a sufficient number of separate time studies are made to yield a representative sample.

Production Study, which consists of a continuous time-log of each operation, delay, or other event associated with the operation and conducted for a long enough period, usually not less than one workday, to provide a presumably adequate base for estimates of time distribution and delays.

Ratio-Delay, in which the proportional time distribution is determined on a sampling basis from a number of instantaneous observations of the work. As measures of past performance, all three methods yield only an estimate of expected or probable performance and each method is subject to error in that the period observed is only a sample of the total performance.

It is presumed that the time-study and production-study procedures are well understood and that we may proceed directly to a consideration of the ratio-delay method.

Procedures in Ratio-Delay Studies

The ratio-delay method is essentially a sampling process which involves: (1) a machine or a worker whose activity is divided into a number of different categories;

(2) a large number of instantaneous, random and, for practical purposes, independent observations of the work; and (3) the theory that the ratio of the number of observations in any one category to the total number of observations will yield a reliable estimate of the ratio of time expended in that category to the total time.

The ratio-delay method is statistically acceptable if the observations are random, independent and unbiased and if the number of observations is sufficiently large. Consider first the question of how to get random and unbiased observations. This question will be explored by reference to a particular example taken from a study of the costs and efficiency of packing house operations in twenty different pear and apple packing plants. The number of different jobs under observation varied from about 12 to 45 per plant and the total number of workers per plant from 25 to 180. Because of the large number of jobs to be studied and the seasonal character of the plant operations, a rapid and economical method of study was required; on this basis the ratio-delay method was selected. In this study the observer periodically followed a specified route through the plant that took him past each work station to be observed. As a preliminary step the work stations to be observed and the observer's route were drawn on a schematic plant layout (Figure 1).
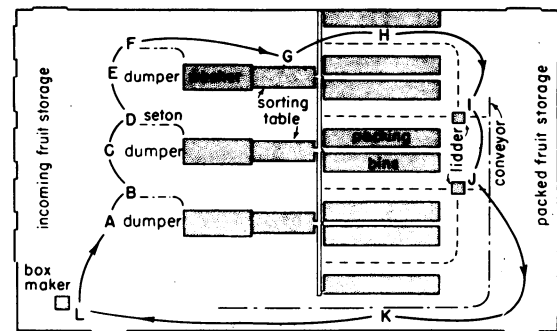
Figure 1 - Ratio-delay observation route.

To avoid bias in classifying the observations, they were made on an instantaneous basis, with every effort made to eliminate any tendency of the observer to anticipate what the work status should be or unconsciously to exercise a preference for recording the working status in one way or another. For example, a particularly "kindhearted" observer might unconsciously prefer to record a worker as "working" rather than "idle." For purposes of illustration, we might describe the type of observation desired as that resulting if the observer were to wear special goggles equipped with a camera shutter. Then, if the shutter were operated when an observation was taken, an instantaneous observation would be obtained if the observer recorded precisely the work status existing at the instant the work station was visible. To assure consistent classification of the observations (both from the standpoint of consistency of one observation with another and from one observer to another) careful definitions were drawn as to the character of each category of work status. Each observation was recorded with a tally mark in the appropriate column of a data sheet. The record of observations on one job, the dumping of fruit from field lugs to a conveyor at three separate dumping stations, is illustrated in Figure 2.

To obtain a random observation it was necessary that all possible delays have an equal chance of being

observed. Since the proportion of delay observations to total observations was to be the basis for an estimate of the proportions in which the total time was divided, it was necessary that the sampling procedure admit the possibility that long delays be recorded more than once.[1] In other words, it was consistent with a random sampling procedure to record the same delay, if it were a long one, on successive trips. A necessary precaution was that visits to a particular station not coincide with a cyclical delay, otherwise considerable bias might have been introduced.

RATIO-DELAY STUDY				NOT WORKING		
Plant: A Date: 7-14-50		No. of	WORKING	break for lots	equip. failure	other
Job	Sta.	workers				
Dumper	A	1	ЖЖ ЖЖ ЖЖ ЖЖ	ЖЖ		
Dumper	C	1	ЖЖ ЖЖ ЖЖ II	ЖЖ II	II	I
Dumper	E	1	ЖЖ ЖЖ ЖЖ ЖЖ	ЖЖ I		

Figure 2 - Sample ratio-delay data sheet.

To meet the objectives of obtaining a maximum number of observations and to have them as random and free of bias as possible, a continuous round of observations was taken. The duration of the trips was approximately uniform although no effort was made to obtain complete uniformity. The duration and the starting time of each trip were so arranged as to avoid visiting the various work stations on a regular time cycle. No observations were made during regular rest periods or during lunch periods. This procedure does not give truly random observations, but probably results in a representative sample for the days studied. The result will approximate a random sample if the procedure of continuous sampling is applied to a situation in which the delays are random in distribution.[2]

The calculation of the delay ratios from the observed data is simple. For the dumping operation illustrated in Figure 2, for example, a total of 78 observations were made, 21 of which were classified as "Not Working." The proportion of total delay observations to total observations is:

$$p = 21/78 = 0.269$$

and, the proportion of "Break for Lots"[3] delay to total observations is:

$$p = 18/78 = 0.231$$

The foregoing ratios of instantaneous observations are estimates of the proportions in which the total observed time was divided. Thus, we estimate that, of

1/ In the literature concerning the ratio-delay study, the usual instruction regarding long delays is either to schedule the observations so that each tour is slightly longer than the longest delay; or if the same delay extends into more than one observation trip, to count the delay only once. The procedure suggested in this paper, however, will result in a more reliable estimate of the delay time.

2/ This sampling procedure becomes less appropriate the more the delays under observation deviate from random occurrence. If delays occur with regularity or are cyclical (e.g., lunch and rest periods in the study referred to above), the delay probably can best be measured directly, rather than by sampling.

3/ "Break for Lots" refers to a suspension of the fruit dumping operation while changing from one grower's fruit to that of a different grower.

the total working time, 73 per cent was actual working time and 27 per cent was total delay time. Delay due to "Break for Lots" is estimated as 23 per cent of the total working time.

Reliability of Ratio-Delay Estimates

How reliable are estimates obtained by the ratio-delay method? One basis for judging their reliability is to compare the sample proportions from the ratio-delay study with the actual distribution of time observed in a concurrent production study. During one day of the ratio-delay study referred to above, a production study of the three dumping stations was made. The actual length and frequency of delays and the proportion of delay time to total observed time on each station due to "Break for Lots" are shown in Figure 3. For the three lines, the
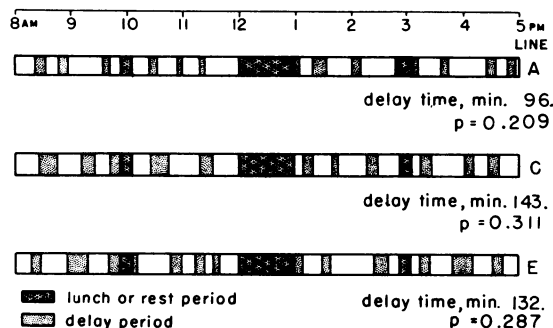
Figure 3 - Production study of fruit dumping operation.

total observed time on the production study was 1,380 minutes and the total delay time was 371 minutes. Hence, the delay ratio for the three lines taken together was 371/1380 = 0.269. These proportions and the proportions obtained from the ratio-delay study are summarized in Table 1.

While the two sets of proportions do not correspond exactly, they are reasonably consistent, particularly in view of the small number of ratio-delay observations. Of these ratio-delay proportions, greatest reliance might be placed on the aggregate delay for the three dumping stations since the aggregate proportion is based on a larger number of observations.

In comparing ratio-delay data with direct measurements, as is done in Table 1, it is easy to attribute more significance to the time study and production study data than they deserve. It is true that the production study, for example, gives the actual proportion of time utilization during the period studied, whereas the ratio-delay proportion is only a sample for that period. But a production study is itself only a sample of the total production experience. One could well argue that a ratio-delay proportion based on a sampling of several days' operation is more representative of the total production experience than is a 1-day production study. There is the further consideration that the ratio-delay proportion can be tested satisfactorily, whereas conventional statistical tests can be applied only to certain types of delays observed by the production study or time study methods. Some statistical inferences relative to ratio-delay proportions are discussed below.

Standard error of a Proportion. The reliability of a sample proportion is indicated by the familiar standard error of a proportion, σ_p, where,

$$\sigma_p = \sqrt{\frac{\pi(1-\pi)}{n}} \tag{1}$$

55

Ratio-Delay and Production-Study Observations on Dumping Operations
in a Fruit Packing Plant[a/]

Line	Production study for July 14, 1950			Ratio-delay observations					
				For July 14, 1950			Total for four-day study		
	Break for lots (minutes)	Total working time (minutes)	Ratio, BFL time to total time	Break for lots number of observations	Total ratio delay observations	Ratio, BFL observation to total observation	Break for lots number of observations	Total ratio delay observations	Ratio, BFL observations to total observation
A	96	460	0.209	5	26	0.192	21	86	0.244
C	143	460	0.311	7	26	0.269	29	86	0.337
E	132	460	0.287	6	26	0.231	21	82	0.256
Total	371	1380	0.269	18	78	0.231	71	254	0.279
Standard error S_p = p (1-p)					·	± 0.048			± 0.028

a/ In this table the ratio delay percentage appears to underestimate the actual delay as observed in the production study (compare the one-day ratio delay percentages with the corresponding production study percentages). This is not, however, a consistent bias; see table 3.

Table 1.

In this equation, π is the true proportion in the population, and n is the number of observations in the sample. In a practical problem we do not know the true proportion. But, if the sample observations are independent, we can obtain a point estimate of σ_p by substituting the sample proportion, p, for the true proportion. The estimated standard error then is

$$S_p = \sqrt{\frac{p(1-p)}{n}}$$
(2)

where S_p is the estimated standard error, p is the sample proportion, and n is the number of observations in the sample.[4]

It is recognized that the ratio-delay observations are not independent, but they probably approximate this condition closely enough for practical purposes. We shall assume the frequency distribution of sampling errors to be normal, this being the limiting distribution as the sample size becomes infinitely large. The error due to the assumption of normality is not large except for small values of π, or a small sample size. It is customary to accept the normal distribution as satisfactory in all cases where the product, $n\pi$, is greater than 5. When $n\pi$ is small, the assumption of a normal distribution results in underestimating the probability that the sample proportion will be within a stated number of standard errors of the true proportion.

To illustrate the possible magnitude of the sampling errors let us consider an earlier example regarding a fruit dumping operation in which 18 of a total of 78 observations were classified under "Break for Lots." The proportion of "Break-for-Lots" time then is 0.231. The estimated standard error of this proportion is, from equation (2),

$$S_p = \sqrt{\frac{0.231(1-0.231)}{78}} = \pm 0.048$$

In terms of probability we may make the following statements regarding the sample proportion and its estimated standard error.

(1) The true proportion is a fixed, invariable number. Our real interest is in knowing how near to it we may expect our sample proportion to come. On this point we may say, with the chance of being correct 68 per cent of the time, that our sample proportion does not deviate from the true proportion by more than one standard error. Thus, we may say regarding the above example that our sample proportion of 0.231 may differ from the true proportion by an amount equal to, or less than, one standard error (in this example, approximately ± 0.048); and we can make this statement with a 68 per cent chance of being correct, assuming a normal distribution of the sample proportions.

With the standard error we may then construct a confidence interval the magnitude of which can be adjusted according to the level of probability desired. Confidence intervals for three levels of probability are expressed in column 2 of Table 2 in terms of multiples of the standard error of the sample proportion.[5]

(2) The estimated standard error is itself an estimate and is subject to sampling error. But unless the sample is small, this error is insignificant. For example, the standard error of the estimated standard error in the above illustration is only 1.29 per cent.[6] In other words, the estimated standard error of 0.048 has a standard error of approximately 0.0006.

4/ For a small sample (n less than 30), it is appropriate to modify equation (2) by substituting (n - 1) for n.

5/ For more details, see any table of areas under the normal curve of error.

6/ The relative sampling error in the standard error is given approximately by the equation $S_s/S = 1/\sqrt{n(n-1)}$. For the above example, $S_s = 1/\sqrt{78(78-1)} = 0.0129$. $S_s = (0.0129)(0.048) = 0.0006$.

Now suppose we wish to say, with stated chances of being correct, that the sampling error does not exceed a specified amount, θ. It is evident from the above that the admissible standard error of the proportion is influenced by the level of confidence desired. This relationship for three levels of confidence is indicated in column 4 of Table 2 from which it appears that, if we insist on a higher probability, a sampling procedure must be followed which yields a relatively smaller standard error. From the equation for the standard error, it is clear that this can be accomplished by increasing n, the number of observations.

TABLE 2

Confidence Interval at Three Levels of Probability and Admissible Standard Error, σ_p, in Terms of Admissible Sample Error, θ (Assuming Normal Distribution of the Sample Proportions)

Probability	Confidence Interval	Admissible Interval	Maximum Admissible Standard Error
1	2	3	4
0.68	$\pi \pm 1 (\sigma_p)$	$\pi \pm \theta$	$\sigma_p = \theta$
0.95	$\pi \pm 1.960 (\sigma_p)$	$\pi \pm \theta$	$\sigma_p = \dfrac{\theta}{1.960}$
0.99	$\pi \pm 2.576 (\sigma_p)$	$\pi \pm \theta$	$\sigma_p = \dfrac{\theta}{2.576}$

Number of Observations Required. We now come to the interesting question: For a given accuracy of estimate, how many observations will be necessary? Note that the standard error formula, equation (1), can be transformed to

$$n = \frac{\pi (1 - \pi)}{(\sigma_p)^2} \quad (3)$$

Suppose we wish to say, with a probability of 0.95 of being correct, that our sample proportion is within 0.05 (absolute) of the true value. The admissible error in the sample proportion, then, is ± 0.05; or, in the terms used earlier, θ = ± 0.05. We have also noted that at the 95 per cent level of probability (assuming a normal distribution), θ = 1.96 (σ_p). Then

$$\sigma_p = \theta/1.96 = 0.05/1.96 = 0.0255$$

If, for illustration we assume a ratio-delay proportion of 0.279, we may substitute in equation (3) to find the necessary number of observations as:

$$n = \frac{.279 (1 - .279)}{(0.0255)^2} = 309$$

These relationships are represented graphically in Figure 4. Two levels of probability are represented (95 per cent and 99 per cent) and curves are included for two admissible ranges of error (0.05 and 0.10).

In planning a ratio-delay study, Figure 4 would be useful as a guide to the number of observations that probably would be required. This would involve entering Figure 4 on the vertical scale with an approximate estimate of the true proportion, π (such as might be obtained from a tentative sample of 50 to 100 observations, and observing

the indicated sample size for the level of probability desired. Suppose, for example, the preliminary sample indicated the proportion to be about 0.20, the level of probability desired is 95 per cent, and the admissible error is 0.05 (i.e., θ = 0.05). Figure 4 indicates that approximately 245 observations would be required.
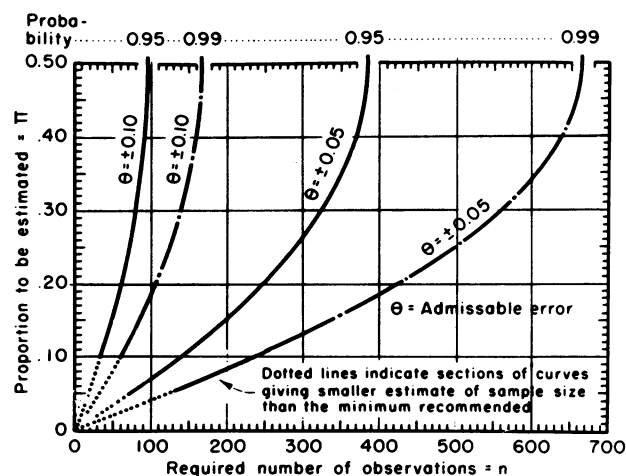
Figure 4

It is evident that the above procedure is not as rigorous as might be desired. A correct use of Figure 4 to estimate the sample size, n, requires that the true proportion, π, be known. This presents a dilemma since we may expect some error in the sample proportion and there are no means of determining π, the true proportion, short of observing all possible events. But, if all possible events are observed, we no longer have a sampling problem. This difficulty can be eliminated by computing the necessary sample size in terms of an interval estimate, a procedure that requires a much more complex statistical analysis than is given above. The results based on an interval estimate would closely approximate those derived as in Figure 4, except for small proportions. The substantial deviation when p is small accounts for the recommended minimum sample size indicated in Figure 4. As a practical compromise in using Figure 4, it is suggested that the curves be regarded as giving an appropriate indication of the approximate required sample size for all but small proportions. To estimate the sample size required we would first take the minimum size sample recommended for the level of probability and admissible error limit selected, compute the preliminary sample proportion and use this proportion to estimate the required sample size from Figure 4. If Figure 4 were to indicate for this "trial proportion" a sample smaller than the recommended minimum, no further sampling would be required. If a larger than minimum sample were indicated, the preliminary sample would be expanded to the desired size.

Some Considerations in Using the Ratio-Delay Study

In summary, we may note that the ratio-delay technique is a sampling procedure whereby the proportional time distribution to various categories of work status can be determined. It is proving useful as an industrial engineering tool on the following basis:

1. With a sufficiently large number of observations, sampling errors relating to the classification of observations can be reduced to reasonable limits. From a number of studies where comparison with direct time measurements was possible, the sample proportions of instantaneous observations appear to yield a close estimate of the

actual division of work time. For example, from the plant studies previously referred to, other comparisons between ratio-delay and production-study proportions are given in Table 3.

TABLE 3 - Comparison of Delay Percentages Observed by Ratio Delay and Production Study Methods

Plant	Type of delay [a]	Job	Production Study	Ratio-delay Study	No. of Observations	Standard Error S_p
A	BFL	Set-on	.174	.167	67	.046
A	BFL	Dumper	.174	.167	67	.046
A	BFL	Sorter	.174	.197	67	.049
B	Conveyor stopped	Lidder	.157	.184	49	.055
B	BFL	Dumper	.031	.038	52	.026
C	BFL	Set-on	.269	.218	78	.047
C	BFL	Dumper	.269	.279	78	.051
C	BFL	Sorter	.269	.251	78	.049

* BFL = Break for Lots

Favorable comparisons between ratio-delay and production-study proportions have also been noted in other reports (c), (d), (f).

2. With the ratio-delay method an estimate of sampling error can be obtained by means of simple statistical tests; this frequently is not true with regard to the production and time study methods.

3. In the determination of delay allowances, the method is less costly to apply than either the production-study or time-study methods. In the plant study cited in this report, for example, the field time required in the ratio-delay study is estimated to be less than 20 per cent of the time required to obtain a one-day production study of each job. This estimate is based on obtaining ratio-delay proportions with an admissible error of 0.05 at the 95 per cent level of probability. The estimate of field time actually is quite conservative since the estimate of required number of ratio-delay observations was obtained by treating each worker individually. The number of workers per job in this plant, however, varied from one to 70. By aggregating the observations on workers in like jobs, it would be possible to obtain the desired accuracy in the ratio-delay proportion in a still shorter time. The estimated saving in this study is greater than has been reported in other studies; estimated savings of 33 to 70 per cent have been noted in other reports (c), (d), (f).

4. The ratio-delay sample may be more representative than a time study or production study, since it may easily be composed of an aggregation of observations taken over a period of days or weeks (assuming no essential changes in the plant organization or working conditions during the period of observation) and, thus, reflect average conditions more accurately than several isolated time studies or a production study confined to a single day.

5. If made on a department or plant-wide basis, the ratio-delay study can provide, in a sense, a simultaneous measure of delay at all points and, on this basis, is an excellent device for indicating how effectively plant operations are integrated and at what points improvements in work methods to eliminate delays would be most effective. These relationships would not be so effectively revealed by a succession of isolated production or time studies.

6. The ratio-delay data may be less biased than the production- or time-study data from the standpoint of the worker's reaction to observation, since the worker is under observation in the ratio-delay study for a very short period. Even so, in the particular study referred to in this paper, some worker reaction was noted in a few instances. The reaction usually was in the nature of a "make-work" tendency on the part of a worker who apparently felt uneasy about being recorded as "idle." An experienced observer, however, can offset abnormal worker reaction. The observer can, for example, obtain a "flash" observation on entering the work place; he may actually make his observation after having passed the work place; he may observe from across the plant, etc.

7. Some jobs do not lend themselves to time study. In some such instances the ratio-delay method is effective in estimating delay time; or, it might even be used in establishing production standards by relating observed working and delay time to the output during the study period.

8. The ratio-delay method shares a common handicap with the production- and time-study techniques and that is the bias introduced by the rate at which a particular individual works. It is conceivable, and not unlikely, that "delay time" observed for some individuals exists only because they work at an abnormally rapid rate and thus "work themselves out of a job." Conversely, the bias for a slow worker would be in the other direction. Owing to the nature of the ratio-delay study, any such bias appears difficult to eliminate. It seems unlikely, for example, that a system of ratings such as is applied to time studies could be devised. If, however, observations on a number of different workers are aggregated to obtain the ratio-delay proportion, the effect of rate-of-working by an individual would tend to average out.

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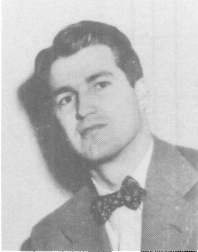
VISUAL INSPECTION OF CYLINDRICAL SURFACES IN COMBINED TRANSLATION AND ROTATION

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Since the time of Frederick Taylor, when the scientific method was first seriously used to attack the problem of "man at work," much attention has been devoted by a great many people in several professional fields to studies of how to increase a worker's efficiency and satisfaction with his job. However, one area of this field, that of visual inspection, has remained relatively untouched. This investigation attempted to gain some information in one corner of this area.

The purpose of the investigation was to determine an operator's ability to sight and select defects on the surface of small cylindrical specimens as they moved past him at various horizontal translational speeds while turning at various rotational speeds in both a clockwise and counter-clockwise direction. Industries using visual inspection similar in nature to that investigated reported that their workers were quite frequently affected by "belt sickness" and "whiting out," a form of nausea they believed might be caused by the movements of parts past a worker on conveyor belts. The experimental tests were planned to gain information concerning these questions.

The chief problem in the design of the equipment was in providing a controlled speed and direction of rotation of the cylinders for a desired horizontal translational speed. This was accomplished by designing a conveyor table to support and give the cylinders their motion. Rotation was considered as "forward" when rotating in the same direction as the translational motion and "backward" when rotating in the opposite direction.

After approximately twenty hours of trial runs in which two operators participated, four basic tests were set up to investigate the conditions under inquiry. In organizing and presenting the data collected, the measure of central tendency used for a distribution of scores was the mean efficiency, where an operator's efficiency was defined as

$$\text{Efficiency in per cent} = \frac{\text{Number of defects selected}}{\text{Number of defects in the sample}} \times 100$$

The measures of scatter about the mean used were the standard deviation and the range. The distribution of scores of the conditions tested were checked at random for skewness and kurtosis, and the distributions appear to be sufficiently of the normal type to be described adequately by the mean and the standard deviation.

Six operators between the ages of 23 and 30 years were chosen from the male population of the university. Four were right handed and two left handed, all had excellent color perception, and each operator's vision had to be corrected to at least 20/20. When the operators reported for their first test, they were given a training period in which to familiarize themselves with the equipment and

how the tests were run. None of the operators had any difficulty in learning the job quickly, and at the conclusion of the training period the operators began immediately on the first of four tests given. All the tests used a sample size of 500, 30 per cent (or 150 cylinders) being defective.

The main test studied the effect on the operator's ability to select defective cylinders while they were rotated at fast and slow speeds in a forward or backward direction and at a fixed, translational speed between the range of 75 FPM to 180 FPM. Data were also collected over the same range of translational speeds when the cylinders were given no rotational motion. The cylinders moved past the operator in a single row at twelve-inch intervals.

Figure 1 presents a graphical representation of the data collected. Sufficient data were collected to make the following statistically valid conclusions.

1. The optimum combination of translation and rotation in terms of.worker satisfaction and efficiency occurred at a translational speed of 90 FPM and a forward rotation of 80 RPM (41.8 FPM cylinder surface speed). The oper-
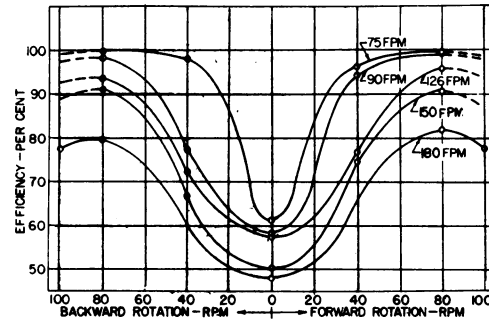
FIG. 1 MEAN EFFICIENCIES FOR THE TEST ON COMBINED TRANSLATION AND ROTATION.

ators consistently worked at an efficiency better than 99 per cent with a standard deviation of 0.7 per cent.

2. Efficiencies decreased with an increase in translational speed. The upper limit at which the operators could move fast enough to select the defects they could see was between 150 and 180 FPM. Speeds below 90 FPM were generally considered too slow by the operators, but the efficiency remained above 99 per cent..

3. Forward rotation received better efficiency scores and was preferred to backward rotation by all operators. The speed of rotation, however, had more influence than the direction on worker satisfaction and efficiency.

4. Lower standard deviations occurred generally at the lower translational speeds and at forward rotations. The consistently lowest standard deviations were obtained at the 80 RPM (41.8 FPM cylinder surface speed) forward rotation.

5. The combination of 126 FPM and backward rotation of 40 RPM (20.9 FPM cylinder surface speed) caused severe feelings of nausea to four of the six operators and a mild nausea to a fifth. The operators believed the nausea was very similar to seasickness and was caused chiefly by a conflict in motions. The nausea, in fact, could be induced only in those operators who were subject to seasickness. It never occurred at the beginning of a test period, but only after an operator had been working for at least a half-hour, and it occurred only when working on this combination of speeds.

After determining the best direction and speed of rotation for the translational speeds (i.e., forward rotation

of 80 RPM), secondary tests were made on the conditions that were believed to have the most effect on an operator's output and efficiency in selecting defects. These tests included varying the distance between the cylinders in a given row, changing the directions of approach of the cylinders in a given row, changing the directions of approach of the cylinders from right to left to left to right and varying the number of rows.

The following statements were based on tests for which insufficient data were collected to make the results as statistically valid as the above. However, the information should serve as good indication for the direction of further investigation.

  · 1. Right to left approach versus left to right approach had no significant effect on the efficiency, but all the operators preferred the cylinders to approach from right to left.

    2. Closer spacing of eight inches and four inches with a lower translational speed increased the productivity and was preferred by the operators to the twelve-inch spacing at higher translational speeds.

    3. Increasing the number of rows increased the productivity for a given efficiency probably due to an operator's ability to inspect more than one cylinder at a glance.

    4. As shown on Figure 2, when the trend was toward an increase in productivity with an increase in rows and closer spacing for a given efficiency. However, there is probably a point where an increase in the number of rows at the expense of translational speed would no longer increase the productivity because there would be so many cylinders in view at the same time that too little attention could be given to each cylinder.

As the reader will recognize, this investigation has by no means exhausted the need for research in this area of visual inspection. It is the beginning of an attempt to give some factual information to those who have been required to make decisions in a field where the chief source of information has been opinions that were little more than conjecture.
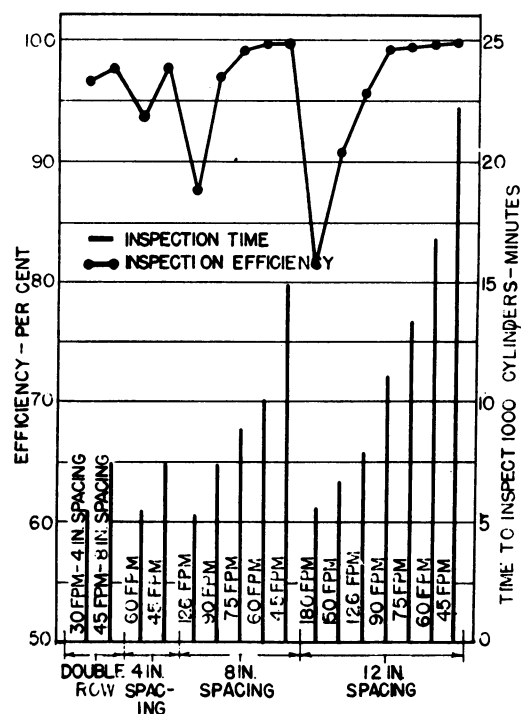

FIG. 2 TIME TO INSPECT 1000 CYLINDERS WITH THE RESULTING EFFICIENCY AT A FORWARD ROTATION OF 80 RPM UNDER THE VARIOUS CONDITIONS TESTED.

THE HUMAN FACTOR IN THE DESIGN OF INDEXING MACHINES

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Columbia Pictures Corp.

Culver City, California.

As greater demands are placed on our industry today, every possible means for increasing production must be considered. There is great need for investigating the problems of "man at work" since it is this area that has been most commonly overlooked in the past. This was demonstrated in the last war when limitations on production output were not always due to the functional design of the machines and equipment but in many cases were due to the capacity of the human operator. Thus, when designing machines consideration of the human factor is of primary importance since in the final analysis it is the human being that holds the key to successful industrial progress.

This study was undertaken to further augment the knowledge surrounding the operator-machine inter-relationship and to investigate the effect that varying the operating conditions of a manually fed indexing device has upon human behavior at that machine.

This study proposed to answer the specific question: In operating such a machine at a given number of indexes per minute, what effect will be observed in operator performance when the proportion of dwell time to action time per indexing cycle is varied?

The typical approach to this question seems to be a reasoning that if the operator is given more time in which to perform his operation, i.e., if the machine is designed with a longer dwell ratio, he will be able to produce at a higher rate. (Dwell ratio refers to that portion of the indexing cycle during which the dial plate is in the stopped position.) Therefore, the tendency in designing machines of this category is towards using an indexing action with a longer dwell ratio. However, such reasoning does not give an actual dwell ratio that will allow the operator to perform at his optimum rate. If the dwell ratio is increased, it is logical to assume that at some point the quick action of the machine thus necessitated will become disturbing, frustrating, or distracting to the operator and will then curtail his production. On the other hand, if the dwell ratio is reduced then at some point there will not be sufficient time for the operator to perform his necessary operation. From this reasoning it appears that there is a dwell ratio at which the operator will perform at his maximum rate of production. The specific purpose of this study was to attempt to find whether such an optimum dwell ratio exists, and if so, what that ratio is.

The machine used in this study simulated the action of an industrial dial feed type punch press where the work cycle consists of the operator placing a part into a nest or jig located on a dial plate while it is in the stopped or dwell position. During the dwell time, and at a safe distance from the operator, the actual operation is performed

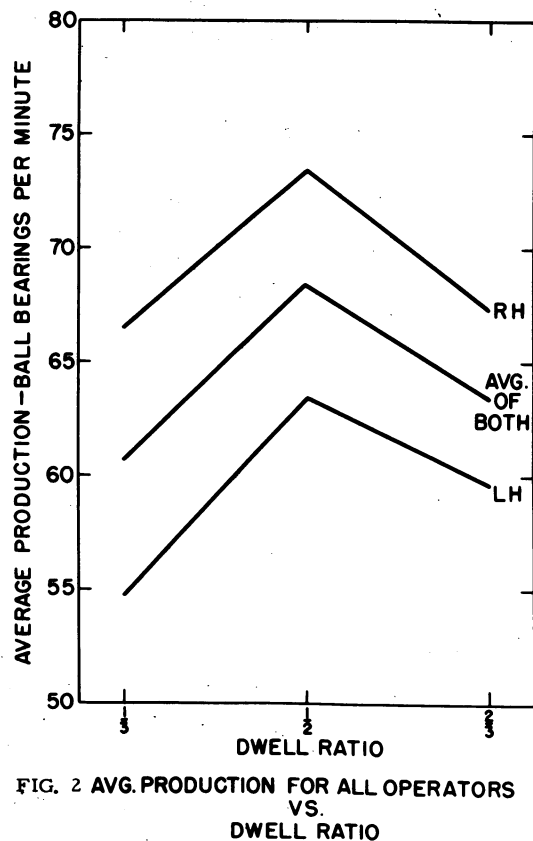FIG. 1 FRONT VIEW OF INDEXING MACHINE

FIG. 2 AVG. PRODUCTION FOR ALL OPERATORS
VS.
DWELL RATIO

on another part which has been indexed to a position under the ram of the punch press. The work cycle is completed when the dial plate is indexed some predetermined fraction of a revolution and comes to rest again.

In this study the operators grasped 11/16 inch diameter steel ball bearings simultaneously with each hand, from tubes directly in front of the indexing device. (See Figure 1.) These ball bearings were carried to the table and placed into 3/4 inch diameter holes in the dial plate. The ball bearings carried by the left and right hand were placed into two separate concentric circles of holes in order to permit the production attained by each hand to be counted individually.

As the dial plate was successively indexed clockwise one-tenth of a revolution, new holes were presented to the operator. At a subsequent dwell position, these ball bearings dropped into a collection tray below the table top.
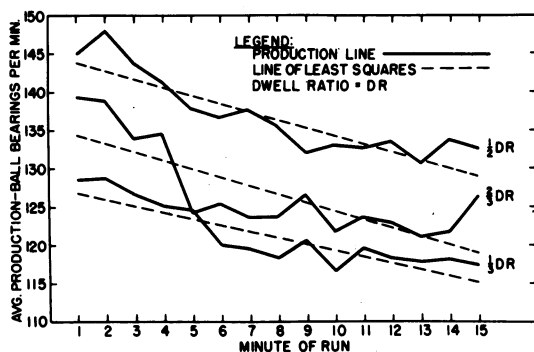

FIG. 3   AVERAGE PRODUCTION VS. MINUTE OF FINAL TEST RUN
ALL DWELL RATIOS – BOTH HANDS

In falling, the ball bearings passed through a coil and permanent magnet set-up causing a pulse of voltage to be generated. This pulse was amplified electronically and ultimately caused a recording type counter to register. Thus, the production attained by each hand could be counted and recorded for each minute of the test run.

The bottom of the collection tray was pitched so as to cause all the ball bearings to be funneled into a tube which led to an elevator type conveyor. The conveyor lifted the ball bearings to an elevation above the table from where they returned to the tubes from which they had been originally grasped. Thus, the operator was continuously

supplied with ball bearings and the services of an extra assistant were not required.

A simple harmonic motion cam caused the dial plate to index one-tenth of a revolution for each revolution of the cam. Three different cams having dwell ratios of one-third, one-half, and two-thirds of the indexing cycle were studied at a speed of ninety indexes per minute. Thirty-seven right-handed male university students were tested at one of the above dwell ratios for two forty-five minute test periods which occurred on successive days. Conclusions derived from this study were based on the last fifteen minutes of the second day's testing.

Figures 2 and 3 show the average production attained of all operators during the final test run for the three dwell ratios studied. From this figure it can be seen that the average production values of both right and left hands are highest when the dwell ratio is equal to one-half the indexing cycle. The production attained using this dwell ratio of one-half is 10% higher than that for a dwell ratio of one-third and is 9% higher than with a dwell ratio of two-thirds the indexing cycle when comparing the productions of the right hand. Further, it should be noted that the difference in the production attained when using a dwell ratio of one-half and one-third, was statistically significant at the 2% level. Also, the difference in production attained when comparing the one-half and two-thirds dwell ratio was statistically significant at better than the 10% level.

From the above, it appears that a division of the indexing cycle such that dwell time is equal to action time permits the operator to work at his best rate, and variations in the dwell ratio in either direction from the above ratio cause a decrement in the operator's production. Thus, the results of this study demonstrated that the dwell ratio in the indexing device has an effect upon the production rate obtainable by human beings loading such a machine. Therefore, it is suggested that the results of this study be used and tested in an industrial situation and designers of such machines be advised of the effect of dwell ratio upon human performance.

The results of this study and others that have been conducted clearly indicate the need and applicability of such research in the industrial situation. The traditional approach of improving equipment through better functional designs has brought much to our technocracy. If so-called better designs are really to result in increased productivity, the human factor must be adequately dealt with in the design.

STUDIES IN MULTIPLE GRASPING AND POSITIONING OF SMALL PARTS

Albert Shapero,
Management Engineer,
The Emporium, San Francisco.

This study was undertaken in order to further develop the body of data that will furnish design criteria to the designer and the industrial engineer in the area of man-at-work.

The experiment was set up to investigate some of the factors operating on manual work in the assembly of small parts, and arose out of questions that have springboarded from the justly renowned Iowa studies conducted under the aegis of Dr. Ralph M. Barnes.

1. The first factor investigated concerned the use of multiples or handfuls of parts in assembly work, and the conditions under which multiples would be most effective.

2. In undesigned, uncontrolled manual work situations, both one handed work and symmetrical, simultaneous bi-manual work are rarities, yet these are the methods which have been investigated in great detail. Other methods of work should also be examined and evaluated.

3. In assembly work it is important to know how size and difficulty of positioning of assembly components influence the time to perform an assembly method.

Experimental Procedure

The experiment was set up using a complete assembly. The component parts were designed to have three basic geometric shapes, three degrees of positioning difficulty and three sizes. (See Figure 1.) Three combinations of these components were used as basic test assemblies. Multiples or "handfuls" were identified as four units per single handful and were compared, method by method, against single units per hand. Three assembly methods were used: one handed, bi-manual, and a third method which can be identified as the "transfer" method. The transfer method of assembly was defined as an operation in which one hand gets the component from the bin, and, subsequently, acts as a supply platform for the other hand to operate from, getting and holding new components as needed.

Two test groups were used, male and female. All subjects were right handed, and all were tested for manual dexterity in order to assure a sample typical of the general working population.
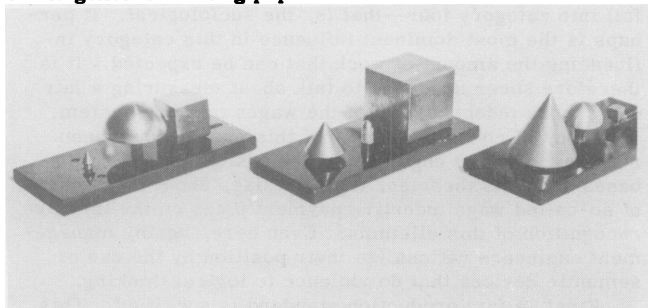

FIGURE 1

Results

1. Best method in terms of time was the bi-manual, single unit method. This was followed by the transfer, bi-manual with multiples and one handed with single unit methods none of which varied statistically from each other. Slowest method of all was the one handed with single unit method. Notes were taken of the subjective reactions of the subjects who performed both transfer and other methods. The subjects unanimously preferred the transfer method. This was considered of interest since all experimental runs were of a half hour's duration. It was felt that these subjective reactions might be of greater significance in an all day situation.

2. In evaluating these reactions to the work methods an analysis was made from the viewpoint of body mechanics. Two hypotheses were developed that may explain these reactions.

The first, based on work of the Prosthetic Devices Research Project at the University of California, is that a work method which requires less muscular stretching or contracting would operate at a greater muscular efficiency, therefore, would be less fatiguing, and more acceptable subjectively. The second was that effective work depends on total body balance which includes two dimensional, side to side balances; front to back balance, and diagonal balance. Complete body balance would reduce fatigue.

3. Patterns in two dimensions emerge from the size variation and difficulty of positioning data.

Conclusions - See Figure 2

1. The effect of size on time finds the medium sized component varying significantly from both small and large sized components. The latter two sizes do not follow any pattern in relationship to each other.

2. As positioning difficulty increases the medium sized components increasingly deviate from the small and large components.

The intra-hand or hand muscle actions were examined, and it was observed that in the case of the medium sized component, the action, unlike that for the other sizes, was not continuous, requiring a minute readjustment of thumb and forefinger. It, therefore, appears that there is a region of component sizes in the vicinity of the 5/8" diameter size in which the hand mechanism operates less efficiently. Unfortunately not enough physiological data is available for finer analysis.

A few indicator results have been obtained which point the way to further experimentation and further development of manual assembly criteria.
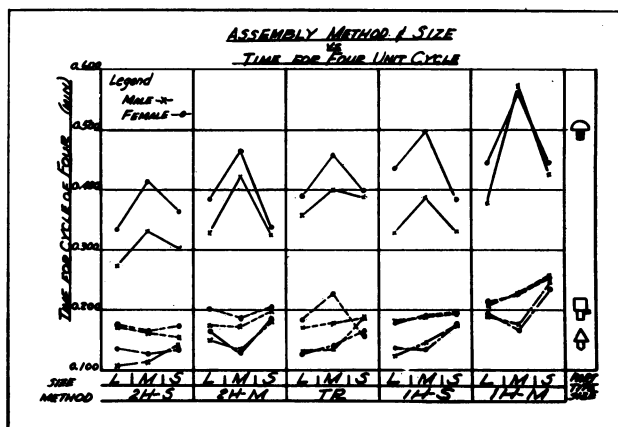

FIGURE 2

LUNCHEON SESSION

UNION PROBLEMS IN SETTING PRODUCTION STANDARDS

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Director of Management Engineering Department,

International Ladies' Garment Workers' Union,

New York, N. Y.

Almost every discussion about union-employer problems on production standards starts with the members of both groups in agreement upon two fundamental principles which they both publicly acknowledge.

Ask a union leader what he believes or ask an employer what he believes. In each case you will get the bromide, "I believe in a fair day's work." If either the employer or the trade unionist feels any concern over the opinion of the members of the academic world, then this bromide will be followed by its corollary platitude that production standards development requires no haggling but merely determination of facts. Facts. What a hard nugget of a word. It sounds so austere standing there as a cold, hard-headed challenge to the alleged emotional hysteria attending a high pressured bargaining session.

A fair day's work operationally tells us nothing. It is a pious moral expression.

Nobody is against it and when anybody comes out in favor of it he has said precisely nothing. A fair day's work only acquires meaning when both the employer and the worker have reached an agreement. It is an equity-concept. It no more means the full expenditure of all the worker's energy short of exhausting illness than does a fair wage mean the full expenditure of the employer's funds for wages short of bankrupcy. Engineers generally approach the question of wages and work standards as two separate questions. The argument generally follows the ensuing pattern. The amount of work expected of a worker is a scientifically measured variable based upon facts. Wages, it is conceded, at least since the unions have become strong enough to insist that they be heard, is a matter for bargaining. The key word here, of course, is facts. But what is a fact?

A fact is a selective description of a total experience. The phase of experience which is emphasized in our so-called facts depends upon the particular set of prejudices that each one of us brings to our observation post. Let me cite some specific examples.

One of the truisms with which the average time study engineer is indoctrinated very early in his career is that work rates should not be based upon past performance but upon time study. Now past performance constitutes a

very sound body of facts which can be analyzed statistically to detect the characteristics of the work place, the nature of the job and the working environment producing the work standard. The engineer, however, is guided by a set of value judgments which leads him to reject this set of facts in favor of a different set of facts. He wants more production from the employee and so his set of facts are derived from motion study principles which he is inclined to view as immutable and unchangeable. The gestalt psychologists and the English school of industrial engineers who have come under the influence of Gillespie reject this set of facts as at best limited; at worst, false.

I am not ready at this point to go into the relative merits of this controversy, but I do want to emphasize that smug tributes to the divine sanction of facts merely betray the limited concept of the person who uses the appeal. It generally means he simply does not know the nature of facts. It may seem strange but perhaps what is needed in many of our engineering schools is a course in the logic of scientific method. It can very well be part of the new emphasis on the humanities in engineering education. I submit that it is impossible to consider the matter of a fair day's work scientifically without the specification of a wage, both its amount and its system of payment.

The development of scientific production standards must depend upon the derivation of a sound statistical sample from a distribution of work times. These work times if they are to yield a sound, meaningful, statistical sample must, in turn, come from a statistically stable parent population.

It is axiomatic that a statistically stable population must be free of any dominant assignable cause of variation. The working environment making up the surroundings within which the worker uses his tools is subject to so many disturbances that it is well-nigh impossible to list them, much less isolate their individual effects. These variations may be classified as follows:

1. The purely mechanical.
2. The psychological.
3. The physiological.
4. The sociological.

The wage system and method of wage payment would fall into category four--that is, the sociological. It perhaps is the most dominant influence in this category influencing the amount of work that can be expected. It is therefore sheer nonsense to talk about measuring a fair day's work independently of the wages or wage system.

I am, of course, aware that this problem has been recognized by the engineering profession. In fact, it bases all of its theories, true or false, about the behavior of so-called wage incentive payment plans on the intuitive recognition of this dilemma. Even here, again, management engineers rationalize their position by the use of semantic devices that do violence to logical thinking.

First, a fair production standard is specified. This standard, it is alleged, is independent of the wages.

Workers are then informed that if they exceed this standard they will receive an additional reward. Thus, wage incentive payment plans are defined as extra pay for extra effort. But is it not a little silly to ask for extra effort in excess of a fair production standard? If anything, we should discourage extra effort in excess of a fair production standard; that is, we should, if we wish to support the artifice of such a definition of a fair production standard in the first place.

Now, those of us who are associated with the labor movement are inclined to reject this rigid concept of a fair day's work. We recognize that the concept of a fair day's work must be integrated with the concept of a fair day's wage. They are two inter-dependent variables. It is for this reason that we are inclined to take an altogether different view of incentive wage payment plans than management. It is for this reason that we reject the management time study dogma that the development of fair production standards must be developed independently of past performance.

Perhaps a better term for the trade unionist's equivalent of management's wage incentive wage payment plans would be production wages; that is, wages vary with production. A minimum day wage is specified and all production in excess of a mutually agreed upon norm is paid for at a 1:1 ratio. It is assumed that management's obligation is to make available an earning opportunity to the workers of whatever is the mutually agreed earning opportunity. It is further assumed that it is the worker's obligation to take advantage of this proffered opportunity or his wages will suffer accordingly. Should management fail to make this opportunity available on the other hand, even for causes beyond its control, then management would be obliged to pay workers for lost time at this average hourly earning; that is, the equivalent of what management calls the incentive rate of pay.

There is no artificial distinction in our thinking between a so-called day rate and a so-called incentive rate. We have the same proprietary interest in the so-called incentive rate that management insists we have only in the day rate. This is merely a recognition that it is management's function to assume manufacturing risks rather than to transfer them to the working force.

You may think that I am being unduly querulous and argumentative about words. Many of you may point out that in the last few years management has been compelled in most union agreements to pay average hourly earnings for idle time. Well, then, am I not tilting against windmills in quixotic fashion?

However, the current importance of these distinctions I am trying to make was perhaps best brought out in the Stolper Steel case which in January, 1950 went up for appeal to the Federal Court. The details of the case are perhaps best brought out in a letter I wrote to many of my own professional colleagues more than one and one-half years ago.

"I am writing to you because of your prominent position in industrial engineering affairs and what I believe to be your active interest in promoting sound industrial engineering practice.

"A situation has arisen in the state of Wisconsin which threatens to destroy all of the progress made in the past few years in reaching an understanding between the professional industrial engineers and the organized labor movement.

"The matter involves the Stolper Steel Manufacturing Company, the International Union, United Automobile Workers of America, AFL, with whom the company has a collective agreement, and the Wisconsin State Labor Relations Board created by state statute.

"The International Union, United Automobile Workers of America, AFL, has been one of the leading labor unions in adapting its collective bargaining practices to modern industrial engineering techniques. Some time ago their entire General Executive Board attended classes for eight hours a day for one whole week, under the direction of Hy Fish of the Roosevelt College Faculty, to familiarize themselves with job evaluation, time study and the design and administration of wage incentive payment plans. Their international representatives have had similar training. Other unions are hardly encouraged to follow suit by what has happened in the Stolper case.

"Briefly, the facts of the case are as follows. On the fifth day of August, 1948, the Stolper Manufacturing Company and the Union executed an agreement. Section 12 of this agreement set up a wage incentive payment plan. The agreement provided that this section go into effect April 15, 1948 and continue until October 14, 1948. It was to renew itself automatically for periods of six months unless notice was given by either party in writing at least sixty days prior to any six months' expiration date.

"Under this agreement, production climbed to anywhere from 120% to 131% of standard. It seems to have been higher in the early days of the agreement (around 131.3%) and fell off to around 121.7% on February 6, 1949.

"As a result of dissatisfaction with the operation of the plan, the Union gave proper notice and terminated the agreement as of October 14, 1948. The company nevertheless unilaterally announced that it was continuing the wage incentive payment plan. Production, beginning February 13, 1949, fell to 100.3% and then varied between that percent and 104.0%. The men said in effect that they would give a fair day's work for a fair day's pay; they were not interested in the incentive increment; they wished neither to exert extra effort nor to receive extra pay.

"The Wisconsin State Labor Relations Board has denounced this action as interference with production and as a slow down, and has ordered the Union to restore the "incentive level" of production. In other words, because the men had demonstrated that on a voluntary basis it was possible to reach 125% of a fair day's work, the Board has in effect ruled that this now becomes an obligation on the part of the men. Naturally, the labor member of the Board dissented and pointed out that even if the company were to discontinue paying the premium for extra effort, the union then would still be obligated to produce at 125% of a fair day's work.

"If this ruling should be permitted to stand, then those of us who are industrial engineers identified with the labor movement would have no other recourse than to recommend to all labor unions in the State of Wisconsin, or for that matter to any labor union operating in any state with a similar law, that they discontinue all wage incentive payment plans in their contracts and adhere strictly to the time work method of wage payment. Furthermore, we would be obligated to warn these unions that they must limit their cooperation with the employers in raising the level of productivity. This raised production level, which comes as the result of cooperation, would then become an obligation on the part of the men to which they would have to adhere, irrespective of any change in the attitude of the company

or method of payment.

"I believe that you will agree with me that such a course of action would destroy everything that has been done in the last few years to bring the trade unionist and the industrial engineer to a mutual understanding. It seems to me, under the circumstances, that a movement ought to be initiated by concerned organizations such as the Management Division of the American Society of Mechanical Engineers, the Society for Advancement of Management, and the Industrial Management Society of Chicago with the following purposes:

1. To investigate completely the facts in the case outlined above;
2. If it is determined that these facts are such as to threaten the effective application of sound engineering practices in a collective bargaining situation, to stand ready to file supplementary briefs as expert friends of the court in the litigation that is to follow the determination made by the Wisconsin State Labor Relations Board.

"May I hear from you on this matter."

Almost all of the people to whom I wrote responded in rather sympathetic terms, but might I add that the organized professional societies took a minimum interest in the matter. It is difficult to stand in judgment where I myself am so deeply interested, but I cannot help feeling that a profession that expects to command public respect for its professional standards should show more energy in defending its basic principles against distortion. You can readily see, therefore, why it is so important that the whole concept of a fair day's work be recognized as a function of a fair day's pay and why the concept of a fair day's work, independently of the size of the wage payment or the system of wage payment, is a mere abstraction.

The acceptance of this concept leads to its corollary of a fair day's work as a function of the statistical distribution of past performance. Adam Abruzzi of Columbia University has completed and written up his researches into the measurement of productivity by time study methods. Unfortunately this study has received nowhere near the circulation that it deserves. The relationship of his research to these concepts of fair productivity level provides the tools with which a more sound statistical foundation may be developed for our time study techniques. Abruzzi has taken up the operational implementation of many of the statistical criteria for scientific time study which I proposed some years ago in my own trade union analysis of time study. He has gone far beyond the boundaries that I drew at the time and has developed many valuable theoretical concepts of his own. The empirical materials for many of his conclusions were gathered in factories under contractual relationship with our Union. The operations in our factories are mostly man-paced without any interfering fixed machine cycle. Thus, an excellent opportunity was provided to conduct these researches. Our own union's interest in these conclusions is obvious. I cannot in the short time alloted to me do justice to Abruzzi's over 300 pages of manuscript. I do hope to examine some of its significant highlights.

It would be fruitful to examine the answers to three time study questions proposed by Abruzzi; it is even more important to investigate the methodology by which these answers were derived. These three questions are:

What are the criteria which may be used to determine that a process is standardized and ready for a time study?

What constitute meaningful summarizing statistics of time study data?

How valid are current standard data procedures?

The philosophy of Abruzzi's approach to the analysis of time study data may be summarized as follows: "Subjective procedures of rating current productive rates to predict the time of a theoretical normal worker has no function in an objective methodology."

This of course means two things in terms of union policy:

1) Subjective rating procedures are rejected as objective determinants of a so-called scientific production standard in collective bargaining.

2) So-called scientific studies such as the rating project conducted under the auspices of the Society for the Advancement of Management are rejected. The distribution of the subjective prejudices of the industrial engineers of America about what they would like to be a normal working speed is an interesting game but hardly a serious objective investigation.

Inasmuch as the labor movement was not even consulted on the original design of this investigation, we can only regret the waste of so much good energy. Pointless questions, however, still can elicit only trivial answers. This is true even when they are supported by impressive academic redentials. It is not a matter of the sincerity of the investigators, for whose integrity I have the highest regard. It is just a matter of the logic of the questions which they ask. Now this, of course, does not mean that rating of time studies is excluded from collective bargaining; it merely means that in the absence of more objective criteria, the rating remains a subject for collective bargaining. When it comes to prejudices I am confident no one will begrudge us our own.

Let us now talk about standardization of the job. When is the job ready for a time study? An examination of the literature discloses qualitative descriptions that vary from one extreme to another. One authority demands virtually the performance of a micro-motion pattern that satisfies the micromotionist's concept of the most economical combination of elemental motions. Others, like Carrol, are all for taking the study on the job just as it is found. They feel that the job pattern can never satisfy the demands of the perfectionists and tend to the other extreme.

Abruzzi departs from these qualitative descriptions and merely asks one question: Do the performance times of the workers satisfy some rational operational criteria of statistical stability? He has defined this stability on two levels, local stability and grand stability. Local statistical stability is measured in terms of the variation in production times over a continuous series of items made over a few hours or at most a continuous day. Grand statistical stability is measured in terms of the variation in production rates of a series of small samples taken over an extended time interval from increments considered qualitatively to be taken under essentially the same conditions.

The criteria for local stability consisted of building up Shewhart control charts for the means and ranges from as many as 70 subsamples, consisting of three items each, from a total of 210 continuous readings on a single individual. This was done for individual elements as well as overall cycles.

In addition, Abruzzi has introduced a new criterion of stability, the mean square successive difference ratio test.

Significantly small ratios indicate that successive observations are positively correlated; significantly large values indicate that successive observations are negatively correlated. Thus this statistic becomes valuable to detect any trends in the data. The same methods used to determine local stability were in turn used to detect grand stability except that in this case the collection of data took place in very much the same manner that data collection for ratio delay studies takes place. Random readings in continuous series of five items were taken. They were distributed during the four basic work periods of the day. Again, these tests disclosed the existence of grand statistical stability.

$$\frac{\delta^2}{\tilde{s}^2} = \frac{\sum\limits_{i=1}^{N-1} (x_{i+1} - x_i)^2 / (N-1)}{\sum\limits_{i=1}^{N} (x_i - \bar{x})^2 / (N-1)}$$

$$x_i = \text{ANY READING} \ (i = 1, 2, \cdots, N)$$

$$N = \text{NUMBER OF OBSERVATIONS}$$

The disclosure of the existence of this grand stability does prove that scientific time study is possible. That is, time study which is performed in accordance with the requirements of sound statistical inference. However, what remains to be disclosed is whether or not the limits of variation for both means and ranges are so wide that the results are of little economic significance for setting production standards. Abruzzi concludes from his findings that control charts with 3 sigma limits for groups of workers show equal degrees of variability even though they show widely different mean unit rates of productivity. The most important finding, however, is that local stability does not necessarily imply the existence of grand stability. They are two independent entities.

Inasmuch as trade unions are interested in the long term characteristics of earning opportunities it follows at once that they are much more interested in the conclusions derived from grand stability rather than from local stability. This, of course, means a change in the conventional method of collecting time study data. Where before a continuous short run study was considered adequate, now small runs of five readings taken at random intervals over an adequate period yield more adequate data.

The next question which we wish to examine is how valid is current standard data practice. Abruzzi examines both the macroscopic type of data and the microscopic data. In the course of his examination of microscopic data he describes the fundamental fallacies of the validity test proposed by Maynard, Schwab and Stegmerton for methods time measurement. I have published this analysis in my review of their book for the Cornell Industrial Relations Review and there is little point in repeating the conclusions here.

Abruzzi's principal contribution to this field arises from his examination of what constitutes a logical subdivision of a total work cycle into elements. His statistical analysis was designed to determine whether or not the usual subdivisions of cycles from the most macroscopic to the most microscopic were statistically independent. These elements would have to be statistically independent if they are to be used as an additive set; that is, if they are to carry a time assignment independent of the element that precedes or follows the element being measured. If statistical independence cannot be established for these elements then a minimum condition for their use must be at least a constant relationship or correlation. By the use of rather complex statistical multivariate analysis techniques, Abruzzi found that for some specific operations the nature of the relationship among macroscopic elements, let alone microscopic elements, was so complex that it varied from operator to operator. In fact, at times it varied at different times for the same operator. This is hardly the sort of foundation upon which objective systems of microscopic data can be built. These conclusions would tend to substantiate the findings of the gestalt psychologist and industrial engineers like Gillespie and Mundel. "The whole is greater than the sum of its parts."

Does this mean that trade unions will reject all systems of standard data out of hand? Not at all. We are willing to recognize that they are a rather poor empirical attempt to develop a modus vivendi upon which both management and labor can reach agreement. However, under no circumstances would we permit ourselves to be bound solely by the technology of these systems in dispute cases. They at best stabilize a human relationship. They are useful provided we recognize that the failure to achieve a rate developed under standard data does not indict the worker; the rate may very well point up the limitations of the technique.

The Union's principal problem in the setting of production standards in the past has been convincing the industrial engineering profession that it is a matter for collective bargaining. To prove our point we have outlined the scientific criteria for a method of objective time study along with the economic requirements that collective bargaining imposes on the technique. In the absence of more objective criteria we find that production standards in everyday bargaining are governed much more by John R. Common's concept of goodwill than by Taylor's concept of scientific management. Commons observed as early as 1919 that "scientific management, since it begins and ends with individuals separated from their fellows, has the defects of autocracy. It means government by experts. An expert comes into the factory and makes a study of the operations of the selected individual. That individual and his fellow-workers are much concerned about his time studies, his stop watch, his cold calculations, which decide from them the amount of work that shall be portioned out for the task. But they cannot be consulted. They are objects to be investigated, not investigators."

By way of contrast he pointed out that much more important than scientific management for the solution of this production problem was this concept of goodwill. He defined goodwill as follows: "Goodwill is productive, not in the sense that it is the scientific economizing of the individual's capacities, but because it enlists his whole soul and all his energies in the thing he is doing. It is that unknown factor pervading the business as a whole, which cannot be broken up and measured off in motions and parts of motions."

He then went on to observe that "It is this unmeasured quality of goodwill that scientific managers are feeling after when they explain the breakdown of scientific management."

This observation loses none of its validity today.

HUMAN ENGINEERING SESSION

Chairman--Paul Eliel, Management Consultant, San Francisco

PSYCHOLOGICAL FACTORS INFLUENCING PRODUCTIVITY

Mason Haire, Assistant Professor of
Psychology and Research Associate,
Institute of Industrial Relations,
University of California,
Berkeley, California. [1]

I would like to consider ideas about people and production which may give us some new slants on our problems. For one thing, when we have a measurement of production which we can plot against time (as in the chart below), we take a slightly different look at this problem than we usually do. Ordinarily, when we consider problems of productivity, we wonder mainly about how to raise productivity and why it is not any higher. We very seldom question why productivity is as high as it is, or why it has not just floated on up indefinitely. We usually think--what can we do to get underneath and push up productivity--we never ask ourselves what is holding it down.

It seems useful for us to think of a production rate of this kind as being held firmly in place by a balance of forces. We need to understand and identify these forces in specific situations, for it is doubtful that there are useful general identifications for the forces on both sides of the line. To illustrate, here are some suggestions of some of the factors that operate to hold production down: Resentment of management, the fear of working oneself out of a job, group pressures that hold a person to a work rate, etc. The pressures to make productivity go up may include: Incentive pay, supervision, the desire to do an honest day's work, etc.

Suggesting this kind of treatment of productivity as being held in a dynamic balance of forces leads to some implications for ways to change it. It is one thing to increase the forces below the line and push productivity up against pressure; it is another thing to reduce the forces above the line so that it can "float" up to a new level on the basis of the pressures already there. To increase the forces below the line pushes productivity up to a new balance at a higher level, but probably under considerably more tension. To reduce the forces above the line allows productivity to find a new level without increasing the tension.

We might ask now--how does industrial engineering affect the psychological factors involved in productivity? For one thing, the difficulty of the work is reduced so that to whatever extent production is held down by problems of methods, the downward pressure may be eased

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1/ Summarized and reported by F. Theodore Malm, Institute of Industrial Relations, University of California, Berkeley.

and the productivity allowed to go up. Also, wage payment plans may increase productivity by putting an increased force below, pushing it upward. In addition, standard setting may work on the level of aspirations, changing ideas of what an acceptable standard is. I do not know to what extent we are working in industrial engineering to push up production from below; and, to what extent we are working to reduce the forces on top. I do think that asking the question in those terms can be particularly fruitful if by thinking in terms of the relationship between the worker and his job and his management we can increase productivity without running into the cost of the by-products of high psychological tension, such as absenteeism, turnover, and grievances--all the kinds of agression that may be found in a work force. I think we might see to what extent we can act to reduce identifiable forces operating to keep productivity down rather than attempt to increase forces operating to push productivity upward.
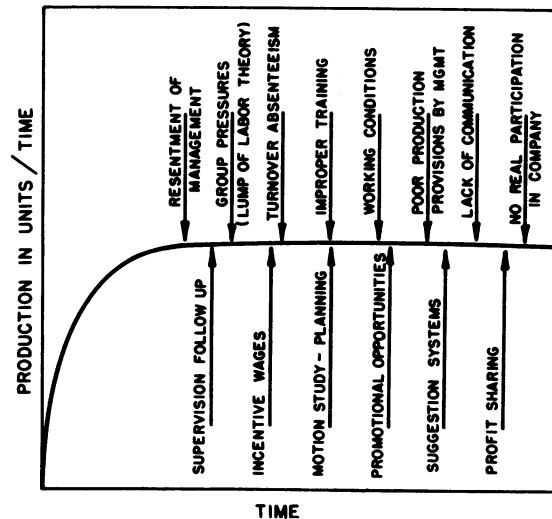
FORCES HOLDING PRODUCTION IN EQUILIBRIUM

In this connection, I would like to suggest examples of the things we ought to think about in terms of psychological factors influencing productivity. Much research in industrial psychological factors has been carried on at a rather peripheral level, such as the best length of a handle to turn a crank. The factors which are going to be useful and important to us are factors that are deeper inside the person--central motivational factors, such as resentment, fear, group pressures, and things of that sort.

As one example, let me suggest what may be an important principle in work techniques, that there are certain behavior patterns that continue of their own accord; that have a momentum of their own. I think that there

are behavior patterns that flow naturally from one step to the next, and that we can capitalize on them in building work situations.

One instance of this is found in child behavior--when the parent asks the psychologist, for instance--how are we going to get junior to drink his orange juice? When we find that the unilateral command, "Drink your orange juice," does not work, we begin to look for other techniques. One of the things that we find most effective is for the moment not to talk about his drinking the orange juice, but to get him to pick up the glass in his hand--not drink it--just hold it. The child probably will be very much more willing to pick up the glass and hold it. Once he has the glass in his hand our worries usually are over.

Another illustration of this comes from an experiment in which a motion picture camera was hidden in the wall of an office. The professor conducting the study asked for volunteer subjects, each to come at a scheduled hour. When the subject came, the professor said, "Come in," and went on writing. After a few minutes, the subject would get nervous and speak, but the professor only said, "I'm busy, wait a minute," and went on writing. After a few more minutes, the experimenter said, "Have a cracker," and the subject would eat one. "Have another," said the professor, again and again, shifting his tone from an invitation to a command until the student had eaten all the crackers he wanted, and a few more besides. Then, when the subject had reached a point of real resistance and would not eat any more crackers, the professor suggested, "Well, just take it in your hand. You do not have to eat it." Holding the crackers in this way, the subject went on to eat many more after he had absolutely refused to take any on command.

In giving these illustrations, I do not mean that we should use similar techniques to trick people into doing things they do not want to do in work situations. I do suggest, however, that there are many patterns of behavior acts that are easier to do in sequence than otherwise, and that this idea has been exploited very inadequately in laying out work situations. I wonder if there is not an opportunity for us to find work situations where we can construct sequences of behavior acts which have within themselves a set of forces that work toward conclusions, sequences which are self-generating in the sense that they generate their own force toward conclusions.

Another notion I would like to suggest to you has to do with the psychological importance of subgoals in production. For example, I remember visiting the plater room of a small New England paper manufacturing company where I was working. In the plater room, the girls were making "sandwiches" from sheets of paper, linen, and zinc, which were later put into a press to give a pattern to the paper. The girls were working at a good pace. I said to them, "You certainly can do that fast. I don't see how you can do it." The girls answered, "You think that's fast? Watch!" Then they did their work about three times as fast, until they said, "See?" and went back to their normal pace. In terms of our earlier discussion, I wonder what it was that was holding their level of production where it was when I came into the room--a level which had been steady for years before, and which thereafter went on for several years at the same old level. How can we produce artificially such substantial changes in productivity? After wondering about this for some time, it occurred to me that what happens here is that we have provided short term, immediate subgoals--something generally lacking in normal industrial production. We usually have the same long run goal operating every day, and we only accomplish a fraction of it on any given day.

When we see the amount of work to be done only as a very long term assignment, stretching out indefinitely, the strength of this force acting on productivity is minimized. I wonder if there are not many situations where we can use the natural subgoals in the work to provide the same kind of stimulus that my question to the plater girls in the paper factory provided for them. In situations where there are seasonal peaks, a specific order to be filled, a job to be accomplished, a specific bit of competition to be met, etc., and where it is possible for the worker to know about the problems in the situation, we get the kind of subgoal I am thinking of, and get the additional production which comes from the additional incentive.

We have many bits of anecdotal evidence that indicate that these "subgoals by chance" operate. When I used to work in the summer in the lumber business, we had one fellow there, a great, big chap, who usually worked along at a perfectly steady rate. One day we got in a car of cement, and this fellow was told he could have the afternoon off if he could unload the car of cement in the morning. He did it! He walked into the car and picked up a pack of cement under each arm, in and out on a dogtrot the whole time, until he had accomplished this job in record time because of the presence of this subgoal.

I am not suggesting that we manufacture subgoals and hand out afternoons off as a reward for doing things, but there are many subgoals which are integral parts of the operation and are not utilized by being made known to the people who are involved in them. We tend to think, I believe, that goals and subgoals are a concern of management. Perhaps if we stopped trying to protect some of these prerogatives and encouraged the involvement of hourly-paid workers in the goals and subgoals, we would find we had discovered an important additional incentive for productivity.

The union movement, I think, has been given a great deal of force by the provision of subgoals. There is always something new, something coming up to look forward to, towards which to work. To break up the kind of monotony that our industrial production usually has seems to give the union movement a good deal of impetus. This is not the whole motivation of the union movement, perhaps not even an important part of the motivation, but as a technique it is one of the things which has contributed a good deal of force. I ask, then, why we cannot plan industrial process to utilize these kinds of goals and subgoals.

In summary I have been suggesting that we turn away from peripheral factors such as hand-eye coordination and turn deeper into the person, his motivation, and his relation to his job, to find the sort of factors which hold production in the balance we talked about earlier. As we begin to understand these factors, we can get ready for what would be a most significant experiment. We should stop considering the human being as the dependent variable who must adjust to the demands of the machine. Instead, we could begin with a product and develop the list of things which would have to be done to the raw material to get that product. In laying out that list, we should consider the characteristics of our operators as human beings, characteristics in terms of motivation, rate of work, understanding of what they are doing, speed, skills, etc. Then we could say we have these things to use and these other things to do. Now, what kinds of mechanical bridges can we build which will use these skills to produce the end products we want?

HOW INDUSTRIAL ENGINEERS AND MANAGEMENT ALIENATE WORKERS

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One of the distinct advantages of academic life is that it offers an opportunity to develop a degree of objectivity which those employed in industry often find difficult to attain. The faculty member should be interested only in determining facts and, if he desires, can keep himself in such a position that he will not be influenced by many of the pressures which surround the industrial executive. If he rigorously follows the unbiased path of objectivity, he finds that there are many avenues of information open to him which are not available to those who are not in such an impartial position. As one who has attempted to maintain such an impartial position, I have had many unusual opportunities to gain the confidence of both management and labor groups. I have been called upon repeatedly to settle labor disputes, to talk to both labor and management groups about their problems, and have served on numerous committees which have gained for me a rather wide acquaintanceship among industrial engineers, other management personnel and union leaders and workers. Out of these experiences have come some conclusions which I would like to share with you. To a considerable extent, I am sharing with you comments which have come to me. They might be summarized in the title of this talk, that industrial engineers and management in numerous ways alienate workers and thus make their duties much more difficult. In discussing this subject, I am not at all unaware of the fact that there are many things which workers and union leaders do which also do not improve their relations with industrial engineers and management.

We have all heard much in recent months about the idea of a fair day's work for a fair day's pay. Whenever I hear the term "fair day's work" used, I cannot help but feel a little sorrowful. It seems to me that we have our sights aimed rather low. I cannot help but wonder if instead of thinking about a fair day's work, or what constitutes a fair day's work, we should not be much more concerned about how we can obtain from a worker what might be called the "best day's work." I doubt if any of us would contend that what we envision in a fair day's work is the best that a worker could do if he only desired to do better. While I would not for one minute minimize the importance and the necessity for having to determine what constitutes a fair day's work, I still feel that we should devote a great deal of thought and attention to determining the reasons why we do not obtain a best day's work that a worker could produce. All of us are familiar with the fact that a laborer or an executive will work far more than eight hours on a Saturday or Sunday building a wall in his garden or making a model railroad or at some other task, and work with much greater concentration and expenditure of energy than he does during his everyday job at the factory or in the office. I, for one, and I believe you also, would hesitate to predict what the output of this nation would be if every worker were doing everything he could to turn out his best day's work. Such a concept is so far beyond that with which most of us are familiar that we have difficulty in conceiving of it.

I do not propose here today to attempt to tell you all about why workers do not put forth their best day's work. I am sure that the reasons are very numerous and complex and I am also certain that I do not know all of them. However, out of my experiences over quite a few years, I have come to realize that there are certain factors which very definitely contribute to this problem and I would like to offer some of them to you for your consideration.

I believe that two of the very important reasons why this difficulty exists are: first, that there is in most cases no bond of confidence between the workers and their employers; and, second, that the worker has no feeling of security. I would like to discuss these two matters first in somewhat general terms and then give some specific examples of what industrial engineers and management do to bring about this unhappy situation. In order to emphasize these two factors, I would like to quote to you the statements of three persons which have been made in the past year.

At a recent meeting of the Board of Trustees of the Committee for Economic Development a discussion on a particular subject was presented from the viewpoints of a churchman, a businessman and an educator, all three of whom were trustees of the Committee for Economic Development. The churchman, Mr. Charles P. Taft, a prominent Cincinnati attorney, and former president of the Federal Council of Churches of Christ in America, made the following statement, quoting from Elton Mayo, "The greatest incentive is not self-interest but the instinct for friendly and affectionate human association where participation and equality create true security and satisfaction."

In the remarks of the businessman, Mr. Frank W. Abrams, chairman of the Board of the Standard Oil Company of New Jersey, was this statement, "When you stop to think about it, it is absurd that management should be opposed to labor's basic interest and labor to management's."

The third statement is by Mr. William Gomberg taken from a chapter which he wrote in a new book entitled "Small Plant Management." The chapter is entitled "How to Get Along with the Union." I hope Mr. Gomberg will not object to my using his ideas. I assure him that I had selected this quotation and outlined this paper several months before I knew he was going to speak to this Institute. The quotation is as follows, "We can summarize the main objective of the working man in organizing and joining established unions in one word, security; emotional security, social security and economic security."

I believe these three men have stated the problem exceedingly well. I also doubt if many of us would argue with these views. Now let us consider how this breach in confidence has come about, particularly with respect to the actions of industrial engineers and management of which they are a part. I would like to illustrate by examples which have come to me both from management and from labor.

I believe much of the difficulty has arisen through the growth of business into large units. Much of the contact between the worker and the owner of the busi-

ness has been lost. Indeed much of the contact between the worker and management has been lost. In the old days, the owners and managers of businesses to a large degree came from the ranks of workers. They had intimate acquaintance with the problems of the workers and a high respect for the abilities and skills of ordinary workers. Unfortunately, this attitude has largely been lost. Under present conditions, the owners and management of enterprises seldom know the workers by their names or have any knowledge of their backgrounds or real capabilities. To a large degree, individual workers have become punched cards. There has come into being a feeling on the part of management and industrial engineers that workers are not their equals. There has been a tendency to set up a distinct management class in our industrial civilization. As a result, management works and plays together and labor works and plays together except in some of those rare and forced situations where both compete in the company bowling tournament. The fact is that management, the owners and labor have lost touch with each other and simply do not know each other as equal, human beings who have many of the same aspirations and problems. The worker sees no evidence that management considers him as equal and feels pushed aside. Instead of feeling that he is one member of the team he feels more like the water boy. This has undoubtedly been one of the prime factors in the growth of unionism. I believe my reputation in this respect is such that I will not be accused of being anti-union if I say that management should be forever ashamed of the fact that workers ever felt that unions were necessary.

I am particularly happy to have Mr. Gomberg as one of the speakers at this Institute. I hope he will not be the last labor representative to be on our programs. I also hope that his presence may have induced some other representatives of labor to attend our sessions.

One thing that has grown out of this situation is a concept that management represents only the owners and must think and act in a certain way because the owners would want them to think and act in that certain way. I believe there is considerable doubt as to whether industrial engineers and management should represent the owners any more than they do the workers. At least this is an idea for us to think about. Perhaps we need to redefine the duties of management. I have seen numerous instances where management personnel, instead of doing and saying what they really believe would be best in a particular situation, do or say what they believe (and sometimes quite mistakenly believe) those higher up in the organization would want them to say and do. I have one example of this very clearly in mind where the head of a fairly large company told me that one of his chief concerns about one of his assistants was his failure to make proper decisions in cases involving the workers. He was very much concerned about this. A short time later I happened to be out with this particular subordinate one evening and in the course of our conversation he made a number of statements and remarks which I am quite sure reflected his honest opinion about how some of these problems involving the workers should be handled and which revealed that he actually believed quite differently than he acted. In fact, he cautioned me as follows, "For goodness sakes don't ever tell anybody in the company that I think this way." Actually the way he thought and believed was exactly how the manager of the company would have liked to have had him act. He was convinced, however, that

he had to think and act in a certain way because that was the way the high management of the company would want him to act. I would be considerably surprised if a number in this room have not at some time felt much the same as did this assistant plant manager.

From numerous other experiences, I am convinced that this situation exists far more frequently than most people think. I felt somewhat encouraged recently when the Chief Industrial Engineer of a rather large company, who had come to the University to interview seniors for possible employment, stated that his company had adopted the policy that all of their future executives had to spend at least two years in their time study department and that the primary reason for this was to force them to be able to get along with the workers under what might at times be trying circumstances and to get to understand that the worker was the key man in the organization and without his cooperation their corporation could not progress.

The problem of worker security is one which is certainly not simple and yet is one which must be met face to face. It is of such prime importance to the worker that unless he has some reasonable assurance as to his job tenure, or at least knows definitely what the company policy is, he cannot be expected to give the amount of cooperation which the company would like. Workers are naturally suspicious of any change which might possibly have an effect upon their security. I am convinced that in many cases the failure of workers to produce a good day's output is really the result of their fear that someone is going to be displaced if they increase their productivity. I recently was invited by a union to give a series of talks to their shop stewards on the subject of "Wage Payment Plans." I found that this particular company was engaged in instituting a new wage payment plan and that they were meeting with considerable opposition on the part of the workers. After a few meetings, the workers very clearly and without any hesitation told me that their sole reason for bucking the plan was because it looked to them like it was going to result in some of their fellow workers losing their jobs. Actually, the workers agreed that there was nothing wrong in the basic idea of the wage payment plan which was being instituted; but, they had received no assurance from the company that employees were not going to be laid off as the result of the installation of this plan. This is just one example of many that I have encountered where incentive programs, wage payment plans, or suggestion systems have not worked effectively because of lack of cooperation on the part of the worker. In another instance a group of workers told me that they would have nothing to do with the suggestion plan of the company and remarked that they knew of more ways in which the company could save money than the company had ever thought of. As a matter of fact, in about fifteen minutes they told me of several specific places where they knew that large savings could be made and gave exact details as to how it could be done. When I innocently asked why they did not suggest these to the company their reply was to the effect, "Do you think we are going to suggest ourselves out of a job?"

Anyone who has had any responsibility for managing a company knows that guaranteeing employment security is not a simple matter. On the other hand, I believe it is entirely possible to make certain guarantees which would be perfectly acceptable to the workers and at the same time offer little difficulty to management. Although some will consider this to be entirely ridiculous, I am quite convinced that most any company could adopt a policy

that they would not displace any existing employee of the company because of any change in method or improvement as long as the volume of output did not decrease. In most companies there is a sufficient turnover of labor from natural causes, or there is sufficient expansion to take care of those who are displaced through methods improvement. Note that the policy which I have just stated does not say that they will continue the number of employees at a constant value. Instead it merely assures those persons presently employed that they will not be displaced because of methods improvement. Of course, this places upon the company the burden of finding other jobs within the company for these men. Actually, in some cases, this means the company must expand its activities in order to employ these displaced people and in some instances it might mean finding some kind of temporary job for them for a few months until the activities of the company did expand sufficiently to absorb them. However, I am firmly convinced that this would act as a spur to management to increase activity and that the benefits which would be achieved if such a policy were adopted and, just as important, made known to the employees, would more than offset any cost that it might place upon the company in order to fulfill its obligation. Actually, I have known of several companies who have an unwritten policy of doing just this but in most cases they have been afraid to tell the workers that this was their policy. I have on several occasions discussed such a practice with shop stewards and union officials and have found them very wholehearted in their agreement that this would do much to improve relations. All have agreed that they would never expect the employer to maintain the working force if output decreased substantially. If the adoption of such a policy would bring forth worker cooperation and tend to get the best day's work instead of just a grudging fair day's work, I believe all of us would agree that it would be very worthwhile.

Now, let us direct our attention to certain practices, frequently employed by industrial engineers in making time studies, which contribute measurably to the lack of confidence between workers and employers. First of all, I believe it should be axiomatic that it is just as essential that a time study be fair to the worker as it is that it should be fair to management. Time study is essentially a fact finding process. Just as a good research worker conducts an experiment to find out what facts occur and then records them, a good time study man should conduct a time study to determine exactly what happens and record the facts. If the facts, and all of the facts, are determined and the time standard is based upon them there is little need to worry about whether or not the standard can be upheld in the face of worker opposition. I have upon several occasions been requested by unions to make a check upon rates that were in existence in certain plants. In each case, I am happy to what the facts were. In some cases, I have found that the facts were that the rate was correct and the worker had no kick coming. In every case where I reported such, the union has seen to it that there was no more argument.

One practice which is too frequently employed in making time studies and which has caused a great deal of trouble is that of throwing out certain observed time values merely because they were considered to be abnormal. I must, in all fairness, state that I have never seen a case where abnormal time values were thrown out but that most of the values thrown out were long times. For some reason, it appears that unusually short times are never abnormal. Frankly, I must agree with the

workers that such a practice does not seem to fall within the definition of fact-finding. This, of course, does not mean that one must use a time value which is the result of an element being done incorrectly. It does mean that the time should not be thrown out just because it is long. If time values are observed they should be used in setting the standard. As an old Yankee professor of mine used to say, "Don't tamper with the 'dater'."

Another practice which is quite often employed is that of using so-called "selected times" in determining the elemental time which is to be used as the standard. I will admit that if selected times are used properly they can give good results. However, I feel that this practice is potentially dangerous and I want to assure you that in every case that I have encountered the workers are extremely suspicious of this practice. Very frankly, they do not like it. It is my opinion that in a good many cases where selected times are used they are selected so as to confirm a previous conviction that the time study man holds.

Certainly one of the requirements for satisfactory relations between the industrial engineer and the worker is that every act of the industrial engineer must be in the open and above suspicion. Many of you will find this hard to believe, but, within the last two years, I had a case where the workers reported to me that the company time study men were frequently hiding behind posts in order to make check times upon them. I, too, was very skeptical and thought that they certainly were mistaken but I made a rather extensive investigation and I had to come to the conclusion that either the company's time study men were actually hiding behind posts making such studies or else their actions were such that the workers had ample reason to believe that this was what they were doing. In either case, something was definitely wrong in the company's program and I would like to point out that this was not a small company, but one of the largest companies in the United States whose name you would all recognize instantly.

Another practice which industrial engineers frequently follow, many times quite innocently, but which has a considerable disturbing effect upon workers and helps to break down the mutual trust, is frequent rate changing. I believe all of us recognize that there is usually some difficulty whenever rates are changed but I doubt if most of us recognize just how serious an effect this can have upon the worker. Rates should be changed as seldom as possible. It is usually better practice not to make small changes from month to month but allow them to accumulate and then make a substantial change in method at one time and make the necessary adjustment in rates. After all, we must remember that rate changes have a very direct effect upon the worker's pocketbook. Even though he may be able to make changes in his methods or manner of working, so he can keep his earnings at the same level, they do cause him to go through a period of readjustment. In connection with this, I believe it is desirable to always remember that industrial engineers should not give in to some worker objection and fatten up a rate when it is not actually deserved. Such gifts will usually back-fire and the ultimate results may be rather bad. I recall one instance recently where there was a considerable dispute in a plant which the workers told me in confidence they knew they were going to lose and they deserved to lose. It involved the taking off of one man from a work crew. This man had been added to the work crew about two years previously when they had got into a dispute about a rate and, as they put it, "we won that time." They knew that they actually did not deserve to

win. They admitted to me that they had known ever since they had won the case two years before that the company was sooner or later going to find a way to get rid of this worker. They now recognized that the company had made a sufficient change so that they had no chance of winning the argument, but they were determined to fight the case as far as they thought they dared to put up a good front. In the meantime production was suffering and a lot of bitter words were being thrown back and forth.

Another factor which I believe must be faced realistically, if confidence between the worker and the employer is going to be restored and maintained, is that involving the sharing of benefits which result from methods improvement. The distribution of these benefits is certainly not a simple matter. However, it is rather easy to understand why workers feel that at least they should have some share in the benefits if they cooperate in seeing to it that new methods work or help in the working out of new methods. In many cases, I believe it is actually the lack of any definite policy as to the sharing of benefits rather than the amount of benefit that causes the distrust on the part of the worker. It is my belief that a company will never achieve the objective of obtaining the best day's work until it has some definite program for worker participation in the benefits and profits. This certainly is not the cure-all but is one step. There are enough examples where such programs have been extremely beneficial to the owners of businesses, as well as to the workers, to recommend them to us all.

Another matter wherein confidence of the worker may be lost is in the failure of management to give the workers as much information as possible about the future prospects of the business, its plans and particularly its problems. If a worker is interested in the business, he is also interested in its problems. This gives him a feeling of belonging and being a part of the enterprise, yet in too many cases I have seen, management seems to take the stand that they should never tell the workers anything if they can possibly avoid it. At times it is true they adopt a very magnanimous attitude and proceed to tell them a very little bit about a very few things and feel that this is meeting the issue. Actually, in most businesses there are very few things so secret that they cannot be shared with the worker. It is recognized that frequently management does not know the answer to

some problems that are arising but I doubt if it would be a great error to make the admission to the workers that there are certain problems which management can foresee and that are going to have to be met even though the answers are not now known. Certainly, we cannot expect the worker to show much concern for the enterprise if he knows nothing about it. Similarly, we cannot expect a worker to understand company aims and policies if they are not published and made known to him.

These problems which I have presented are just a few of those which I feel are important in trying to enlist the cooperation of the worker, in making him feel that he is a vital part of an enterprise, and, therefore, should be interested in contributing his best. Some of you may feel that these things I have talked about are not particularly important and that the worker should not expect any different treatment than he is getting. Whether or not this is true, I can only say that I have tried to relay to you the sentiments expressed to me by workers and assure you that they do feel that they are important. I cannot help but believe that if the worker feels these problems are important then they are important. They are, therefore, problems for industrial engineers and management to consider seriously. Closing our eyes to them will not do much to increase the worker's feeling of "belonging" or make him believe we are interested in his security.

Most of us are familiar with an old saying which admonishes us to "do unto others as you would have them do unto you." I suspect our failure to carry this out in our dealings with workers is more a matter of not being able to put ourselves in the worker's position, thus enabling us to understand how our actions affect him than it is to our not believing in the fundamental correctness of the commandment. If we are genuinely concerned with workers as human beings, just like ourselves, we must be interested in their problems, anxieties, and ambitions. We must acknowledge that they are regular members of the first team and are capable of having a keen interest in the outcome of the game. They must genuinely feel that they are not working for a company but for our company. We, as industrial engineers, can do much to bring about this feeling. Certainly we should do nothing to prevent it.

PANEL ON HUMAN ENGINEERING

Chairman--Paul Eliel, Management Consultant, San Francisco
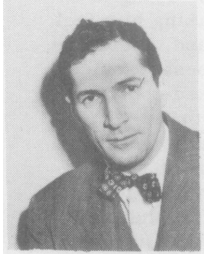
William Gomberg
Director of Management Engineering
Engineering Department,
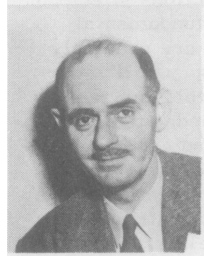International Ladies' Garment
Workers' Union,
New York, N. Y.

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Question: How much of a cumulative change can be permitted to take place before making a change in standards? Mr. DeGarmo: I don't think you can give an absolute rule to it. In general practice, I certainly wouldn't want to make a change of less than five per cent. In some cases you might want to go as high as ten per cent. After all, we've got to keep in mind the limitations of the accuracy of the standards we're going to set along with the change. However, that doesn't mean that if some minor changes of lesser extent take place before you make the final change in rates that you should ignore them or not take cognizance of them. I think it's very important that you do recognize that some change has taken place even though you may not make an immediate adjustment in the rate; otherwise, you may let yourself in for a lot of headaches.

Question: Have you any information regarding the advisability or success of separate standards for men and women as compared to the so-called universal-type standards? Mr. Mundel: I'd say that the standards are usually set on the basis of a worker who is physically fit for the job at hand. I couldn't conceive of separate standards for men or women. Perhaps, the one thing we learned when we used so many women in industry was that the women couldn't do what men shouldn't. I see no reason for separate standards for them. Mr. Gomberg: Ditto. The policy in our union is one piece rate for whatever you make, man or woman.

Question: Is there a psychological tendency in industry to assume that a man is not so much of a man if he works through the day sitting down? I ask this because I have seen many cases where if stools were provided the work could be performed just as efficiently with less fatigue. Mr. Haire: Let me restate the question. Is there a feeling that a man is not doing a day's work if he's sitting down to do it and consequently we don't let him sit down, though we might just as well. In general, I feel that in a lot of our situations where we plan work conditions, there is an implicit unacknowledged, unrecognized kind of hangover from a puritanism in our culture. It is the assumption that if anything is pleasant it can't be good for you. It's the same point of view, I think, that says that the medicine has to taste bad or it won't do you any good, and that if anybody is at work he oughn't really to be enjoying it or he's probably not doing

much work. For instance, girls on an inspection line probably shouldn't be chatting with one another, because they enjoy chatting with one another. So we'd better put them back to back so they won't chat with one another. Of course they'll look over their shoulders to chat with one another and won't pay any attention to what they're doing. Now, I don't know any example where people have been done out of stools, but I would think that might come under the same general heading.

Mr. Troxell: I remember, a couple of years ago, in a strike on a railroad in California where the locomotive engineers had a number of grievances. One of them had to do with seat cushions. They were worn out, and the company wouldn't buy them new ones. It appears to me that locomotive engineers don't figure they're not men because they sit down when they hold the throttle.

Mr. Kaltenborn: This reminds me of a story which I'd like to relate here. Mr. DeGarmo spoke about how the industrial engineer alienates the worker. I think an equally provocative subject might be how the industrial engineer alienates management. One of my former associates who was a top manufacturing man for one of the leading farm implement companies has this as one of his favorite stories. He uses it to illustrate why he, as a manufacturing man, sometimes looks askance at the engineering department. It seems that many years ago, when this farm implement company was just ready to come out with their first tractor, the diagrams and the designs, etc. had been all carefully prepared. They were about to go into production when to their horror they discovered that they hadn't yet a design prepared for the seat. He hurriedly summoned the engineers into his office for a conference, and they agreed to come up with an appropriate design promptly. A week later they had another meeting and they discovered at that time that no real progress had been made. The second week another meeting was held, and it was discovered that there were two distinct groups in the engineering department. Each group had gone out and made some very careful statistical studies of the shape and contour of that particular part of the anatomy. However, the samples didn't agree and their conclusions were very much to the contrary. The third week, when the status quo continued to exist, this executive got up in disgust, told the engineers to follow him, and walked down the road until he came to a sandpile, plopped himself in the sandpile, got up, pointed, and said, "Now you make it like that." He always closed the story by saying, "They've made it like that for forty years."

Question: At the Denver meeting of the American Psychological Association, Mr. Gomberg attacked one of Mason Haire's former associates for using psychological techniques as a shoddy device to fool the worker. Does he view Mason Haire's remarks in the same way?

Mr. Gomberg: Let me make something clear. I have listened to Mason Haire today; and I'm completely in sympathy with his approach. In fact, the reason that I attacked one of the men in Denver was that his whole emphasis was on worker selection, rather than taking a group of workers and saying that these are the men that have to make a living, so let's adapt the jobs to them. If he is a colleague of Mason's, then Mason must meet him standing on his head, because the approach is diametrically opposite. I don't want to go into a repetition of everything that happened at Denver;

it's in the proceedings, if you're curious.

This brings me to a point I wish to make. I may be wrong in gathering it, but Paul DeGarmo gave me the impression of a pattern of thinking which goes along the following lines. The union is essentially a protest institution--that is its only function. That is a common assumption. Therefore, if a union arises, it's because of some mistakes that management has made. If management had understood human relations, if management had understood all of these variables, now, in their old age, they wouldn't be saddled with unions. I don't think the reason for the popularity of Roethlisberger's book was so much its content. Commons had said all of the same things in 1919, and never received the circulation and the excitement that the Roethlisberger book received. The popularity was because it was published in 1938. Now go back about 12 years, and if you'll remember, in 1938 the whole country was agog because the Wagner Labor Act that the Liberty League had declared unconstitutional had just been declared constitutional by the U. S. Supreme What happened was that a great many industrialists suddenly found themselves face to face with a union. It became mea culpa, mea culpa, mea maxima culpa, what did I do that now I have to have a union as an affliction in my old age. Mayo answered that you didn't understand human relations. Now, if you go on that assumption, you'll be in no end of trouble with the union. For this reason: the job of a union is not to be just a social protest institution--sure it's a protective device, but its job is to fulfill certain functions in the factory which you as a manager can't fulfill. You have to think of your factory as essentially an industrial government; the function of the union is to be his majesty's loyal economic opposition. I'm borrowing the phrase from the British. Consequently, the union is always performing a function whether the manager is a good one, a poor one, or a bad one. It adds up to this: if you have a neurotic manager, you'll have a tough union to deal with; if you have a decent manager, you'll still have a union to deal with, but it'll be easier to get along with. However, the one thing that you must reconcile your thinking to is that the union is there to perform certain functions that the manager can't perform. When a manager says, well, I can get along without a union, it's like saying well, I can marry myself. This makes as little sense to us. The whole discussion of getting along with the union or without a union reminds me of a dissertation on the relative merits of marriages with and without grooms.

Mr. DeGarmo: I think that Bill Gomberg got a wrong impression from what I said. I would agree that under this present situation we've got the union and that they do certainly serve another function, ideally should. However, I suspect he would agree with me that the way the union came into being in the first place was as a protest institution because of non-recognition on the part of management of certain of its obligations and of the rights of the workers.

Mr. Gomberg: I think unions would have still arisen even if the manager had been an ideal manager. In fact the ideal manager of the 20's, "Golden-Rule Nash," thoroughly understood this and went to his men and said, "Look, there are certain functions that you must do for yourselves. I can't do them for you; the institution through which you perform those functions is the union." He asked his people to join the Amalgamated Clothing Workers of America. That's the point that I'm trying to get across to you, because otherwise all

of your thinking is conditioned by something that was implicit in some of Mayo's disciples' reasoning. This reasoning ran something like this--a union is an abnormal institution; it's a sort of psychological aberration that takes place when you miss up on some of your techniques. Now you just take our medicine and the union will disappear along with your arthritis and chilblains.

Mr. Mundel: I think there is an aspect of this that a lot of people are missing. That is the fact that union-management relationships are not just a simple black or white proposition--treat the union right and everything is rosy. I think we have to realize the fact that the union, despite the fact that it may not be a protest group still may be placed in a position of having to protest very vociferously that which it believes in order that a more radical group does not say to the workers, "Well, they're selling you men out to management, let us take care of you fellows."

Question: What is your reaction to Mr. Gomberg's talk, Mr. Mundel? Mr. Mundel: Well, to make my remarks very general, I was much interested as I usually am. Actually, I don't think we find ourselves on such different sides of the fence. I think we might say the points we have in common are that we both recognize that the so-called facts of time study are sometimes quite soft and fuzzy. Also, while Bill of course says that his union does not wish to trust itself to the irrationalities of a system, I would say the industrial engineer is not particularly anxious, on the other hand, to trust himself completely to the irrationalities of an operator. I know the union would resist vigorously the automatic progression of a clerical procedure which resulted in a rate which supposedly was so accurate that when it was performed it accurately reflected the worker's abilities. I also say that the industrial engineer would resent very much the opposite, and that is, if the worker can't make the rate that something is wrong with the rate. I remember arbitrating in a case that illustrates this point. It was in the garment industry--sewing a pocket. Supposedly the grievance arose because the operator could not possibly produce the required amount of work in the specified time. Actually, past production records revealed that a very, very similar operation, including additional work which had since been removed, had been performed at an even faster rate for many years by a different operator. In this particular case, it boiled down to the fact that this operator just wasn't physically capable of a typical production performance. I would not be willing to say we must go by what he can do any more than I think the union would be willing to say why, whatever you come out with is right. There is a good deal of give and take in this sort of thing. I think if we're all a little bit more intelligent about this we're all going to come out a lot happier.

Mr. Gomberg: I see Marvin understands the dynamics of the trade union and he's put his finger right on it. Look, as a union officer I wouldn't want to be victimized by just one of our operators--we're entitled to our share of neurotics too. I would worry if all of the operators weren't making that pocket. What you have to understand is this--in your relationship with the union, you must be guided by a realistic concept of what constitutes peace between you and the union. Most of you have an idyllic picture of peace that more nearly resembles the graveyard than

it does dynamic living peace. Let's see if I can't be specific. Most of you fellows must be married; now, don't you ever fight with your wives? If you don't there's something wrong with both of you, I think. But every time you have a fight there isn't a divorce. The divorce is the ultimate in the breakdown of the marriage relationship, just as the strike is in the particular relationship that we have, though we have to remarry and possibly get stuck again. In this dynamic picture of peace you have to expect certain rough spots. You have to take them as a matter of course instead of just moaning that if only we understood one another, we would have ideal peace. There isn't this picture of ideal peace between a mother and child it doesn't exist between a wife and a husband. There is one place it does exist, in the graveyard.

Question: What progress is being made in the determination of fatigue both physical and especially mental, in connection with allowances? Mr. Mundel: Fatigue is possibly the most misused and abused term existing in literature today. It means all things to all people. It is defined as a decrement in output due to previous activity. However, we find many situations where there is none. That does not mean that people don't get tired. If, on the other hand, we describe fatigue as a subjective feeling on the part of the operator that he is getting tired of his work we may find fatigue occurring in many situations where at the same time we find output going up. There has been work done in this area by the British and Americans for many years. The present trend, as near as I can make out, on the determination of fatigue allowances is to abolish them as a group and to provide allowances for more specific items. This is because the time allowed for a task is the average time for that task over the working period, and, the allowances, rather than being for fatigue, are for specific blocks of time away from work or for specific physical needs. I think that's real progress.

Question: You stated that we should not cook up subgoals, that they should be natural. Would you define or give an example of a natural subgoal as applied to industry? Mr. Haire: Yes, I think I can give some suggestions about what they might be. The thing that first comes to my mind in that connection is an example from the very nice article that Russell Davenport wrote for "Fortune" on the Scanlon Plan. He described a machine tool company with a labor-management participation committee and a profit sharing plan. Here, the hourly paid workers had an over-view of the company's problems that they hadn't had before. The worker saw the company's competitive position and saw the company ready to refuse to bid on a job because they couldn't meet a competitor. Seeing the pressure of that situation, they met and beat the bid. They turned out a level of productivity that they probably wouldn't keep up indefinitely. There's one illustration--it isn't the only way to get a subgoal. I think that the fact that we don't find subgoals when we look for them is symptomatic. That's kind of an interesting symptom that we don't, because as a matter of fact, we don't build them in very much. We disregard them. What we seem to try to do chiefly when we make up production systems is to build the production system on the basis of the processes that have to happen to the parts, and there aren't any subgoals as far as the

parts are concerned. They just stretch on indefinitely; however many we put in. This is the kind of thing I mean when I speak of building the production process to suit the part rather than to suit the people. The subgoals are very often there if we only design our process to bring them out. Maybe if the worker sees the whole widget made and finally puts it in the package, maybe it's knowing that this particular bunch of them are going somewhere into airplanes. Very often, during the war, subgoals were provided by knowing that this material was going to such and such a place. I not so long ago talked to people making things at the Navy Research Laboratory in Inyo-Kern. They were making those big bazookas to go to Korea. They certainly had a terrific subgoal and a terrific level of productivity for that. It's a little hard to give specific examples that will fit all the kinds of processes which you people work with, but I think you can find them yourselves in your own processes.

Mr. Kaltenborn: I think Mason has put his finger on a very important thing, but I'd like to emphasize a slightly different aspect of it which is that I think that we not only don't know what our subgoals are, but often don't even know what our overall goals are. Try an experiment some time: Ask the chief executive officer of some substantial company, "What is the purpose of your business enterprise?" Listen to his answer; see how quickly it comes forth; how long he he has to fumble before he comes up with an answer. In the same company, ask members of lower supervision that same question, "What is the purpose of this company or what are the purposes?" Listen to their answers. Watch the mental process which they go through before they come out with an answer. Then get out to the rank and file employees on the bench and ask them the same question. I think you'll find a very interesting situation. Number one, you'll find that even the members of the management group themselves don't have any very clearly defined delineated ideas about specific, even general goals or purposes. You'll find a very different feeling about it, a very different set of goals, or understanding of what the goals are, on the basis of different levels asked. I think you can ask a question, then, which is, "Has business a purpose?" We know it has a purpose, what is the purpose? If you answer the question that the purpose of the business enterprise is to make a profit you immediately run into the fact that that is not a purpose or a goal which is socially acceptable to the people whose cooperation you need.

Mr. Gomberg: I was rather fascinated by this dissertation of Howard's. I'll agree with him that if you go around asking what they do you're not getting information; what you are doing is irritating what I call their throttle-bottom coefficient. Let me illustrate what I mean by the throttle-bottom coefficient. At the beginning of the century, as you know, Chicago was still the place where the most distinguished industrial pirates of the country were staying. At that time it was quite customary to hold them up to youngsters as a very apotheosis of American achievement. If you asked someone like one of the old pirates how did he make his success, you would get an answer like, "By getting up early and eating Danish pastry at eight o'clock in the morning and having a thin lunch." If you want to use that as a subject for investigation you probably could write a PhD thesis but you don't get information. I don't see why you should complicate the

goals of business. It's quite simple; it's to make money. Of course, it's not socially unacceptable to do it; it's socially unacceptable to acknowledge it. If you want proof of the operational validity of what I'm saying, what was the reason that business would not go into defense industry unless they got five year amortization certificates? To make sure that they made money on the thing. Now I don't disagree with that; that's the way your enterprise has to operate. Business ought to get rid of its inferiority complex and say what's on its mind. Half the trouble comes from this double talk.

Mr. Haire: I want to add one more word on this. I agree with Bill about what the goals of business are. I think that this test that Howard suggested of asking management isn't a proper test, partly because, as Bill says it arouses the throttle-bottom coefficient and a stereotyped answer, and partly because the reason why you don't get much answer is because it's a very difficult question. If we should ask any of us here, what are we here on earth for or what do we want to get out of life, it would be an awfully hard thing to give a reasonable answer about what we want to get out of life. Yet, we all have goals and we all work towards them. I think management and the hourly paid workers have difficulty in phrasing it and so forth, I think that comes chiefly from the problem of verbal facility. That isn't quite the kind of thing I meant to point to about subgoals. Let me give one more illustration that may bring it out. I live in an old house. I do a lot of fixing up, I'm the general handy man about. Each thing that I do is its own separate task and I'm anxious to finish it. When I finish it there'll be something else. My wife just probably hasn't told me what the next job is. If I conceived of my role as handy man as being just to go on day after day fixing things, it would have no push or incentive in it. This way I build the light fixture one day and by the time I finish the light fixture we probably need some steps. Each one of those is a goal in itself and each one corrals a whale of a lot more of me than if I saw it as an endless job of just fixing things. That's the kind of thing I mean by subgoals.

Mr. Kaltenborn: I don't mean to minimize, obviously, the fact that we have to have profits in a system such as ours in order to perpetuate the business enterprise and I don't want to indicate that the profit motive isn't a realistic motive in our business enterprise system. I simply want to indicate that there are a lot of other motives that go to make up the purposes of any managerial group in a business organization other than the profit motive. You don't have to read very far in order to discover a fact all of us know. In many companies today there is an almost complete divorcement between the management of the company and the stockholders. They are management-controlled companies rather than stockholder-controlled companies. The board of directors are not selected by the stockholders; they are selected, in fact, by the management. Where you get into that sort of situation you find that their interests and desires depend upon more than the question of whether the company as a business organization is going to make a profit. I simply have the feeling, which I think is sound, that people work more effectively if they are working toward goals which they themselves realize and to which they subscribe.

Question: How do you get a quick, cheap way of installing an incentive plan if you've never had one?
Mr. Gomberg: I'd have to know the history of the

union, the history of the relations there, the union members, what their background is, where they come from, what experience they have had. Suppose some of the boys are there from the automotive industry of the 30's where they were making food money in '29 and suddenly their rates were cut to hell in '31. No matter what I tell them as a trade union engineer won't convince them. The answer is that there is no quick answer. You've got to analyze your situation, determine what social forces there are favoring the installation, what the forces are against it, weigh them, and then develop your own strategy.

Question: Is it possible to develop professional standards for industrial engineers in order to test their knowledge, competence, and ability before turning them loose in the plant? Mr. Gomberg: They've done it for other branches of engineering by the registration acts. How effective it is I don't know. Sometimes I suspect when I look at a CPA or Bar examination that these acts are not so much designed to test the qualification of the newcomer as they are designed to keep the company closed. It's really a closed shop with a statutory interpretation couched in socially acceptable language to express qualifications. The reason I say this is that all the qualifications of necessity have a verbal description without any real quantitative corrolary to them. I've never bothered to become a registered professional engineer. I see absolutely no reason why I should sit down and learn all about stress analysis. I'm not going to build a building, nor are most engineers who pass that exam. Yet, the closed shop boys have managed to get that wording into the professional act of New York State.

Mr. Mundel: Sometimes we get so engrossed in the time study function, which has so much connected with it, that we overlook the fact that that's only one small phase of the industrial engineer's job. Sometimes we think that the industrial engineer's job is synonymous with the time-study man's who is merely a technician performing one of the functions of the industrial engineer. We saw some of the other functions yesterday; the process-finding people. The true industrial engineer's job is a design job, which means taking into account the raw material, the product and its productibility, planning the equipment necessary, all the physical facilities required to produce it, the materials handling, the materials control, quality control, production control, and cost control arrangements and their places in the organization so that they are properly placed. In short, the industrial engineer's job is to make an organization that will produce a product to meet a given economic market in a predictable manner. Let's not get this time study business mixed up with industrial engineering.

Mr. Haire: I had the feeling that the question had as its main emotional charge something slightly different from what's been answered. As I interpret the question, "Is it right for industrial engineers to influence the take-home pay of workers when the industrial engineer may not, in some cases, be competent?" To that point, I would say that the industrial engineer is very, very fortunate to be protected by the collective bargaining system. As I see it, the take-home pay

will be hammered out at the collective bargaining table. A lot of the rates that are set just give you points to argue about at the collective bargaining table and you don't need to worry about the responsibility because we have some checks and balances on unilateral management.

Question: What would you do if junior would not even pick up the glass? Mr. Haire: That question really applies to industrial situations. It is not unlikely at all that we will have some resistance built up against whatever the process is. To keep the orange juice analogy, maybe you can't even get him to come to the table; you can't get him to come into the room. I don't know at what point the problem is going to start. However, I don't think that this changes the principle that underlies it, which is to take small steps. You've got to work first at very gradual steps in the relationship between the company and union, or the company and the worker.

Question: Why do so many grievances result in a rupture of normal relations between management and workers? Mr. Gomberg: I don't think many do. I think you're proceeding on an assumption that's false; those are the only ones that get the publicity. Have you ever stopped to think how many are settled peacefully that you never hear about? You shouldn't infer that my earlier remarks mean that you're going to get idyllic peace. The thing that you must always keep in mind is, that in a normal relationship between people that are alive, not dead, frictions will develop and the publicity that attends this relationship will not be concerned with the 99.9% of the time they get along well, but with the one time that they have a rupture. That's why it's news.

Mr. Kaltenborn: If we're talking here today about human engineering, I assume that what we're striving for is good human engineering. The absence of strikes is not necessarily an index of good human engineering. You can have industrial peace in what I would call an industrial concentration camp, but you don't want that. You can find plenty of examples of companies where there hasn't been a strike for a long time, but where you wouldn't think it is a very healthy situation. On the other hand, you find examples of companies where there may be sporatic strikes but where the relationship is really a healthier one than it is in the first company. Nor, would I rate the industrial relations or industrial engineering goodness by an examination of how many grievance cases went to arbitration.

Mr. Troxell: These nuisance strikes over small grievances are apt to reflect a bad discipline situation within the union too. The machinists of San Francisco for instance furnished an example of that during the war. The International had to step in and get that team on the road.

Question: What are the real functions of a union and what is being done by unions about them? Mr. Gomberg: In order to avoid another long dissertation I would suggest that you read the book ASME has just published called "Small Plant Management." There is a whole chapter devoted to the subject "How to get along with the Union."

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  Levi Strauss & Company
  San Francisco
GIOVANINI, Frank
  Johns Manville Corporation
  Pittsburg
GOFFMAN, J.
  Columbia Steel Company
  Pittsburg
GOMBERG, William
  International Ladies' Garment
  Workers' Union
  New York
GRABSTEIN, Norman E.
  Columbia Steel Company
  San Francisco

GRAMS, Stanley
  Benicia Arsenal
  Vallejo
GRASSI, R. C.
  University of California
  Berkeley
GREENE, Dan S.
  Bethlehem Pacific Coast Steel
  Millbrae
GREENWOOD, Frances C.
  United Employers, Inc.
  Oakland
GROSS, John N.
  Mare Island Naval Shipyard
  Vallejo
GUTENTAG, C. E.
  Catalog & Advertising Producers
  Los Angeles
HACKER, L. D.
  Ford Motor Company
  Richmond
HAIRE, Mason
  University of California
  Berkeley
HALE, L. P.
  Colgate-Palmolive-Peet Co.
  Berkeley
HAMMARBERG, H. V.
  University of California
  Berkeley
HAMSTRA, R. H.
  McMurry, Hamstor & Company
  San Francisco
HANCOCK, K. C.
  Western Condensing Company
  San Francisco
HANNA, J. H.
  Pioneer Rubber Mills
  Pittsburg
HARRIS, Milward
  Friden Calculating Mach. Co., Inc.
  San Leandro
HARWOOD, Aubrey
  Golden State Co., Ltd.
  San Francisco
HEAD, Harvey J.
  Columbia Steel Company
  Pittsburg
HEDT, T. P.
  Calif. Processors & Growers,
  Oakland
HELVERSEN, F. D.
  Crown Zellerbach Corporation
  Portland, Oregon
HENICH, J. Dry
  Columbia Steel Company
  Pittsburg
HESS, Robert G.
  Coast Counties Gas & Elect. Co.
  Santa Cruz
HIGHTOWER, Dorthea
  University of California
  . Berkeley
HILL, George S.
  Benicia Arsenal
  Benicia

HODSON, W. K.
  Methods Engineering Council
  Pittsburgh, Pennsylvania
HOFFMAN, J. R.
  University of So. California
  Los Angeles
HOYT, G.
  Industrial Engineering Student
  Oakland
HUFF, Edward
  Schmidt Lithograph Company
  San Francisco
HUGHES, H. M.
  University of California
  Berkeley
HUNT, John
  Bank of America N. T. & S. A.
  San Francisco
HUNT, John E.
  Pacific Public Service Company
  San Francisco
IRWIN, Don
  University of California
  Berkeley
JOSSIS, S. A.
  Pabco Products, Incorporated
  Emeryville
JUNG, Harding
  Benicia Arsenal
  Benicia
JUUL, P.
  Link Belt Company
  San Francisco
KALTENBORN, H. S.
  University of California
  Berkeley
KAMPERMAN, R. D.
  Ford Motor Company
  Richmond
KASSEBOHM, Walter
  The Marchant Calculating Mach. Co.
  Emeryville
KEACHIE, E. C.
  University of California
  Berkeley
KESSLER, Emanuel
  Jas. Graham Manufacturing Co.
  Newark,
KHAN, Jerome
  S.F. Port of Embarkation
  San Francisco
KLOCK, Franklin G.
  Cutter Laboratories
  Berkeley
KNISLEY, L. E.
  Campbell Soup Company
  Sacramento
KUSHNICK, C.
  Link Belt Company
  San Francisco
LAGONI, Harry
  The Borden Company
  San Francisco
LAMBERTI, N. A.
  McCulloch Motors Corporation
  Los Angeles

LANG, Robert J.
Oakland Municipal Airport
Oakland
LAPSLEY, J. T.
University of California
Berkeley
LASHBROOK, T. S.
Owens Illinois Glass Company
San Francisco
LOCKWOOD, Robert W.
954 Buchanan
Albany
LORTIE, Francis N.
Burroughs Adding Machine Co.
San Francisco
LUCHETA, Harry W.
Colgate-Palmolive-Peet Co.
San Leandro
LUDKEY, Norman E.
Bethlehem Steel Company
Burlingame
LUETH, P. F.
Union Oil Company of California
Oleum
McCALL, J. D.
Columbia Steel Company
Pittsburg
McCAULEY, B. G.
University of California
Berkeley
McCURDY, Robert
National Motor Bearing Co., Inc.
Redwood City
McEVOY, J. B.
Libby, McNeill & Libby
Sunnyvale
McFATE, William M.
Columbia Steel Company
Berkeley
McLIN, Paul E.
Benicia Arsenal
Benicia
MALCOLM, D. G.
University of California
Berkeley
MALM, F. T.
University of California
Berkeley
MANAGEMENT PLANNING &
REVIEW DEPARTMENT
Mare Island Naval Shipyard
Vallejo
MANDERS, Martin
Union Oil Company of California
Oleum
MARSHALL, G. L.
Columbia Pictures Incorporated
Culver City
MARTIN, Jay W.
Oakland Municipal Airport
Oakland
MARX, J.
Columbia Steel Company
Pittsburg
MASTERSON, C. S.
Campbell Soup Company
Sacramento

MEYERS, Harold
Muirson Label Company, Inc.
San Jose
MILLER, Edward E.
Columbia Steel Company
Pittsburg
MILLER, H. E.
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MOSHER, B. C.
Golden State Co., Ltd.
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MULVANY, Harry A.
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MUNDEL, M. E.
Purdue University
Lafayette, Indiana
NELSON, H. R.
Johns Manville
San Francisco
NETHERBY, Steve
Levi Strauss & Co.
San Francisco
NORDAHL, J. D.
Coast Manufacturing & Supply Co.
Livermore
NORDHOFF, W. A.
Douglas Aircraft Company
Santa Monica
NORRIS, Stewart
Schmidt Lithograph Company
San Francisco
OBRECHT, John
Simmons Company
San Francisco
OLSON, Harold L.
Johns Manville
San Francisco
ORR, W. F.
Vegetable Products
Vacaville
OSMOND, Cecil
National Motor Bearing Co., Inc.
Redwood City
PARKER, Wendell
Cutter Laboratories
Berkeley
PARSONS, Robert D.
Muirson Label Co., Inc.
San Jose

PARUN, William
Fibreboard Products, Inc.
Antioch
PATTERSON, D.
Columbia Steel Company
Pittsburg
PEARSON, Carl A.
Simmons Company
San Francisco
PETTITT, G. A.
University of California
Berkeley
PINGER, R. W.
University of California
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PIPER, T. E.
Northrup Aircraft, Inc.
Hawthorne
POPA, George
Friden Calculating Mach. Co.,Inc.
San Leandro
POSTLETHWAITE, F. H.
Libby, McNeill & Libby
San Francisoo
PYLE, R.
Pioneer Rubber Mills
Pittsburg
QUICK, J. H.
The Work-Factor Company
New York, N. Y.
READ, Stanley N.
Sunset-McKee Company
Oakland
REARWIN, Heath
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San Leandro
REED, H. L.
Fibreboard Products Company
Stockton
REILLY, Robert
Bank of America N.T. & S.A.
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RICE, William H.
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Pittsburg
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SALVESON, M. E.
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SAMSON, D. W.
    Campbell Soup Company
        Sacramento
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SCHAEFER, Wm. J.
    Schmidt Lithograph
        San Francisco
SCHAUMBURG, G. W.
    Geneva Steel Company
        Salt Lake City, Utah
SCHEBLE, Max C.
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        Salt Lake City, Utah
SCHLOSS, Lynn A.
    Montgomery, Ward & Company
        Oakland
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    Columbia Steel
        Pittsburg
SCHUYLER, John
    Simmons Company
        San Francisco
SHADE, A. R.
    Fibreboard Products Company
        Stockton
SHAPERO, A.
    The Emporium
        San Francisco
SHARP, Lee S.
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        San Francisco
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SISCO, Robert C.
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SKELLS, John
    Guy F. Atkinson Company
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        Oleum
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        Pittsburg
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        Pittsburg
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        Richmond
WOOD, F. W.
    Marchant Calculating Company
        Richmond
WOOLLEY, Ellis H.
    Naval Supply Center
        San Francisco
WULFF, H. B.
    Campbell Soup Company
        Sacramento
ZIMMERMAN, Jesse
    San Jose State Junior College
        San Jose
ZIMMERMAN, Ralph
    National Motor Bearing Co.,Inc.
        Redwood City

Quality Control

Time Study

Production Analysis

Dispatching

Flow Diagrams

Work Measurement

Safety Programs

Work Simplification

Standard Costs

PRODUCTION

Production Control

Scheduling

Routing

Training

COSTS

Incentive Systems

Production Planning

Methods Improvement

Inventory Control

Cost Reduction

Man-Machine Charts

Methods Analysis

Engineering Investments