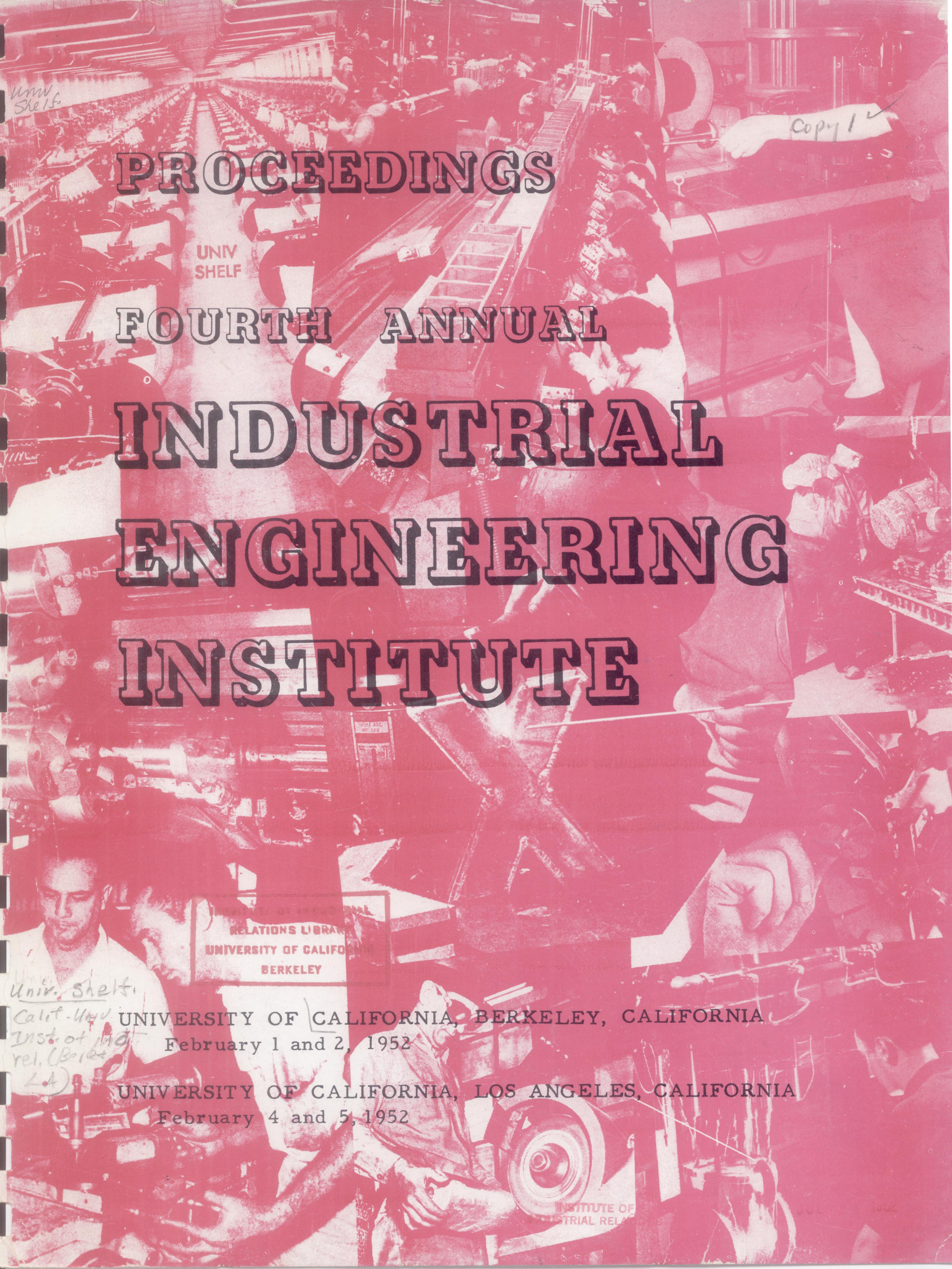

PROCEEDINGS

FOURTH ANNUAL

INDUSTRIAL ENGINEERING INSTITUTE

UNIVERSITY OF CALIFORNIA, BERKELEY, CALIFORNIA
February 1 and 2, 1952

UNIVERSITY OF CALIFORNIA, LOS ANGELES, CALIFORNIA
February 4 and 5, 1952

PROCEEDINGS

FOURTH ANNUAL INDUSTRIAL ENGINEERING INSTITUTE

DONALD G. MALCOLM, Editor
Assistant Professor of Mechanical Engineering
University of California, Berkeley, California

UNIVERSITY OF CALIFORNIA

BERKELEY

Friday and Saturday
FEBRUARY 1 and 2, 1952

Presented by:

DIVISION OF MECHANICAL ENGINEERING

DIVISION OF ENGINEERING EXTENSION

INSTITUTE OF INDUSTRIAL RELATIONS

SCHOOL OF BUSINESS ADMINISTRATION

DEPARTMENT OF CONFERENCES AND SPECIAL ACTIVITIES, UNIVERSITY EXTENSION

In cooperation with:

AMERICAN INSTITUTE OF INDUSTRIAL ENGINEERS

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

SOCIETY FOR ADVANCEMENT OF MANAGEMENT

LOS ANGELES

Monday and Tuesday
FEBRUARY 4 and 5, 1952

Presented by:

DEPARTMENT OF ENGINEERING

SCHOOL OF BUSINESS ADMINISTRATION

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SOCIETY OF APPLIED INDUSTRIAL ENGINEERS

PUBLICATION FACTS

For those interested in some of the technical details in the publishing of these Proceedings

The manuscript was prepared on I.B.M. Executive Electric Proportional Spacing Typewriters. Documentary type face, approximately 11 point in size was used for the text, and Modern, approximately 10 point in size was used for the footnotes and titles. The typewritten copy was reduced to 75% of its original size. The total words per page is approximately 1150 to 1200.

**Camera, Plates and Lithoprinting
By
The Elliott Printing Company
1016 Jackson Street
Oakland 7, California**

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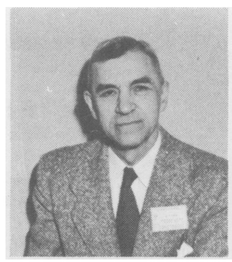

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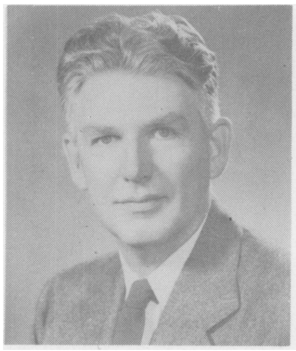

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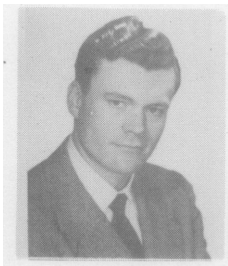

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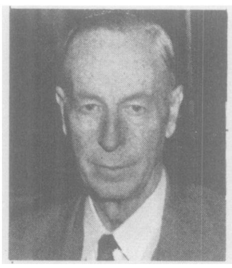

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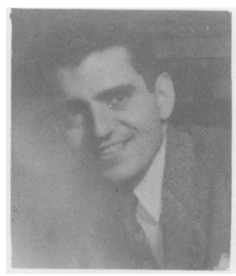

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ADDRESS OF WELCOME

H. A. Schade, Director
Institute of Engineering Research
University of California
Berkeley, California*

Those of us who are engineers often have some difficulty in defining our profession and, particularly in these days of much closer relationships between the basic sciences with engineering, it becomes increasingly difficult to provide a suitable definition, particularly for those younger men who are interested in adopting engineering as a career. It has been said, for example, that the characteristic function of engineering is design of a machine, using machine in its broadest sense, which involves the analysis and prediction of performance and costs. Equal weight must be given to both these criteria. Another way of saying the same thing, perhaps, is to define engineering as the art and science of combining men, money and materials for the purpose of improving the material side of our civilization. Now, in some branches of engineering generalities of this kind are difficult to apply, but it seems quite clear that that area of engineering which is the subject of this Institute today, namely, Industrial Engineering, is one of the purest forms of engineering in the light of definitions of this kind.

There is, however, it seems to me, an apparent paradox here. The history of industrial development in this country, particularly those parts which are dependent upon the techniques of mass production, seems to indicate that these techniques, by and large in the past, have been developed principally without much reference to the formalized academic studies of engineering. In fact, it seems quite clear that many of the great men who have been identified with the development of industrial mass production techniques have been men who were certainly engineers, but with little or no academic training in anything called Industrial Engineering. Consequently, Industrial Engineering is one of the areas in engineering in which the realities of the production plant and the academic exercises of professor and student need to be very closely allied. In fact, here the professor must learn from the practitioner more than in many other branches of engineering. For that reason, conferences of this kind, which bring together these two elements of a branch of engineering seem to me to have a very unique value. In such conferences the result of research and studies made both by the academician and the practitioner are set forth with an invitation for comment and criticism, and the hope is, of course, that by means of such reactions both groups will be benefited.

Also because engineering schools, unlike most other professional schools, offer an undergraduate professional curriculum is this close contact exceptionally necessary. The time is short for an engineering student to learn what he must learn within his four years of professional study, and at the same time to maintain contact with the practice of his future profession outside. Contrast this, for example, with the medical profession where many more years of study and contact between the academic and practitioner side are regarded as natural.

Another means of accomplishing some of this contact, so desirable from the engineering school's point of view, is found in the cooperative program for undergraduates, such as that in operation here at Berkeley under the leadership of Professor DeGarmo, under which students of Industrial Engineering spend six months at the University and six months in positions in industry alternately through their undergraduate career.

As you know, the same program will be offered at Los Angeles on February 4 and 5, which is an indication of the growing interest of this type of meeting.

Consequently, for all these reasons, we regard Institutes of this kind in all branches of engineering, but particularly in Industrial Engineering, as being of the utmost importance, and I have no doubt that from that point of view this one will transcend the importance of its predecessors.

*Wesley L. Orr, Assistant Dean of the College of Engineering, University of California at Los Angeles delivered the welcoming remarks at the Los Angeles session.

ORGANIZATION FOR INDUSTRIAL ENGINEERING SESSION

Session Chairmen: G. S. Drysdale - Berkeley, February 1, 1952
D. G. Malcolm - Los Angeles, February 4, 1952

TIME STUDY TRAINING FOR SUPERVISION AND UNION

J. F. Biggane, Chief Industrial Engineer

The Maytag Company, Newton, Iowa

Our Time Study Training Program for Supervision was organized first to acquaint top and middle management with the objectives of Time Study, and secondly, to give to supervision a full appreciation of the subject, including some training in effort rating and in actually taking a time study. The object was not to qualify foremen as time study engineers, but rather to enable them to use this tool of greater productivity more effectively. Since May, 1949, we have given this training to thirty (30) people in our Top Management, 300 Supervisors, and 150 Union personnel.

Before describing the content of a Time Study Course for Supervision and how to organize and to conduct such a course, let us ask why should such a course be conducted anyway. To us industrial engineers, the obvious answer is that establishment of correct labor standards requires knowledge and the resulting cooperation between the line organization, all staff departments, and Union. But why do supervision and Union want time study training, and if they do, what can they expect to get out of it? I believe that they want training because they are confused about time study. The greatest criticism of time study by incentive workers is its complication of language and arithmetic. Even the foreman is of little help for he generally knows no more about the procedure than the worker. This ignorance has led to suspicion and distrust. Supervision and Union want time study training so that they can save their own self esteem in being able to explain it to the operator. The situation is particularly bad when your plant is expanding and new foremen are being created every day. Imagine yourself in the shoes of one of these new foremen, having little or no knowledge of incentives and therefore forced to call in a time study engineer when trouble arises with his operator.

Maybe we industrial engineers think that the foreman and Union want the knowledge so that they can confound us later when we don't perform in the manner as described in those "lectures back there"! I don't think so. Supervision wants to know how time study works because they know it leads to greater production. The union wants it because they know that it will increase the employees' money income. The supervisor will get no production unless the employee gives it to him; the Union steward will not stay in office unless he can explain the why of labor standards being changed. Both Management and the Union have a vital and legitimate stake in the employee. If our time study training demonstrates that we know how to get the basic information for determining the right method and effort involved in a job, Supervision and Union will have more trust in us. They will also arrive at the conclusion that knowing how to use a fair incentive leads to greater productivity and maintains more friends among employees than trying to obtain special deals which will return to haunt them when all employees ask for special treatment. As a result of Time Study Training, we have found that both foremen and Union are actually trying to assist the operators to understand and accept our labor standards. The number of labor standard grievances received by our Company has decreased from 308 in 1947 to 37 during 1951.

Sure, there will be times when you will wonder whether the training was worthwhile, especially when a foreman seems to close his mind to an understanding of one of your labor standards. But wait, you received many benefits yourself from holding these conferences. You had to know what the present practices were in your Time Study Department. The Department records had to be complete, put in shape, and filed properly so that the time studies on an operation over a period of years could be traced easily by foreman or Union on demand. Perhaps the prime benefit was that your engineers who taught the course learned this also, and in addition became known and respected throughout the Company. It is gratifying to see Union stewards consulting my engineers directly and in the early phases of a misunderstanding, and to see these misunderstandings clear up and fade away--without the red tape of clearing through me, and without involving any more officials of Union or Management. The greater the number of people who get into the argument, the less it seems to pertain to the original complaint from the operator!

If you were to make a preliminary investigation in your plant, I am sure you would find not only a need, but a desire from supervision for Time Study Training. Suppose you were to find this so, just how should you proceed to act on this matter? On the premise that you may find something of value from the way in which we approached the problem, I will describe some of the more important points in our procedure, omitting much of the detail and visual aids actually used in our training course, as I assume that most of you are familiar with time study practices.

KEYS TO SUCCESS

What we are after today is to try to discover the keys or "spark" which will make your program successful.

The first important key is to enlist the aid of Top Management, not only to lend prestige by their attendance at your meetings, but so that they, too, can learn something about Time Study and what contribution it is making to the Company.

The second important key is to be sure to include in your Time Study Training, the staff departments, such as production planning, cost department, payroll, tool and process engineers, and time-keepers who are responsible for production counts. Mix this staff personnel with shop supervision, since they all share the common problem of making the best use of time study as a production tool. Conduct your meetings as much as possible on a conference style basis so that you can obtain plenty of comment and opinion.

The third important key is to organize a "trial" group and take them through the entire course in advance of your regular sessions so that you can test their reactions and make whatever changes are necessary. We organized two groups and told them that they were especially selected to try out our training material and to help us develop it to suit their needs. Be sure to select an operating executive who deals with the incentive plan to attend all of your sessions with this trial group. In our case, the Vice President of Manufacturing attended with one group and the General Manager of Manufacturing attended the other. They proved very helpful in explaining the background for Time Study policies when difficult problems arose throughout the course.

The fourth important "key" is to impress the foremen with the impartiality and value of the information they are going to receive, by having the program introduced by some one well known in the Industrial Engineering teaching profession, say, for example, the head of the Department of Industrial Engineering from your nearest State University. We were fortunate to secure the services of Dr. Ralph M. Barnes, of the State University of Iowa. To lend further importance and note to our first meeting, we took it out of the Company premises and held it down town at the hotel. It was attended by the top operating executives of our Company, including the President, several Vice Presidents, the Manager of Manufacturing, the Operating Department Superintendent, and the heads of the various staff departments, such as Research and Development, Comptroller, Master Mechanic, Chief Engineer, etc. The first meeting was a preview of the entire course and lasted five (5) hours, with appropriate rest periods. The regular course consisted of 12 sessions of 1-1/2 hours each attended by 15 people on a conference style basis.

Dress up your meetings with exhibits of equipment used by your profession and explain them with large, colorful signs. Get some emotional appeal as well as logic into your meetings. We displayed a stopwatch; movie camera; a special projector used for training purposes in effort rating; a productimeter for automatically measuring delays as substitute for production studies; various Time Study forms; some graphs and curves showing increases in production as the incentive program was installed; etc. During the conferences, in addition to the exhibits, we used several types of slide projectors, and two movie projectors, so that there would be no delays due to rewinding. The overall effect was quite fast moving and dramatic.

The theme of our Time Study Training for Supervision was that:

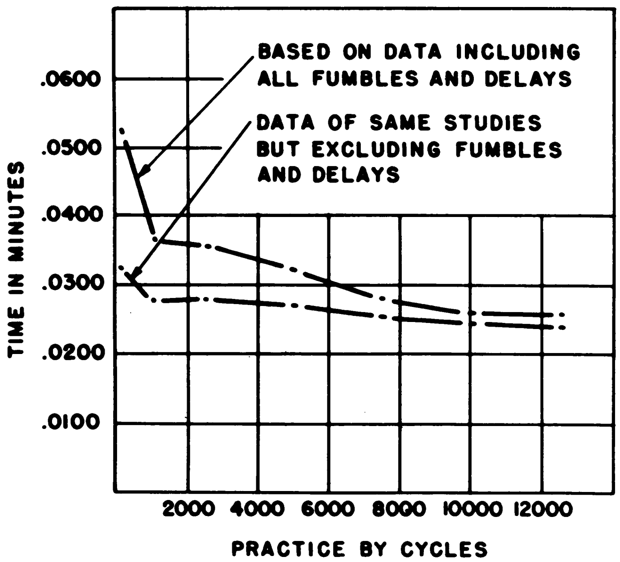
1. Knowledge of the incentive plan would assist them to obtain greater productivity with better quality and lower cost.
2. This training would bring them closer to their workers, as well as increasing the workers' respect for them, since it would enable them to explain to the workers just why certain things are done in time study and how they are accomplished.

Before presenting the technical information, we introduced our subject with an explanation of the reasons for installing incentives and how they should be administered. In opening the first meeting, I acknowledged the presence of our top executives and stated that we would not only give our own opinion of the work which we had been doing, but had invited Dr. Barnes as an impartial authority to present to them a few statistics on how our practices and results compared with that of 89 companies on whom he had just finished an Industrial Engineering Survey.

Dr. Barnes then discussed briefly:

1. The general economic effect of installing incentive systems.
2. Maytag statistics as compared with those in his nationwide survey on Industrial Engineering, such as: the percentage of direct factory labor which had been put on incentive; the average earnings in per cent above the base rate; etc.
3. The necessity for consistency of working conditions and accuracy of time studies if incentives are to be successful. This could be assured by:
   a. Establishment of exact work methods.
   b. Training the operator in these methods, and developing his skill.
   c. Correct effort rating.

To illustrate these he showed slides of operator left and right hand charts, and layout of proper work place; his movie of the simulated punch press operation experiment at Iowa City, showing development of skill by the operator over a period of 8,000 work cycles; and his movie of effort rating.

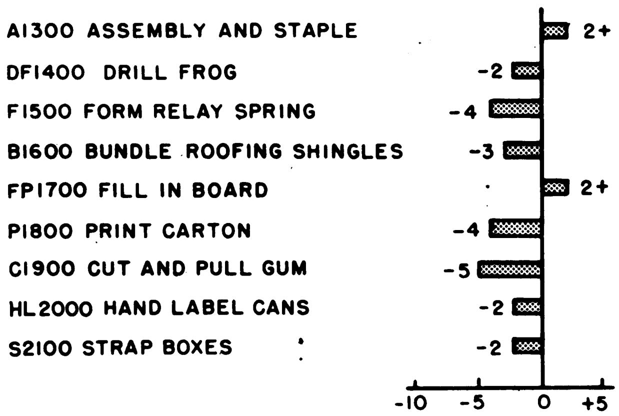


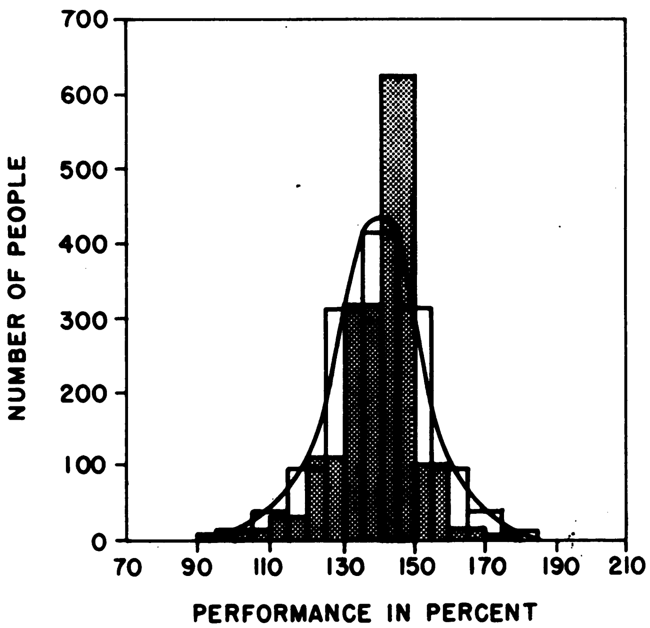
4. He next described how our results compared with those revealed by his Nationwide Survey; for example, our industrial engineers' effort rating results on the walking test and on his RB 540 film; and a chart showing Maytag incentive earnings as compared to a normal distribution curve.

To get the conferees to take an active part in the conference, we then showed Dr. Barnes' effort rating film #540, which consists of nine different operations such as: Drill Frog in Plow Bottom, etc. Blank forms were passed out to each member of the conference and he was asked to rate each different operation shown in the movie. At the conclusion of the movie, the National Average rating for

MAYTAG

RATING COMPARED WITH NATION-WIDE WORK MEASUREMENT PROJECT - FILM RB540





1278 Incentive Workers October-December, 1948

each operation was given so that each conferee could compare his rating to it. Naturally, the answers were pretty much off-center and there was much laughing and kidding among various small groups of conferees when they revealed their results to one another. They very quickly came to understand the difficulty of effort rating and, of course, this led to questions on just how our industrial engineers overcome their difficulties in this respect. Particularly, they asked how were we able to set correct labor standards.

This gave me an opportunity to state the responsibility of all parties concerned if labor standards were to be successful:

1. The cooperation of Supervision is necessary in preparing the operation before requesting a time study, making sure that a good method has been established; the machines, fixtures and tools are operating properly; the materials meet the proper specifications; the operator is normally qualified physically and mentally and has had some training on the operation.

Date..

REQUEST FOR REVIEW OF LABOR STANDARD

(Final Disposition Should be Made in 5 Working Days after receipt by Ind. Eng. Dept.)

Part No. and Name..

Oper. No. and Description..

Machine Name..............................Mach. No..............................Standard..............................

After having worked on this job and followed standard instructions, and having given the above operation a good trial of..............hours..............days (Minimum of 16 hours), I believe that this standard should be reviewed because:..

....

....

....

Employee..Check No..............................

I have instructed the above employee in the standard method of performing this operation and have observed that he is following this method. I have done my best to correct the troubles as stated. I believe operator is failing to make his Labor Standard because (See back of this sheet for suggested list of items to be checked):

....

....

Job Foreman..Date..............................

I have rechecked the above and agree with it:

....General Foreman

....Dept. Head

Review and Comment:

....

....

....

....

Ch. Ind. Eng..Date..............................

Comment..

....

....

Union Representative..Date..............................

The check list given below will serve as a guide to determine the possible variances or sources of trouble. Indicate by "Yes" or "No" that you have reviewed each. Make any other comment you wish.

.... 1. Does the worker have the proper labor standard sheet?
.... 2. Is he following the method and sequence of elemental steps exactly?
.... 3. Is he doing any extra work operations?
.... 4. Is he working on the right machine?
.... 5. Are speeds and feeds proper?
.... 6. Is the set-up right and are correct tools being used?
.... 7. Are the machines and tools working properly?
.... 8. Is the material the standard one?
.... 9. Are the delivery, inspection, tool room, or other services holding him up?
...............10. In your opinion, does the labor standard specify the best method?

Another important consideration is the ability and effort of the worker:

.... 1. Is he normal as to physique and health?
.... 2. Has he been adequately trained for the job?
.... 3. Does he have an awkwardness that can be corrected by further training?
.... 4. Is he exerting full incentive effort?

2. The time study engineer contacts the foreman and together they recheck these items, paying particular attention to evidence of the operator's attitude. An accurate time study cannot be taken unless the operator's attitude is acceptable. The study should be delayed and help given to the operator until he can adjust himself more favorably.
3. The Labor Standard, when completed, is delivered to the foreman and explained fully and completely to him and to the operator.
4. The labor standards must be maintained and kept current and can be only if supervision informs industrial engineering promptly of any method changes.
5. The grievance procedure on labor standards must provide for easy communication between employees and the industrial engineering department.

Maybe you think it is silly to invite complaints. Maybe the old statement that "consistency is better than accuracy" used to sound silly too! Our incentive system complaint procedure is often used by operators to complain about matters entirely unrelated to labor standards. Perhaps it provides operators with an emotional outlet and acts like a "safety valve" on their entire feelings toward the Company. As stated previously, we received a total of 37 labor standard grievances during 1951, with only six grievances open at any one time from the entire factory.

With the completion of this introduction by Dr. Barnes and myself, one of our industrial engineers then proceeded with the technical detail. This leads us to the fifth important key.

Prepare a foreman's time study manual which will cover the essentials of your training course. Make it simple and easy to understand, with plenty of illustrations and simple cartoons. Get a commercial artist, if necessary, to help you illustrate your ideas. I can tell you what was covered in our training conferences by making reference to our manual.

TECHNICAL DETAIL

First, is its purpose in the Preface on Page 1:

"This manual has been prepared for you, a supervisor, to explain in detail the procedure followed for determining and maintaining labor standards. Because you have already had training in Work Simplification, this manual places special emphasis on how we make time studies, apply standard and special allowances, and prepare the 'Labor Standard Sheet'."

Second, it states what the supervisor can get from time study training:

"You will discover that thorough acquaintance with this procedure will help you in taking an active part in the wage incentive program with self assurance and confidence."

Finally, it infers that some supervision already approve of its contents:

"Special appreciation is due those shop superintendents and foremen who assisted in the preparation of this manual."

PURPOSE OF WAGE INCENTIVES

1. INCREASE PRODUCTION PER MAN HOUR
2. INCREASE EARNINGS FOR WORKER
3. STIMULATE INTEREST IN JOB
4. MEASURED PAY FOR MEASURED WORK
5. PROVIDE BASIS FOR DETERMINING LABOR COSTS
6. ASSIST SUPERVISION
7. REDUCE COSTS

I. PURPOSE OF WAGE INCENTIVES

1. Stimulate interest in job.
2. Increase earnings for worker.
3. Increase production per man hour.
4. Reduce costs.
5. Assist supervision. Schedule production, keep worker busy, and safe.
6. Measured pay for measured work.
7. Provide basis for determining labor and burden costs.

OUR OBJECTIVE FAIR DAY'S WORK FOR FAIR DAY'S PAY

II. OUR OBJECTIVE

A fair day's work for a fair day's pay.

Nearly everyone prefers to do more than a fair day's work when the reward is adequate.

WAGE INCENTIVE EXTRA PAY FOR EXTRA EFFORT

III. WAGE INCENTIVE

Extra pay for extra effort.

These last two became slogans. I suggest you popularize this last slogan particularly. You will quote it many times in the future when requests arise to use incentives improperly.

IV. ESSENTIALS OF GOOD INCENTIVE PLAN

1. Must be fair to employee and employer.
2. Must reward employee in proportion to increased output over standard.
3. Must be easy for employee to understand and compute his earnings.
4. Must promote quality production.
5. Must be based on accurately established standards.
6. Standards must be guaranteed against "rate cutting."

ACCURATE LABOR STANDARDS DEPEND ON:

1. DEVELOPMENT OF BEST PRACTICAL METHODS
2. TRAINING WORKERS TO DO THE JOB USING BEST METHODS
3. ACCURATE MEASURING OF WORK BY STOPWATCH CONSIDERING EFFORT, APPLYING ALLOWANCES
4. FOLLOWING UP ESTABLISHED LABOR STANDARDS TO ASSURE PROPER APPLICATION

V. ACCURATE LABOR STANDARDS

The sixth important "key" is:

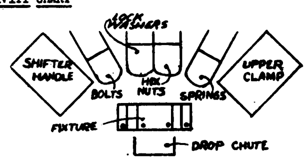
Remember to use role playing, particularly to illustrate any subject which may be either a ticklish or argumentative one. In our conferences, we put on a little skit illustrating the difficulties arising due to poor labor standards with several of our engineers simulating two employees working along side of each other but each doing a different job. One man had a proper labor standard and was kept quite busy on his task. The other evidently had a very loose labor standard or one which was entirely out of date, and as a result, had time to eat a banana, read a magazine, go to the wash room frequently, take time out to watch the beautiful office girl go by, and pester the first man with questions and conversation all day long so that the first man could hardly get his work done. Unfortunately, it was pay day and when the operator with the easy job showed his pay check for $85.00 to the operator who worked so much harder and whose pay check read only $70.00, the results were loud and obvious!

Perhaps another "key" to creating sparkle and interest, and at the same time to teach the value of a learning period--during which the operator develops skill and speed--is to set up an actual operation in the classroom, having one conferee perform this operation at every session. Ours consisted of a simple fixture for fabricating two assemblies simultaneously. Using both hands, the conferee picks up two bolts in each hand and positions in fixture. The left hand picks up shifter handle while the right hand picks up upper clamp, carries to shifter handle, both hands line up holes and position handle and clamp over bolts in fixture. Repeat for second assembly. Each hand then picks up two lock washers and positions one on each of two bolts. Repeat for two hex nuts. Each hand picks up tension spring and positions on hook on clamp. Right hand picks up stretching tool and pulls end of spring, hooking it into hole on the assembly. Repeat for second assembly. This last element requires some dexterity. Finally, right hand asides tool, and each hand picks up an assembly and drops it down chute.

The conferees were asked to select one of their number who was to perform this operation during the last 10 minutes of each of the conference sessions. They were warned that the same thing was being done in the other conferences, and that the time for doing the operation by the representative of each conference group would be compared at the end of the series of conferences. This spurred each group into selecting their most active member who, in turn, tried his best to perform the operation in the least amount of time. Each conferee was given a stopwatch and timed the operator as he performed the assembly. After several trial assemblies, it became obvious to the group that improved method changes should be put into effect immediately if they were to beat the cycle time obtained by other groups.

Slide 12 MULTIPLE ACTIVITY CHART

Part No. A4910 Part Name Shifter Handle
Oper No. 10 Oper. Descr. Assemble Complete
Mach. Type Bench
Dept. No. 9 Oper. Rev. Date 11-13-48
Investigated by: C.S. Dept. 6
11/18/48 Date

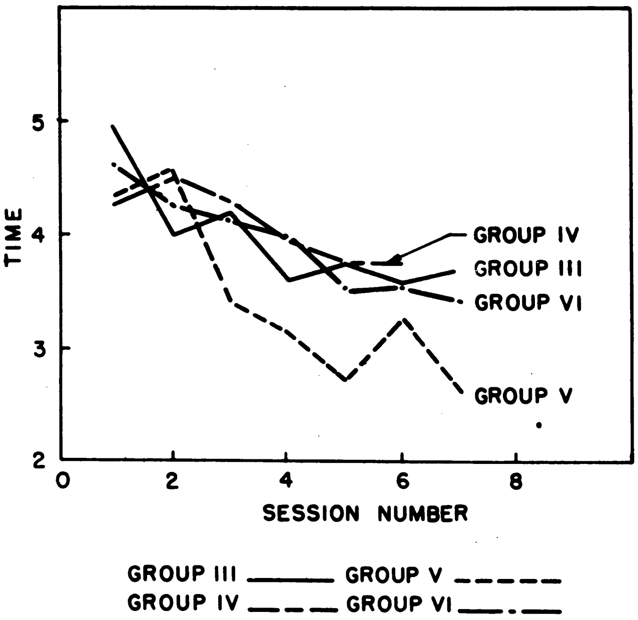


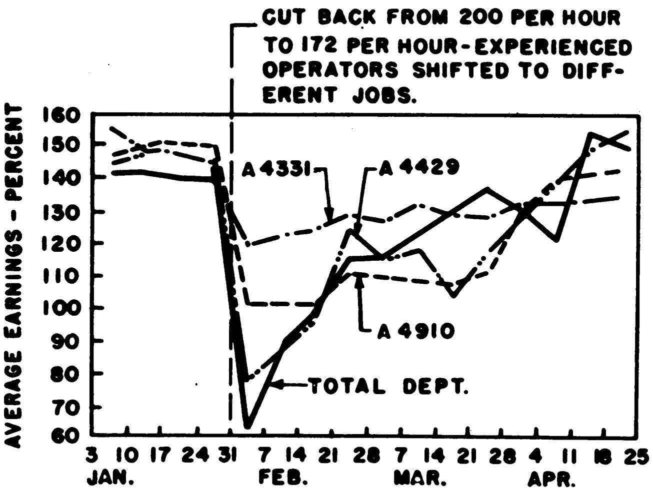
Activity of Left Hand		Activity of Right Hand.	
Reach to Parts Bin Pick up 2 bolts Carry bolts to fixture Position bolts in fixture	.0838	Same as Left Hand	.0838
Reach to Parts Bin, Pick up Shifter Handle (A4478) Carry to Fixture, Line up holes with those in upper clamp Position Handle ½ clamp in fixture over bolts,	.1260	Reach to parts bin, Pick up upper clamp (15080), Carry to Shifter Handle in L.H., Line up holes with those in Shifter Handle, Position Handle & clamp in Fixture over bolts.	.1260
Repeat Previous element	.1260	Repeat previous element	.1260
Reach to parts bin, (54863-X) Pick up 2 split lock washers, Carry to Fixture, Position one on each bolt	.0765	Same as left hand	.0765
Reach to parts bin, Pick up 2 hex nuts, (52728-X) Carry to Fixture, Position one on each bolt, Start by hand approx. 2 turns.	.1345	Same as left hand	.1345
Reach to parts bins, Pick up Tension Spring, (14995), Carry to Fixture, Position closed loop over hook on upper clamp	.0643	Same as left hand	.0643
Reach to Assembly # 1, Hold, Reach to Assembly # 2, Hold	.0694	Reach to stretching tool & pick up Position tool in open loop of spring Insert loop in hole of eccentric(14997). Position tool in spring loop on As'y #2, Insert loop in hole of eccentric	.0694
Grasp Assembly, Carry to drop chute & release	.0334	Aside stretching tool Same as left hand	.0334

Irregular Elements

Stock up shifter handles	45 pcs. - .25
" " Upper clamps	75 pcs. - .22
" " Lock Washers	500 pcs. - .18
" " Hex Nuts	350 pcs. - .18
" " Bolts	350 pcs. - .20
" " Springs	350 pcs. - .30
Remove and replace finished parts box	75 pcs. - .40

Incidentally, when these sessions were held each week, the times obtained by each group were somehow or another mysteriously related to the other groups so they knew what record they had to beat! It was remarkable how the time for doing the operation decreased from week to week as the operator picked up skill on the job! Note that after performing only 70 cycles, the time per assem-





Average Weekly Earnings Dept. 9
The Maytag Co., January 3, 1949 to April 25, 1949

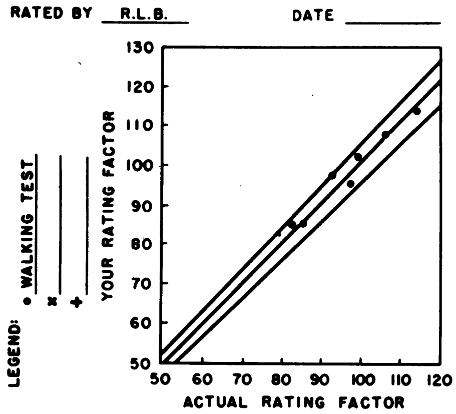
bly decreased from .45 minute to .36 minute, or approximately 20 per cent. At this point, a slide was shown giving some actual earning performances for several employees when they were transferred to operations of a similar character to their usual work.

To summarize, this classroom demonstration convinced supervision that:

1. The job must be prepared before requesting a time study.
2. The work place layout must be correct to establish the best method.
3. The equipment and tools must be in good operating condition.
4. The materials being supplied for the job must be right.
5. The operator must be qualified and trained.
6. There is a difference in pace among operators.

EFFORT RATING:

Your time study training for supervision should include effort rating training so that supervision can understand how to judge the pace at which an operator works. We conducted actual walking tests with the conferees, selecting one of their members to do the walking, another to time the tests by stopwatch, and the rest to record their effort rating. At the conclusion of the tests, each man was given the true effort rating as calculated from stopwatch readings and plotted his own ratings on a curve to see whether he fell with the goal of plus or minus 7 per cent of the true value.



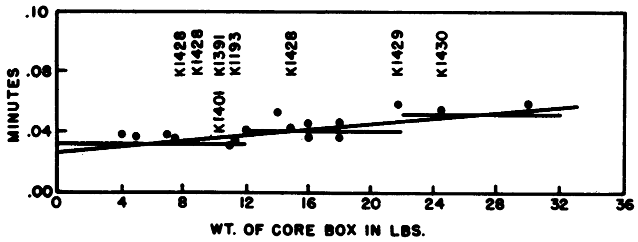
BY	TRIAL NO.	1	2	3	4	5	6	7	8	9	10
	YOUR RATING	95	100	105	85	102	113	97	85	107	102
O	ACT. RATING	98	100	101	81	100	115	93	83	107	100
	% VARIATION	-3	0	+4	+4	+2	-2	+4	+2	0	+2

Rating Graph

In addition to this test, the conferees' effort rated film RB 540 and compared their effort ratings with the national average, and with the results of our own industrial engineering department so that they would know our degree of accuracy. We then showed them the results of our engineers' rating on approximately one dozen different type operations throughout our factory, so that they would know that we were consistent in our effort rating and had set good labor standards. Some of these operations, such as polishing castings, were very difficult to effort rate, and I believe the foremen were impressed with the fact that they would need a great deal of training before becoming reasonably qualified to rate correctly.

To teach the details of taking a time study and calculating a labor standard, the conferees were given a time study sheet and a stopwatch, and asked to break down the shifter handle assembly operation performed during the last 10 minutes of their class into elements, to time by the continuous method of watch reading, and to effort rate each element as the conferee performed the operation.

DEPT. #71 CORE ROOM STANDARD DATA 11-22-48
ELEMENT...
PICK UP CORE BOX FROM BENCH AND PLACE IN BLOW MACHINE



They then calculated the true cycle time and compared it to the actual times averaged by the different class representatives in the sessions to date. These times were so different that they recognized immediately the value of effort rating, and what could happen due to small method changes. At this point we showed them how to check time study values against standard data.

The Maytag Company
Ind. Eng. Dept.
Nov. 1948

Slide 26
Labor Standard Data
Issue #2

CORE MAKING - BLOW MACHINE

Demmler 26-81; 27-82; 27-83; 29-84

		Core Box Weight		
		0-12 lbs.	12-22 lbs.	22-32 lbs.
1.	Pick up core box from bench and place in blow chamber of machine.	.0300 min.	.0400 min.	.0500 min.
2.	Trip control pedal with foot and blow cores.	.0330	.0400	.0470
3.	Pull box of cores from machine and place on bench.	.0310	.0370	.0420
4.	Lift top half of box off of cores and place aside on bench.	.0250	.0300	.0340
5.	Pick up and place half box of cores on plate and draw box.	.0540*	.0750*	
	*Check each job as time varies according to physical characteristics of core.			
6.	Assemble half core box in hand with half box on bench.	.0220	.0270	.0350
7.	Pick up drier from bench and place on half box with cores.	.0330	.0400	.0440
8.	Roll half box with cores, and drier, over to place cores in drier.	.0230	.0260	.0320
9.	Lift half box off of cores in drier and assemble with half box on bench.	.0260	.0310	.0350
10.	Pick up drier with cores and place on core plate.	.0300	.0370	.0430

Slide 34

LABOR STANDARD SHEET
Job Instructions
Page 1 of 2

Alward/jl

Sequence of Elements — LEFT HAND	Special Instructions — RIGHT HAND
Reach to parts bin, pick up shifter handle (A-4478), carry to fixture, line up holes with those in upper clamp, position handle and clamp in fixture over bolts.	Reach to parts bin, pick up upper c (15080), carry to shifter handle in hand, line up holes with those in s ter handle, position handle and cla in fixture over bolts.
Repeat previous element.	Repeat previous element.
Reach to parts bin, pick up 2 split lock washers, (54863-X), carry to fixture, position one in each bolt.	Same as left hand.
Reach to parts bin, pick up 2 hex nuts, (52728-X) carry to fixture, position one on each bolt, start by hand approx. 2 turns.	Same as left hand.
Reach to parts bins, pick up tension springs, (14995) carry to fixture, position closed loop over hook on upper clamp.	Same as left hand.
Reach to assembly #1, hold, reach to assembly #2, hold.	Reach to stretching tool and pick u position tool in open loop of sprin on assembly #1, insert loop in hole of eccentric (14997), position tool in spring loop on assembly #2, insert loop in hold of eccentric. Aside stretching tool.

Oper.
Sketch Rev.
Date 11-18-48 Part Name Shifter Handle Part No. A-4910
Description
of Operation Assemble Complete Oper. No. 10
Dept. 9 Machine Type & Maytag No. Bench

Slide 34A

LABOR STANDARD SHEET
Job Instructions
Page 2 of 2

Alward/jl

Sequence of Elements	Special Instructions
Grasp assembly, carry to drop chute and release.	Same as left hand.

Irregular Elements

Stock up shifter handles - 45 pcs/bin Stock up upper clamp - 75 pcs/bin Stock up washers - 500 pcs/2 bins	Stock up washers, nuts, bolts, and springs from stock bins on floor into bins on work bench by carrying tote pan and dumping into bins 5' to right of operator's position.
Stock up nuts - 350 pcs/2 bins Stock up bolts - 350 pcs/bins Stock up springs - 350/bin	Stock up shifter handles and clamps from stock pile 25' from work bench by carrying tote pan and dumping into bins.
Dispose of tote pan of finished parts 5' adjacent to work bench and replace with empty tote pan, 75/pan	

Labor Standard Includes:
1. Visual inspection as required for quality.
2. Clean up of machine and work place at end of shift.
3. Delay due to defective material.

Approved By	Initial	Title	Date	Initial	Title	Date	Initial	Title	Date
		Ch. Ind. Eng.			Supt.			Fact. Mgr.	

Reason for Change
Supersedes Rate Dated ___ Effective Date ___
Oper. Sketch Rev.
Date 11-18-48 Part Name Shifter Handle Part No. A-4910
Description of Operation Assemble Complete Formerly Oper. No. ___ Now Oper. No. 10
Dept. 9 Unit ___ Line ___ Machine Type & Maytag No. Bench

OUTPUT PER HOUR
At Standard 134 At 110% 147 At Norm. Max. 158 LABOR STANDARD .75 Hr Per C

LABOR STANDARD ALLOWANCES

1. Personal - - - - - - - - - - - - - - - - 3%
   a. Taking a drink
   b. Going to lavatory.
   c. Other personal time.

2. Fatigue - - - - - - - - - - - - - 5% to 12%
   Compensates for slowing down on job because of tiredness.

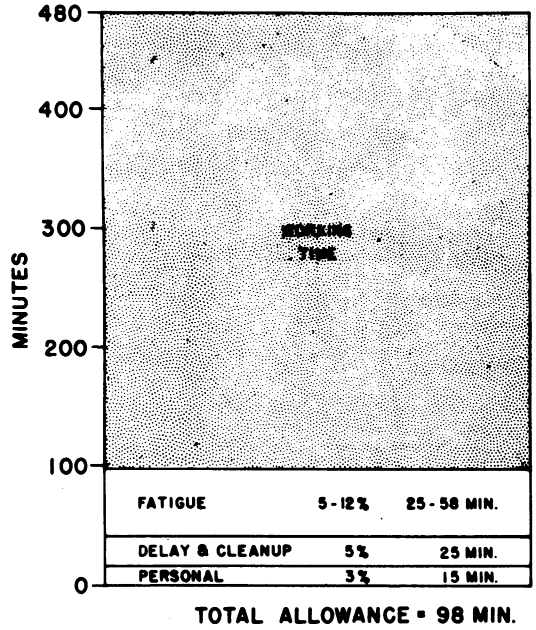
3. Delay - - - - - - - - - - - - - - - - - - 5%
   Includes minor delays of less than 15 minutes.
   a. Mechanical trouble.
   b. Instructions.
   c. Daily Clean Up.

4. Tool Attention - - - - Standard Time Values
   Depends on: a. Actual attention time.
   b. Production during interval between attention times.

5. Inspection - - - - - - Standard Time Values
   Depends on: a. Actual time to use gauges.
   b. Frequency of inspection.

To calculate the labor standard, they were then shown how to determine and add personal, fatigue, and delay allowances to the cycle time, and finally the incentive increment, so that the labor standard could be set to grant "extra pay for extra effort."

Maintenance of labor standards was stressed highly in our training. Poor maintenance was emphasized as the prime reason for failure of incentive systems. If we lose our workers' confidence, we may never get another chance to install incentives. To keep our system current, we make it easy for supervision to report method changes to the industrial engineering department. Two simple forms are provided to the foremen.



Comparison of Allowance Time to
Total Time In a Day

On the first entitled "Labor Standard Method Check" he lists all operations which are running and indicates by a check mark whether the method is exactly as described on the labor standard sheet. If there is an exception, he submits the second form entitled "Notice of Operational Change" on which he merely has to make a check mark

Slide 37

To: Industrial Engineering Department

LABOR STANDARD METHOD CHECK

Supervisor: ____________ Dept. No. ________

Date: ____________ Shop No. ________

1) Every repair or intermittent operation should be checked within the first hour of operation. Regular production operations should be checked periodically, as established by Department Head.

2) The following operations marked (✓) have been checked by me and found to be running exactly as described in the Labor Standard Sheet.

3) The following operations marked (x) have been changed in some manner and are further explained on form 581-S (Notice of Operational Change) attached hereto.

4) Regardless of whether the change has been in effect for some time or is being put into effect now, submit the change through the Work Simplification Unit for credit.

Part No.	Oper. No.		Part No.	Oper. No.		Part No.	Oper. No.		Part No.	Oper. No.		Part No.	Oper. No.

Department Head ____________

Date ____________

indicating the type of change. These fix the responsibility on the foreman because he can have no complaint later when method changes are discovered which have been in existence for some time. It was agreed by all at our conferences that unless the labor standards were kept current and maintained, far more serious trouble was encountered than if the Company refrained from installing incentives in the first place.

"LIGHTS ON"

The final topic covered was the "Rules for Application of Incentive Rates of Pay" which are instructions for special actions found necessary over and above the ordinary routine practice of administering the incentive plan as outlined in the formal labor contract. The more important items discussed were provisions affecting off-standard work, allowances, delays, effect of learners in group labor standards, payment of "specialist" rate for experimental work, etc., and the foreman's responsibility and authority in connection with these. I would advise you to be prepared to state the reasons for each of these rules--and the conditions which lead to their establishment. After all, these rules were based on experience--which your conferees may not have, and they may think them arbitrary. For example, you may have learned a formula from bitter experience on how to introduce learners into an existing group without causing earnings to fluctuate wildly. If you can show the circumstances on which the formula is based, it will be accepted more

The Maytag Company

To: Industrial Engineering Dept. Date ____________

cc: Originating Dept. Part No. ________ Oper.No. ________

Engineering Dept. Operation Description ____________

Machine Type & Maytag No. ____________

NOTICE OF OPERATIONAL CHANGE

Applies to any production operation that is changed in any manner from existing conditions. Must be issued whenever a job is run differently from that specified on the Operation Analysis Sheet or Labor Standard Sheet.

(Note X in space provided)

1. AUTHORIZED CHANGE BEING INSTALLED PER:

________ (a) Change in Specification, number and date
________ (b) Request for change in Analysis Sheet dated
________ (c)

2. EXPERIMENTING WITH THE FOLLOWING CHANGES TO IMPROVE:
PRODUCTION ________ QUALITY ________

________ (a) Tooling (jigs, cutting angles, carbide tools, etc.)
________ (b) Equipment (speeds, feeds, etc.)
________ (c) Sequence of operations
________ (d) New operation added
________ (e) Work-place layout or handling methods
________ (f)

3. JOB CONDITIONS ARE CHANGED DUE TO:

________ (a) Off-standard material
________ (b) Faulty tools or equipment
________ (1) Temporary tools being substituted
________ (2) Job being run on a different machine
________ (3)
________ (c) New tools, jigs, or equipment
________ (d) Improvements to existing tools, jigs, or equipment
________ (e) Gaging requirements changed
________ (f) Sequence of operations changed
________ (g) New operation added
________ (h)

4. LABOR STANDARD REQUIRED: Original ________ Revised ________

Requested by ____________

Authorized by ________ General Foreman

Form #581-S Approved by ________ Dept. Head readily. We stress that one of the prime reasons for having time study training is to pass on to the conferees the wisdom and experience of those who have already failed or succeeded.

GENERAL DISCUSSION

1. Did supervision want the training? The answer must be "yes" because:
   a. Attendance at the conferences was excellent. Griping, usually present when the foremen are asked to take time out for meetings, was not evident, and the foremen asked many questions during the conferences.
   b. Supervisors have told us many times since how much better they now understand time study, and they requested that the conferences be repeated later for newly made foremen.
   c. Supervisors inform us that operators now come to them for explanations of time study and labor standards, as well as to the Union.
2. Did the Union desire the training? Again the answer must be "yes."

When we introduced time study training for supervision in our new plant, the stewards, who were mostly young men, definitely requested time study training. After several sessions had been held, the stewards in the old plant asked us for the training also, stating that they didn't know that it was available to them. At another one of our plants, the stewards asked that they be able to attend with the foremen so that they could exchange viewpoints.

3. What good does it do the industrial engineering department to give time study training to supervision and Union?
   a. Results from supervisory training:
      1. Jobs are better prepared now when we go down to take a time study, even including selection and training of the operator.
      2. Supervisors seem more reasonable in their discussion of "tight" labor standards. More and more they are taking over the job of selling labor standards to operators. Before, they seemed embarrassed when an operator asked questions about the time study, now they show pride in being able to explain the details to the operator.
      3. Before, the foreman abhorred granting allowances to an operator for unusual conditions even when ordered to do so by the factory manager, and would take the operator off-standard. Now that they understand how allowances should be administered, they are granting them more frequently and are getting the benefit of incentive performance rather than a day work pace.
      4. The foremen seem more aware of the effect on a labor standard of "minor" method changes and are reporting more of these promptly.
   b. Results from Union training:
      1. Stewards are more reasonable to deal with when special circumstances arise. They are also more willing to accept special learning allowance arrangements when difficult jobs are to be tried by a group of operators.
      2. Stewards are actually helping us to sell labor standards by explaining to operators on the floor how a proposed labor standard will work. In many cases of doubt they have personally assured operators that the labor standard has been well prepared and will work.
      3. Our new Union President, elected several months ago, who was a steward when he attended the time study conferences, has asked that we give training to his stewards now.
      4. Union stewards ask us "Why can't operators be given this training also?" When we suggest to them that they explain it to the operators, they say "We can't do it as well as you fellows can."
4. To answer the question of "What are the reactions of each group and which shows the greater interest?" I would say that the training was favorably accepted by both groups. The Union group, who in general were younger men, showed the greater interest and seemed more anxious to learn. There are obvious reasons why this should be so.

SUGGESTIONS

1. Remember that some of your foremen may have very little education. We even found that some of ours had terminated their education at the sixth grade. Your conferences should therefore give them some tools that they can actually work with. Do not make your material too complicated.
2. Be sure that each session is attended by a factory manager or a superintendent. His attendance will not only lend importance to the event, but will show the foremen that he is keenly interested and wants them to know how to use the incentive plan.
3. Discuss with the foremen the operating procedures of the time study engineer and show them how they can use the incentive plan, rather than give too much technical information on time study.
4. Use plenty of visual aids illustrating your points.
5. Don't forget the value of putting on a skit (role playing). Of course, alter this skit in accordance with the people who are attending the conference.

I hope that you may find something of value in my presentation today. I have presumed to give it on the premise that by exchanging ideas we may all become better prepared to meet this problem of putting the supervisor and employee at ease concerning the practices of the time study engineer. A word from you as to your approach to the problem would be very valuable to us in further developing our program.

INDUSTRIAL ENGINEERING IN A MANUFACTURING PLANT - A CASE STUDY

Charles A. Bogenrief, Department Head
Industrial Engineering Department
Grayson Controls Division
Robertshaw-Fulton Controls Company
Lynwood, California

This discussion of the subject of industrial engineering in a manufacturing plant shall be confined to the activities of the Industrial Engineering Department at Grayson Controls. First, I believe the background information as to our Company's history, its size and products manufactured is necessary for you to properly relate the facts that I am going to present. Grayson Controls is the third largest division of the Robertshaw-Fulton Controls Company. Other divisions are located at Youngwood, Pennsylvania; Knoxville, Tennessee; St. Louis, Missouri; Bridgeport, Connecticut, and now, also, at Anaheim, California. These plants are engaged in the manufacture of hundreds of items in the thermostat field. Their combined plant areas total one million square feet with more than 5500 employees on the payroll.

The growth of our division of the Company from its inconspicuous beginning in 1928 to the present day, parallels many similar cases in a country where free enterprise is practiced. Twenty-three years ago, Mr. Grayson began his manufacturing business in a one car garage and employed two people. Today, our plant covers 135,000 square feet of floor space and employs approximately 800 workers. At our plant we have production departments including a foundry, plating shop, automatic screw machine department, machine shop and assembly department. Approximately 50 per cent of the personnel are women. We are essentially a metal working industry engaged in manufacturing our products on a mass production basis. During the past year and a half we have produced gas water heater thermostats and space heater thermostats at the rate of from four to five thousand per day. On some units, such as our magnetic devices, our production has reached peaks of 120 thousand units per month. This gives you an idea of the repetitiveness of some of the operations. It also serves to show that many of our machines for producing these thermostats are permanently set up. Much of our tooling program is designed around special production machines, such as Kingsbury drilling equipment, Ex-Cello boring machines, and similar equipment, much of which is designed and built at our own plant. Grayson has not always had an industrial engineering department. The need for one became apparent soon after the beginning of World War II. At that time, the domestic production dwindled to practically nothing and in its place came the job shop types of operation with which we were not entirely familiar. The old piece rates that had been established on the domestic production ceased to exist. Concurrently, the rate of production became increasingly less each week, since it was not possible at that time to place incentive rates on the job shop work. When the Company's first large order was received for ordnance production, the need for an industrial engineering department to make the lay-outs and correlate the tooling methods and other similar functions, was recognized by the management. The original department consisted of three engineers and their first task was the project of laying out the machinery and equipment on that original order. During the years from 1941 through 1945 additional duties and responsibilities were assigned to the industrial engineering department. The personnel was increased and a time standard measurement program was undertaken.

So much, then, for background or history. Now, let us look at the picture as it is today. On the organizational chart the industrial engineering department reports to the Assistant Vice President, who is the works manager. We serve as an advisory department on a staff basis to the line organization. We have no direct authority in the shop and we want none. We feel that a better job can be attained by advising and suggesting to others rather than by actually demanding or ordering. I think this relationship is extremely important and I cannot stress it too strongly. It may seem at times that this relationship would hinder the operations of the industrial engineering staff. On the contrary, we have not found this to be so. In looking back at the projects undertaken and completed, it seems that this has been one of our chief assets. For example, in the case where we must work with the line organization: If the lay-out of a line appears to be out-dated or outmoded and a new lay-out is deemed necessary, the industrial engineering staff rearranges the machines and equipment on paper. The supervisors of the shop department are then called in, particularly the supervising foreman of the group where the change is to be made and the lay-out proposals are discussed. Ideas proposed and developed by the plant supervisors are given full consideration. Wherever possible, we try to incorporate these ideas in the proposed changes. When an understanding has been reached on all matters, the industrial engineering department then processes the lay-out change. By bringing the line supervisors in on a rearrangement of operations such as this, the foremen feel that they are an active participant in the over-all planning. The supervisor can honestly tell his fellow workers that his ideas were considered and applied in the actual lay-out. Another example of this, and I will elaborate more on this point later on, is when the need for a change in a time standard becomes apparent. The engineer assigned to the project of investigating the method and changing this standard contacts the foreman of the line where the operation is performed and explains the need and the reason for a particular change. This takes place before any contact is made with the operator. After the method has been established and the job is ready for the time study, the foreman is called to the job to check the method as outlined on the time study form and, if satisfied, signs the time study. This signature okays the method, but not the time--the latter is our responsibility.

At the present time, our industrial engineering department is comprised of a department head, six industrial engineers, two tool engineers and two clerks. We have under our direction another sub-department called the Scheduling Section, composed of a staff assistant and an expediter. The scope of our operations concerns itself primarily with the direct production department.

However, we do assignments in the indirect departments such as production control, tool control, cost accounting, shipping, receiving, timekeeping, personnel, etc. Usually the work in an indirect department consists of systems, procedures and lay-out.

The industrial engineering department carries on a wide range of activities. Some of these activities could be considered as normal functions of departments such as accounting, industrial relations, production control, etc. By the same token, we do not have jurisdiction over the quality control department and production control department. It is not my intention to infer that just because we do it this way at Grayson, it is the ideal way. I am merely relating and sharing my experiences with you.

Up to now, generalities and not specific spheres of operation have been covered. At this point, I would like to mention what we consider the primary duties and functions of the industrial engineering department. These will not necessarily be listed in the order of their importance to us. I shall purposely avoid stating the importance of any one function as related to another because I realize that each of us has his own particular ranking method based upon how a plant is organized and how the department operates within this organization. These activities are as follows:

1. Time study and time standards. This program encompasses all time standards developed for the incentive and non-incentive work or measurements for any type of control, either direct or indirect. The industrial engineering department maintains complete control of this phase. Other departments are not authorized to change or issue any work standards. Basic data and M. T. M. form the nucleus around which time standards are based.
2. Job Methods. This covers the individual operation methods, in addition to overall line operation planning, preparation of process flow charts, operation analyses, operation flow charts and other analytical studies.
3. Plant Lay-out. This phase of operation consists of originating and maintaining complete lay-out drawings for all departments within the plant. Changes of existing lay-outs, additions to existing lay-outs or proposals relative to lay-out through the installation of new lines fall under this project. Sketches and template lay-outs are submitted to the departments concerned before any attempt is made to actually inaugurate a lay-out.
4. Methods Improvement Program. This, of course, ties in closely with job methods. Principally, it deals with improving existing methods. In an incentive shop, this is a necessary and vital function in maintaining a satisfactory incentive plan.
5. Wage Incentives. The wage incentive program covers both the direct production workers and their supervisors. This supervisory group consists of the supervision staff of the direct departments that have incentive programs. Our incentive earnings are computed on a daily basis for production workers. The supervision incentive is calculated weekly. The direct incentive is a 100 per cent plan with no limit on individual earnings, so long as methods, tool, feeds, speeds, etc., do not change.
6. Job Evaluation. We use a point evaluation plan similar to the National Metal Trades Association plan for metal working industries. The plan covers jobs performed by the bargaining unit employees. Job descriptions are written and evaluated to establish job base rates. To arrive at job relationships for the office and technical groups we use, as a supervisory tool only, the CMA Job Evaluation Plan. Jobs are described and evaluated. Jobs are assigned a salary bracket based upon this evaluation.
7. Merit Rating. Only the office and technical groups are covered by this procedure. The program encompasses the rating of each individual by his immediate supervisor each six months. Such factors as productivity, quality of work, attendance, length of service, job knowledge, are taken into consideration. As a result of the ratings, individual's salaries may move upward or downward within the established salary bracket.
8. Labor Cost Control. For a number of years we have used operating controls to analyze cost trends in the production departments. I want to state at this point that these control figures differ from the normal accounting cost controls. Primarily we consider the accounting method as financial controls. Operating cost controls deal primarily with the controllable costs of each foreman's section in the direct labor departments. No overhead items such as light, heat, engineering time, G and A, are expressed or implied in the calculations of these very important figures.
9. Salary Administration. This function ties in closely with the job evaluation and the merit rating programs. We keep the records and issue the necessary notices on all changes in salary based on changes in job content or as a result of merit ratings.
10. Engineering Scheduling. This sub-department's primary function is to keep records on the status of all paper work necessary to completely engineer a job from the design stage through the pilot run. This can be on a new product, a revision or redesign on existing products. For example, on a new job, follow up records are kept as to the status of the blueprints, the requisitions for tools, gauges, fixtures and machines. These records permit a follow through with departments, such as purchasing, tool control, tool and die, production control, receiving and shipping on all aspects of the project.
11. Job Estimating and Job Planning. All new jobs are estimated by the industrial engineering department. A standard time for each operation is determined before the job is sent to the cost department for pricing.
12. System and Procedure. Scheduling procedures for tool and die and tool control, covering phases of tool manufacturing through machine maintenance are developed and followed up by industrial engineering.

In addition to the foregoing functions, there are secondary duties and responsibilities. These include issuing of special reports, analyses and other records. The industrial engineering department over the past ten years has served as a training ground for new and/or prospective supervisors, particularly for supervisors of the factory operations. We conduct training classes in plant lay-out, methods improvement, time study, job evaluation, and merit rating. We have participation from all levels of the organization, from the bargaining unit employees, union stewards, office employees and many of the engineering staff. Another general function, which we feel is our job, is to coordinate all phases of industrial engineering with the work of other departments. I sit in on all labor grievances involving time standards and job evaluation.

Up to this point I have discussed general aspects of

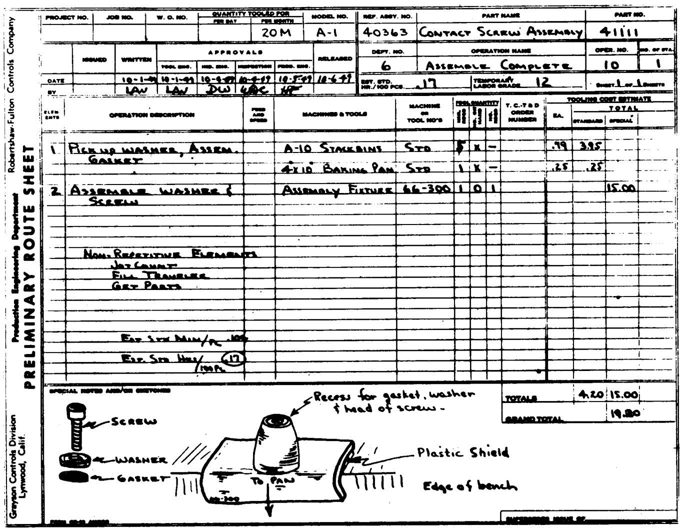
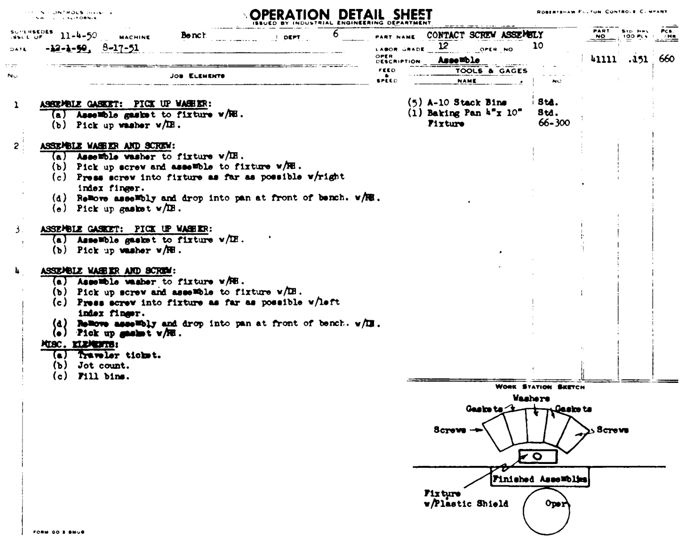


Figure 1


OPERATION DETAIL SHEET

1 ASSEMBLE GASKET: PICK UP WASHER:
(a) Assemble gasket to fixture w/RH.
(b) Pick up washer w/LH.

2 ASSEMBLE WASHER AND SCREW:
(a) Assemble washer to fixture w/LH.
(b) Pick up screw and assemble to fixture w/RH.
(c) Press screw into fixture as far as possible w/right index finger.
(d) Remove assembly and drop into pan at front of bench. w/RH.
(e) Pick up gasket w/LH.

3 ASSEMBLE GASKET: PICK UP WASHER:
(a) Assemble gasket to fixture w/LH.
(b) Pick up washer w/RH.

4 ASSEMBLE WASHER AND SCREW:
(a) Assemble washer to fixture w/RH.
(b) Pick up screw and assemble to fixture w/LH.
(c) Press screw into fixture as far as possible w/left index finger.
(d) Remove assembly and drop into pan at front of bench. w/LH.
(e) Pick up gasket w/RH.

MISC. ELEMENTS:
(a) Traveler ticket.
(b) Jot count.
(c) Fill bins.

(5) A-10 Stack Bins — Std.
(1) Baking Pan 4"x 10" — Std.
Fixture — 66-300

Figure 2

the company's organization, its product and the relationship of industrial engineering to the company as a whole. Now, I should like to examine in detail some of the activities in which we are engaged. Again, the order in which I will present each of these will not necessarily be the order of their importance, either at Grayson's or in your own company.

Many industrial engineering departments are not called in on the preliminary investigations that precede the manufacture of a product. In many cases, the scope of their operations relate only to the time study or "rate settling" function. Our industrial engineering department works closely with the tool and design engineering in establishing the sequence of operations. The tools and methods to be used for all production operations. The manufacturing times are estimated at this stage. Also, industrial engineering assigns the rate of pay or job base rate for each job in accordance with job evaluation. A preliminary route or planning sheet, such as shown in figure #1 is used to estimate the operations. The details of the tools, methods, feeds and speeds, estimated time and inspection approval are all indicated. This sheet is used to plan the job through all preliminary phases including pilot run production. When an operation or job has been established, a final draft is made as shown in figure #2. It is called an operation detail sheet. Many of you may refer to it as a job methods sheet. All pertinent information concerning an operation or job is shown on this record. The industrial engineering department maintains the master files on these copies and revises them, according to any changes that are made. In this manner, a very good check on changes in tooling, methods, feeds and speeds is available. All changes must be acknowledged by an industrial engineer. However, this is not the only means by which industrial engineering can check on methods deviations.

Since we have a wage incentive program covering production workers and, also, because the volume of units manufactured is substantial, time study plays an extremely important role in the industrial engineering departmental operation. Therefore, it seems appropriate to discuss in some detail our approach in establishing standards. It is our desire to consider the operating foreman the manager of his particular section of the business. Prior to initiating any work in a foreman's section, his approval is secured by the industrial engineer in charge. In such a relatively simple operation as the time study of a job, the foreman is brought into

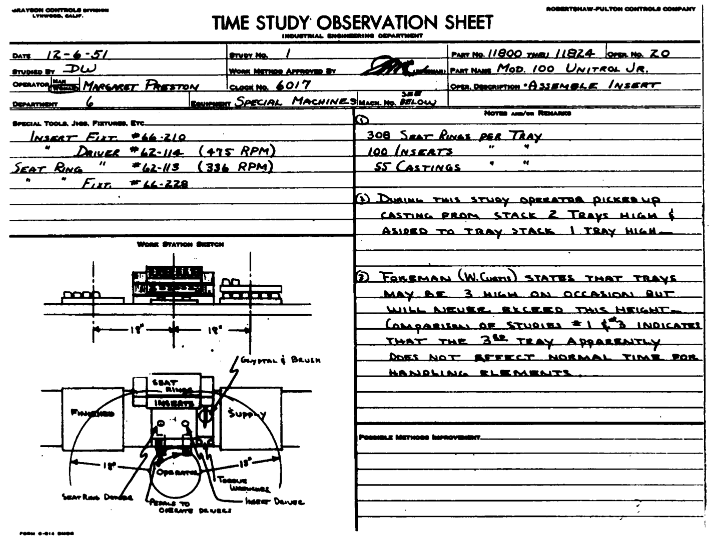


Figure 3 (Front)

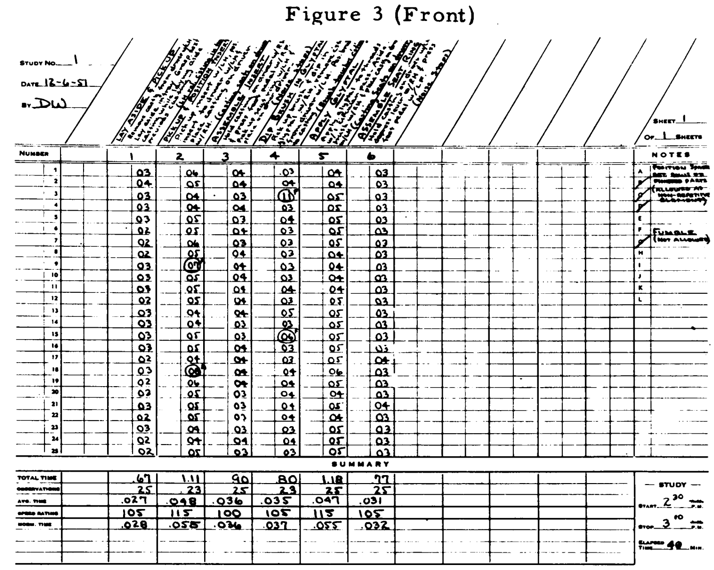


Figure 3 (Back)

the picture prior to any contacts between the industrial engineer and the operator. After this initial discussion, the industrial engineer develops the method of operation and establishes the methods that he wishes to time study. This method is written in considerable detail on the time study observation sheet. The foreman is now again consulted. He either accepts or rejects the method as outlined by the industrial engineer. When he accepts the written method after observing the operation and reading the time study write-up, his signature is recorded on the back of the study. It is not our practice to have the foreman sign for the time as recorded on a time study. His signature is obtained prior to the actual timing of a job. It merely approves the method which we are going to

G-MI DMGOT DATA SHEET

PART OR OPERATION	OP. NO.	DEPARTMENT	DATE	PAGE 1 OF 1	COMPILED BY
11800 THRU 11824 MOD. 100 UNITROL JR.	20	6	12 10 51		DW
DETAIL ASSEMBLE INSERT — TIME STANDARD WORK SHEET	.51 HRS./100 — 196 PCS./HR.	MACHINE NO.	STUDY NO.		CHECKED BY

ELEM. NO.	ELEMENTS	U.M.	N.T.	E.F.	STD. TIME	C.F.	STD. TIME UNIT
1	LAY ASIDE & PICK UP	PC	.027	115	.031	1/1	.031
2	PICKUP & POSITION INSERT	"	.055	"	.063	1/1	.063
3	ASSEMBLE INSERT W/DRIVER	"	.038	"	.044	1/1	.044
4	DIP BRUSH IN GLYPTAL	"	.040	"	.046	1/1	.046
5	APPLY GLYPTAL & ASIDE BRUSH	"	.049		.056	1/1	.056
6	ASSEMBLE SEAT RING W/DRIVER	"	.031	"	.036	1/1	.036
	NON-REPETITIVE ELEMENTS						
7	GET UP FROM CHAIR & BE SEATED				.116	1/50	.002
8	EXCHANGE TRAYS ON CONVEYOR				.110	1/50	.002
9	GET INSERTS				.384	1/100	.004
10	GET SEAT RINGS				.384	1/308	.001
11	GET GLYPTAL & THIN (ONCE PER DAY)				1.000	1/1500	.001
12	JOT COUNT				.050	1/50	.001
13	FILL TRAVELER				.250	1/50	.005
14	ASIDE SPACERS, PAPER & TRAY				.304	1/50	.006
15	POSITION SPACER IN TRAY				.035	1/10	.004
16	TORQUE INSERT & SEAT RING				.148	1/50	.003
					STD MIN/PC		.305
					STD HRS/100 PC		.51
					PC/HR		196

METHODS ANALYSIS CHART — REFERENCE No. 11800

PART MOD. 100 UNITROL JR. — DATE 12-10-51 — STUDY No. 1

OPERATION ASSEMBLE INSERT — ANALYST DW — SHEET No. 1 OF 2 SHEETS

DESCRIPTION — LEFT HAND	No.	LH	TMU	RH	No.	DESCRIPTION — RIGHT HAND
LAY ASIDE & PICK UP						
			5.7	M3B		LIFT CASTING CLEAR OF TRAY
DISENGAGE FROM S.R. DRIVER		DIE	4.0			
MOVE ASS'Y TO TRAY		M22C	23.8	(M22B)		MOVE CASTING TOWARD FIXT.
POSITION " IN "		PINSE	10.4			
RELEASE CASTING		RL1	1.7			
			45.6	(.0274)		
PICK UP & POSITION INSERT						
REACH FOR INSERT		R26B	22.9			
GRASP INSERT		G1B	3.5			
DISENGAGE FROM TRAY		DIE	4.0			
MOVE INSERT TO DRIVER		M8C	11.8			
POSITION " " "		PISSE	9.1			
RELEASE INSERT		(RL1)	8.7	M5C		MOVE CASTING TO DRIVER
REACH CLEAR		(R4E)	10.4	PINSE		POSITION " " "
			16.2	AP1		BOTTOM " ON "
			86.6	(.0520)		
ASSEM. INSERT, GET SEAT RING						
REACH TO SEAT RING TRAY		R16B	15.8	(FM4)		PRESS PEDAL W/R FOOT
GRASP SEAT RING		G1C1	7.3			
DISENGAGE S.R. FROM PEG		DIE	4.0			
MOVE RING TO DRIVER		M16C	18.7			
REGRASP RING		G2				
POSITION RING ON DRIVER		PISSE	9.1	(FM4)		RELEASE PEDAL
APPLY PRESSURE TO SEAT		AP2	10.6	(RL1)		RELEASE CASTING
RELEASE SEAT RING		RL1	1.7	(R6B)		REACH FOR BRUSH
			67.2	(.0403)		

No.	ELEMENT DESCRIPTION	ELEMENT TIME TMU	CONVERSION FACTOR .0006 LEVELED TIME	% ALLOWANCE	ELEMENT TIME ALLOWED	OCCURRENCES PER PIECE OR CYCLE	TOTAL TIME ALLOWED
1	LAY ASIDE & PICK UP	45.6	.0274	115	.0316	1	.0316
2	PICKUP & POSITION INSERT	86.6	.0520	115	.0598	1	.0598
3	ASSEM. INSERT, GET SEAT RING	67.2	.0403	115	.0465	1	.0465
	(CONT'D NEXT SHEET)						
						TOTAL	

METHODS ENGINEERING COUNCIL FORM No. [illegible]

Figure 4

study. It is the function of the industrial engineer to record the time and speed rate the operator's performance to obtain the normal time. This is clearly understood with all supervisors and no difficulty is encountered on this point.

Figure #3 shows a time study. Both the front and back of the observation sheet are shown. This gives some idea of the details which we require of industrial engineers.

We have other means of establishing time standards than the ones just outlined. Figure #4 shows an MTM study for an operation to establish a standard time. Basic data are also used to establish standards on operations where we have been able to acquire a wealth of data.

Before the final time standards are issued, they are taken to the foreman in charge of the operation being studied. At this time, having complete access to information concerning the job, he can and does question any part of the time study or time standard procedure. It is the responsibility of the industrial engineer to sell him on the correctness of the standard. Standards are not issued until the foreman is in complete agreement as to the production requirements, the methods outlined and the effective date of application of the standard. Occasionally, a foreman will ask for a one, two, or three day period before the standard goes into effect. It may seem that this procedure could be very time-consuming and prohibit the effective utilization of the industrial engineer's time. However, the foreman feels that he has had an active part in establishing the time standard, which pays dividends in the long run. We want the operators, if they have questions on the time standard, to contact the foreman. A well-informed supervisor can do much to sell time standards. All time standards once applied are guaranteed not to change, so long as the method, speed, feeds, and other specifications do not change.

Our union contract has a complete write-up on the wage incentive program for production workers. Examples are cited covering many situations that may arise. At present, our wage incentive program includes the direct production workers and their immediate supervisors or section foremen and their assistants. At the end of each day, for the previous day's complete operation, a sheet is posted in each section of the plant, showing all incentive earnings by clock number and name of the operator (see figure #5). This posting sheet shows an index or a relation of work produced to the standard amount that should have been produced for each individual working in that department. As the posting of this sheet takes place prior to the end of the shift each day for the preceding day's production, it is possible to keep current information before the employees and their supervisors. We use tabulating equipment to compile these reports for industrial engineering. All bonus is computed on a daily basis rather than on a job basis. Each day's bonus stands by itself. We use the standard hour plan in administering the wage incentives. Rejected work is deducted in calculating the operator's bonus.

Supervision bonus is calculated weekly and paid semi-monthly. The basis for calculating the supervisor's bonus is the operating control record. (See figure #6.) From the daily posting sheet, which I mentioned earlier, the various amounts of money spent for direct and indirect labor, scrap, rework, etc., are totaled on this weekly report. Items of cost which the foreman can directly control and reduce them if they are excessive, are the only ones that are used in calculating this bonus. Each foreman, according to the type of operations that he

GRAYSON CONTROLS, Division

DAILY POSTING REPORT

Date

DEPT.	EMP. NO.	EMPLOYEE NAME	SEC	PART NUMBER	OPER NO.	PIECES	ACCOUNT NUMBER	ACTUAL HOURS	STD. HRS. PRODUCED	INDEX	HRS BELOW STANDARD	BONUS HOURS	AMOUNT
		ASSEMBLY PISONER	18										
		12 10 51	18										
6	014		18				217	4					50
6	014		18	41111	10	592	101	8	9				113
6	014		18	40367	100	275	101	24	26				325
6	014		18	4245[illegible]	100	177	101	12	16				200
6	014		18				217	2					25
6	014		18	4245[illegible]	100	199	101	12	19				238
6	014		18				217	5					68
6	014		18				104					17	213
6	014		18	42401	100	80	101	4	6				75
6	014		18	41105	20	250	101	9	9				113
6	014		18				101		1				12
								69	86	125			1213
6	023	CELIA M KELLY	18										
1	037		18	40365		60	224	45					727
													727
6	038	SYLVIA MAGNUS	18										
6	038		18				122						17
6	038		18	40365	30	120	101	11	15				204
6	038		18	40365	10	360	101	17	24				326
6	038		18				217	5					68
6	038		18	40365	10	240	101	9	16				218
6	038		18				122						39
6	038		18	40365	30	394	101	35	41				558
6	038		18				101		1				13
6	038		18				104					25	340
								72	97	135			1387
6	058	GLORIA COLLIER	18										
6	058		18	40365	65	276	101	15	22				275
6	058		18	40365	30	108	101	13	13				162
6	058		18	40365	65	324	101	20	26				325
6	058		18	40365	30	204	101	24	21				262
6	058		18	40365	65	132	101	8	11				138
6	058		18				101		1				13
6	058		18				104					14	175
								80	94	118			1175
6	066	EUGENIA G PARK	18										
6	074		18	40365	900	360	101	35	36				450
6	074		18	41105	20	260	101	10	9				112
6	074		18	40365	900	366	101	30	37				463
6	074		18	41006	45	300	101	5	3				38
6	074		18				101		1				12
6	074		18				104					6	75
								80	86	107			1075

Figure 5

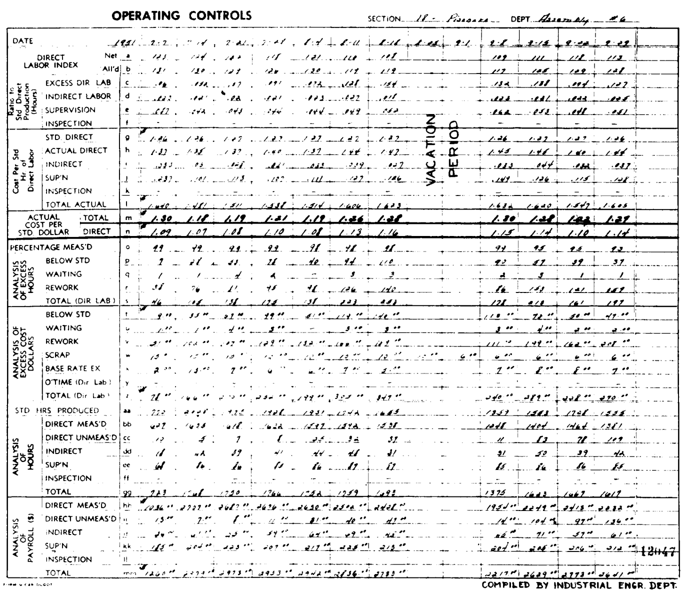


Figure 6

supervises, has a goal which he is constantly striving to attain. You will note that on this report there are no overhead items of cost, such as electricity, gas, lights, engineering time, and other indirect departments. It is felt that by giving the foreman control of certain items and holding him responsible, as a manager, for those items, highly satisfactory results are obtained. Also, the foreman sees the results of his efforts week after week. Each foreman receives the information as shown on this operating control sheet once per week. With previous training in the use of these records, he is able to do an excellent job of analyzing the cost situations in his section. I'll venture to say that practically any foreman in our plant who works with these controls can describe, in considerable detail, cost change affecting his bonus. The major part of the bonus which a foreman may earn under our plan is accomplished by reducing the excess costs, such as below standard operation, reoperation, waiting time, base rate excess, and scrap.

In a manufacturing plant with time standards incentives, one very important aspect of industrial engineering is sometimes overlooked in the hustle and bustle of normal operations, namely, time standards maintenance. Of all the variables that affect an operator's production, method is the most important and consequently, the hardest to control. One may boast about the accuracy of time standards when originally established; one may boast about the excellent methods installed at the time the job is studied, but failure to establish procedures for checking the operations over the period of time to guarantee that methods are still as they were when they were studied, indicates that storm warnings need be posted. Even the simplest job can have terrific methods deviations which do not come to the attention of the industrial engineering department. In many cases, this can be attributed to neglectfulness on the part of the foreman. In other cases, the foreman of the operations does not know that these changes have taken place. Then, we might ask whose responsibility it is to see that job methods are followed. Over the period of years, we have found that it is the joint responsibility of several departments. Primarily, the operating department and the industrial engineering department are the ones charged with this responsibility. To assist the foreman in notifying industrial engineering of changes that he encounters on jobs, we furnish him with a form, as shown in figure #7, known as the Operation Change Notice. Several of these blanks are "dittoed" and supplied to each operating foreman. They are thus always readily available for use. Upon receipt of such notification from the foreman, the engineer goes to the operation, checks with the foreman, obtains the details and makes his notations of the change. The operating foreman has no authority to deviate from the method as spelled out on an operation detail sheet unless he has specific instructions to do so from his immediate superior. However, due to uncontrollable factors, temporary in nature, deviations are permitted. The industrial

OPERATION CHANGE NOTICE

Part No.: 40364   Date: 11-28-51

Oper. No.: 75   Requested By: [illegible]

This operation has been changed as follows:

No stops are available - assembling controls without - Please check for minus standard.

* * * * * * *

This space for use by Industrial Engineering Department only.

Checked by: DW   Date: 11-28-51

Complete detail of findings: Check study made - Condition should be remedied by 11-29. Issued Minus Std of 0.30 Std Hrs/100 Pc effective 11-28 only

MAIL OR RETURN TO INDUSTRIAL ENGINEERING DEPARTMENT

Figure 7

PLUS STANDARD NOTIFICATION

Section: 9   Part No.: 11324

Department 15   Oper. No.: 70

Shift: Day (circled) / Swing   Minus Std.Hrs./100 : .045

* * * * * * * * * *

This Plus Standard is to be used for not more than one 24 hour period

beginning: 11 /28/51, 7^00 a.m. and ending 11 /29/51, ______ a.m.

______ p.m.   3^30 p.m.

Reason: Gate area has been enlarged experimentally requiring excessive grinding

Copies to: Timekeeping: Jack Taylor   Signed: DW

Compiled by Ind. Engineering Dept.

Figure 8

engineering department issues a plus or minus standard to compensate for such allowed deviations. A plus standard is added to an existing standard to give the operator credit for a condition on the operation beyond his control. It protects the incentive opportunity. On the other hand, a minus standard deducts time from the existing standard when an operator does not complete an entire operation. Only the industrial engineering department can remove a standard from an operation. A plus standard notice is shown in figure #8. In the normal course of events during the day, the industrial engineers circulate throughout the plant. Naturally, they see many things overlooked by others. They have the opportunity to observe many operations and note any deviations from the standard methods. When a deviation is noted by the industrial engineer, he immediately contacts the foreman and relates this information to him. As a follow-up, a method deviation notice, figure #9, is filled out and mailed to the section foreman. This notice shows the part number, the operation number, location of section and also describes in detail what deviation was observed, and the percentage of time that it affects the final standard. Based upon the foreman's answer, a final determination is made.

Now, just one more word about plant lay-out. Plant lay-out is an important function of industrial engineering. It ties in closely with the manufacture of new products and/or the change in manufacturing techniques on present products. Consideration is given to factors such as job methods, equipment location, transportation, storage and shipping. Much of this information is available in the industrial engineering department, therefore it is logical that plant lay-out should fall under its direction. In addition to lay-outs of the foundry, machine and assembly departments, we have participated in lay-outs for the shipping and warehouse departments. Projects of this nature entail the design of tote boxes, location of storage areas, and consideration of equipment to be purchased. Comparisons are made showing the savings that can be realized.

A lay-out board consisting of lucite panels scribed in quarter-inch increments, serves as a background for preparing plant rearrangements. Each quarter inch represents one square foot of floor area. All permanent walls, posts, and other equipment are shown on the lay-out with colored scotch tape. Two dimensional templates are used to designate machines. These templates show the location of the operator and the clearance needed for each machine. The lay-outs are prepared at the completion of the preliminary estimating.

Up to now I have covered numerous phases of the activities in which our industrial engineering department participates. It is logical to raise this question, "How do you measure the success or effectiveness of the industrial engineering program?"

It is one thing to create an industrial engineering department but to expand it over a period of years is quite different, for its activities can be expanded only if the work is successful and accepted.

Somewhere along the route the "boss" is going to look for tangible savings to justify the existence of the industrial engineering department--not just savings based upon someone's theory, but tangible savings--savings in real money--savings that are reflected on the Profit and Loss statement. Yes, this can be done. If I may be just a trifle boastful, we have done it at Grayson. The workers also benefit through increased earnings. They like what the industrial engineering department has done for them and the management likes what it has done --isn't that enough?

METHOD DEVIATION NOTICE

TO FOREMAN: J. Reimann — PART NO.: 6159

SECTION: 1 — OPER. NO.: 298

DATE: 6-26-51 — PART NAME: WCT Body

OPERATION DESCRIPTION: Burr Bottom of Gas Cock Hole.

(A) On 6/25/50 this operation was observed being performed not in accordance with the Operation Detail Sheet, as follows:
Operator was not burring inlet hole w/ fibre tool as outlined on detail sheet. D.S. calls for burring every pc., whereas operator now glances into inlet hole after part leaves brush & burrs only as necessary. Parts are apparently satisfactory using this method.

This deviation affects the allowed Standard Time for this operation approximately 20 %.

Observed By: D. Wheeler

(For Foreman's Use Only)

(B) To Industrial Engr. Dept.: The above Mentioned deviation is acceptable to Me.

Comments:
Operator was told by me to inspect each part and remove hanging burrs with fibre tool. Please change detail sheet and standard if this method is acceptable.

Date: 6-27-51

Foreman: [signature]

(If your answer is "Yes", this notice will be considered a request to process this operation.)

(For Ind. Engr. Dept. Use Only)

(C) Job Record Follow-Up:
Removed Oper. from Std 7-1-51 & instituted new method. Received Quality Approval 7-8-51. Issued new std. of .162 Std Hrs/100 Pc on 7-10-51. (Previous std was .190 Std Hrs/100 Pc)

Date: 7-10-51

By: DW

Figure 9

LUNCHEON SESSSION

Session Chairmen: R. G. Bressler, Berkeley, February 1, 1952
G. L. Sullivan, Los Angeles, February 4, 1952

ENGINEERING IN THE FABRICATION INDUSTRIES

L. M. K. Boelter
Dean, College of Engineering
University of California
Los Angeles, California

This discussion shall be confined to the processing of solids (metals, wood, plastics, etc.) and the assembly of components into commodity units or articles which are ready for the consumer.

The problem which faces the engineer may be presented as the following procedure and schedule:

a. Recognition of the need.
b. Evaluation of the objective.
c. Conception of solutions required to fulfill that need.
d. Analysis of all means available to attain that end.
e. Design and/or develop a commodity unit to attain that end.
f. Complete an economic and sociological analysis of the commodity unit and study the implication of the results.
g. Design the production (or construction, or fabrication) procedures and equipment and then possibly redesign the commodity unit itself.
h. Study the actual commodity unit (or product) in the consumer environment and again possibly redesign the commodity unit.

All of the entries in this schedule are rarely the responsibility (or fall under the authority) of a particular professional engineer, but all of the data must be available to him in order that a satisfactory solution will be accomplished.

A criterion required as one step in the establishment of the most satisfactory solution of the problem may be stated as

$$\frac{\partial P}{\partial q\ i} = 0$$

where q refers to cost, time, materials, and manpower.

The application of this criterion is the core of professional engineering. Maximizing the elements defined by the procedure (P) with respect to each of these variables (often considered to be independent variables), utilizing the techniques of the calculus of variations when possible, and adapting the solution required by the temporal, geographical and cultural environment is implicit in this differential quotient. Or again, the above schedule (P) must be accomplished at the minimum of cost in the minimum time with the minimum absorption of available materials, and with the most effective utilization of men. Minimizing the cost of design and evaluation, production and distribution, sales and service within time limits set (and with adequate restrictions upon effective and proper use of materials and men) requires the utilization of analytical and experimental skills and techniques at the highest level. These skills and techniques include the latest and/or appropriate technical information, technical skills (for instance, network analysis), engineering arts, and the techniques in the trades and of the manual skills. The application of this mass of information to the establishment of a satisfactory design and product, minimizing with respect to cost, time, materials, and manpower, is implicit in the practice of professional engineering.

In the following discussion only a few segments of the above schedule will be presented.

Flow

The operation of a fully automatic production line requires the temporal and spatial conjunction of events beginning with the materials and ending with a finished product. The temporal sequences can be arranged through the use of automatic computing devices. In a semi-automatic line, the impact of the operator at preselected intervals and locations is required. Parenthetically, in the analysis of a production system, a servo-mechanism can be substituted for man and endowed with those characteristics required at the particular place. Returning to the production line, the usual plant layout will provide the spatial relations but the concept of flow must be introduced to insure the proper space-time consideration. Exact methods of analyzing this flow system have not yet been devised but, for instance, in linear flow, a concept of frequency (units of commodity passing in unit time), volume rate (projected area perpendicular to direction of flow times flow rate, the latter in linear measure per unit time), volume effectiveness (ratio of actual volume of the commodity unit to volume swept per commodity unit), power required per commodity unit and ratio of ideal power to actual power. These variables are point-functions changing from point to point in the system and often exhibit the properties of a discontinuity. Integration and differentiation of these variables yield further data necessary for design and operation.

The satisfactory design will accomplish the given sequence of tasks (assembly or fabrication or other) in the minimum space at the maximum or proper rate compatible with the physical requirements of the machine and the commodity units, and at the minimum cost (fixed plus operating costs), and also meeting the desired specifications of quality.

The projected areas of the flow paths, including their structural boundaries, on both the horizontal and vertical planes yield further information relative to building layout.

Manpower

So far, the discussion has implied an automatic line, but this goal has not yet been achieved in many instances and indeed may prove unnecessary in certain cases.

But where man's acts are impacted upon the line they may be simulated in the analytical treatment by servomechanisms as noted earlier, and the design must include those elements which make effective manual endeavor possible. Adequate lighting (work speed as well as accuracy depend on the illumination and contrast), the proper sound level (noise is enervating), proper ventilation (correct temperature, humidity, air velocity, air purity, no drafts, correct ratio of radiant to convection fraction of thermal energy to the man), absence of vibration (different frequencies and amplitudes affect the different parts of the human body differently), and preventive safety features must be incorporated into the design.

To this end, all that is known about man's response to the environment created by the engineer must be brought to bear. Many data are not yet available--for instance, the effect of air temperature and humidity on the rate and accuracy of the performance of certain tasks. Parenthetically, a research project is under way in the University of California in which the effect of abnormal temperatures from 125° F to 300° F are being studied.

From another point of view, what tasks can man perform with no deteriorating effects on his health and well-being? Again, a small beginning is being made at the University of California. Elementary tasks have been analyzed, segregated into unit-operations, and the minimum number of skeletal-kinemetic links necessary to perform these tasks has been established. At the moment, the work is being directed toward the design of prosthetic devices but will soon be broadened to include other objectives.

The time-space relations at those production stations at which man contributes deserve and have received special attention. The accomplishment of these tasks minimizing fatigue, monotony, enervation, waste motion, and danger by and to the worker is the goal to be achieved. Energy-motion-time relationships have been established for many specific tasks. Application of these data is mandatory in good engineering practice, but greater knowledge of the physiological and psychological response of men to engineering systems is needed for rational design.

The plant designer should also carefully consider its location. Many geographical, legal, resource availability, and disposal problems must be answered. But restricting this segment of the discussion to man, he must be rested and alert when reporting for work. Long enervating drives between home and work are not conducive to the greatest well-being of the employee and of management.

Operations Analysis

A technique which is gaining stature in engineering is entitled operations analysis. Briefly, a particular operation, say the production of a commodity unit, may be studied experimentally. An independent variable is changed and the effect on the dependent variables observed. Through the application of the appropriate scientific methods (such as factor analysis, the calculus of variations), the relationship of a change of each independent variable on each of the more important dependent variables can be established.

The application of operations analysis to problems concerned with providing increased output, plant expansion, maintenance and quality control, will result in more economical and rational solutions.

Design

Little has been said about the design of tools, dies, jigs, and fixtures. As the properties of materials become known, predictions of the work of plastic deformation and fatigue life will be possible. Again, if the energies required in the separation processes (cutting, sawing, polishing, etc.) are known in terms of the properties of materials, progress in design will result and production rates and costs will be influenced favorably.

Knowledge of the fatigue characteristics will support repair and service schedules, now based almost entirely on unformulated experience.

Often, the analytical procedures available are applied to only the design of a given commodity or production system. But the continuous application of the knowledge of properties of materials and of the several analytical procedures will result in more satisfactory repair and service schedules. Again, the flow of information relative to the commodity performance in its actual environment (which really are prototype tests) to the designer will greatly enrich his knowledge and will result in improved designs.

The reduction of wear and of corrosion, the reduction of the effects of irradiation (fading, etc.) and other deteriorations may also be subjected to analytical treatment with beneficial effects. Plant conservation will be the direct result of these studies.

The foregoing comments yield a brief glimpse of contributions which the professional engineer can make to the industry. Engineers-in-training and young professional engineers may acquire the appropriate know-how through wisely conceived on-the-job training programs supplemented by off-the-job study.

WORK MEASUREMENT SESSION

Session Chairmen: F. H. Wickhorst, Berkeley, February 1, 1952
Donald Voorhees, Los Angeles, February 4, 1952

DEVELOPING STANDARD DATA FOR PREDICTIVE PURPOSES

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The problem of whether standard data can be developed for predictive purposes is one of the most fundamental in work measurement.[1] The basic approach and procedures of standard data are essentially the same today as when they were developed by Taylor, who first proposed that element or motion times be developed for the purpose of predicting cycle times for operations with similar elements or motions.[2]

In general, it is believed that production standards developed from element standard data are both accurate and consistent with one another. Carroll, in fact, is so impressed by the belief that standard data are consistent, that he makes the sweeping assertion that the standard-data approach has no disadvantages and can be applied almost universally.[3] The claim of consistency is so persuasive that it is supported by Gomberg, who is otherwise quite critical of the standard-data approach.[4]

Another significant advantage claimed for element standard data is its superiority over motion standard data. Mundel, for example, considers this superiority to be established by the results of certain laboratory experiments indicating that the time required to perform one motion is influenced by the preceding and subsequent motions.[5] A number of writers take the opposite view, claiming essentially that accurate results cannot be obtained from element standard data as developed by the usual time-study procedures.[6]

There can be no doubt that if these claims are true, the standard-data approach can solve many estimating problems in work measurement at a minimum cost. There is one critical qualification: it must first be shown to have the properties claimed. Putting this in more technical terms, standard data must be shown to give predictions that are both acurate and precise (or valid and reliable). The answer to this fundamental question is long overdue, for recent surveys show that substantially more than 50 per cent of time-study practitioners now develop and use element standard data for predictive purposes.[7]

It is instructive to summarize the available critical views and experimental results on the subject of element standard data. As early as 1916, Hoxie commented that the use of standard data introduced a further unscientific and possibly unjust factor into work measurement.[8] He also made the prediction that its only potentially useful application would be on machine-controlled operations.

In recent years this subject has received a great deal of critical consideration, particularly by industrial psychologists, such as Ryan and Ghiselli, and Brown.[9] Essentially, their position is that: (1) element standard data can be developed only if it can be shown that the times of different elements are independent; (2) element times seem to be interdependent rather than independent.

A small amount of experimental evidence has been reported on these questions, primarily by Barnes and Mundel.[10] They found that the time required to perform a movement is influenced by the preceding and subsequent movements, which suggest that motions, at least, are interdependent.

These views and results do have a certain amount of exploratory value: they show that there is some doubt that motion times are not independent and hence that standard data predictions made from them may not be very useful. However, the extremely limited number of experimental studies reported were made under laboratory conditions on extremely simple tasks performed by small groups of highly motivated test subjects. Much more intensive studies were clearly needed on represent-

[1] The full details of the material considered in this paper are contained in A. Abruzzi, "Work Measurement: New Principles and Procedures," Columbia University Press, 1952. This work also considers in detail all the other major problems involved in this field, such as process standardization and the estimation of production rates and delays.

[2] Frederick W. Taylor, "The Present State of the Art of Industrial Management," Transactions, American Society of Mechanical Engineers, XXXIV (1912), pp. 1199-1200.

[3] Phil Carroll, "Time Study for Cost Control," 2nd Ed. McGraw-Hill, 1943, pp. 18-32.

[4] William Gomberg, "A Trade Union Analysis of Time Study," Science Research Associates, 1948, pp. 158-159.

[5] Marvin E. Mundel, "Systematic Motion and Time Study," Prentice-Hall, 1947, p. 178.

[6] See, for example, J. H. Quick, W. J Shea, and R. E. Kohler, "Motion-Time Standards," Factory Management and Maintenance, CIII, No. 5 (1945), pp. 97-108.

[7] See A. Abruzzi, op. cit., and R. M. Barnes, Industrial Engineering Survey, University of Iowa, College of Engineering, 1949. Industrial Engineering Report No. 101.

[8] R. F. Hoxie, "Scientific Management and Labor," D. Appleton & Co., 1916, pp. 51-52.

[9] T. A. Ryan, "Work and Effort," Ronald Press, pp. 232-235 and E. E. Ghiselli and C. W. Brown, "Personnel and Industrial Psychology," McGraw-Hill, 1948, pp. 268-270.

[10] R. M. Barnes and Marvin Mundel, "A Study in Simultaneous Hand Motions," University of Iowa, 1939. Studies in Engineering, Bulletin 17.

ative industrial workers performing representative industrial tasks under representative industrial conditions. This is exactly what was done in the research project about to be described. Moreover, the problems involved in evaluating the standard-data approach are much more complex and subtle than the available critical and experimental evidence suggests; it was necessary, for example, to employ a number of so-called multivariate statistical procedures to analyze the test data.

The first set of studies was made on element data obtained from representative time studies of man-controlled operations in representative plants of the garment industry. These studies were intended to determine whether the element times in individual operations were independent of one another. Thus, the relationships, if any, among all the elements involved were studied by making a single over-all test, called the Wilks' multivariate test of independence.

The application of this test is quite involved and will therefore not be discussed here; the pertinent details and the data obtained can be found in "Work Measurement: New Principles and Procedures."[11] For present purposes, it is sufficient to summarize the results obtained.

The first general finding was that as originally defined, the elements in the operations considered were generally not independent. Since this turns out to be a crucial point, it should be understood that the element definitions were developed by plant time-study analysts with some assistance from union time-study analysts. These definitions were based on the criteria usually used in the time-study field, e. g., sound and motion "breaks," and so forth.

The test results further showed that not only were the elements in these operations not independent, they were actually tied together by a complicated network of relationships. It should be stressed that: (1) a relatively large number of test studies were made; (2) the data were obtained in the factory rather than in the laboratory; (3) the findings were based on established statistical test procedures.

The test results also produced two more findings of fundamental interest. They showed that the nature and the degree of the relationships among the elements depend on the number and the magnitude of the elements involved. They showed further that the nature and the degree of the relationships vary with different operators and even with the same operator. A large amount of supplementary empirical evidence was also obtained, showing that almost all workers organize their work patterns in terms of the operation as a whole rather than in terms of individual elements.

On the basis of these findings, another set of studies was made to determine whether it is possible to redefine operation elements so that they will be independent. The procedure adopted was to combine two or more elements into groups, which were then considered as the primary operation subdivisions instead of the original elements. These groups were developed on the basis of the statistical and empirical evidence previously obtained. Thus, if elements 1-3 in operation A had a high degree of correlation and they seemed to be performed in terms of an integrated series of motions, the times for these elements were pooled to obtain the times for element group 1, etc.

The primary conclusions obtained in this set of studies were that: (1) in most cases independence (i. e., among element groups) will be achieved after the first application of the grouping process; (2) independence will not necessarily be achieved even after two applications of the grouping process; (3) the amount of grouping required to achieve independence varies with the operator; (4) the number of element groups required to achieve independence varies from plant to plant. (In one plant, independence was usually achieved with from five to seven element groups, while in another, the grouping process had to be continued until only three to five element groups remained); (5) independence is much more likely to be achieved when the average time of the smallest element group is at least five hundredths of a minute and the average time of the median element group is at least ten hundredths.

It is quite important to emphasize that independence is not strictly necessary to develop meaningful standard data. Thus, there is no a priori reason why different workers could not introduce the same relationships among elements (or element groups) in organizing their work methods. On the basis of the test results, however, the likelihood of this is so remote that this alternative is of only theoretical interest.

To summarize the findings presented thus far, it is clear that operation elements defined according to current practice are quite often not independent of one another. Also, element groups can be defined so that independence is achieved in most cases. But having independent element groups does not of itself guarantee that standard data can be developed for predictive purposes. In fact, independence does not even imply that the element-group structures will be the same for different operations or even for different workers on the same operation.

To look into these questions, a third set of studies was made to check on the data previously tested for independence, using a number of multivariate likelihood ratio test procedures to make the analyses.[12] These test procedures, like Wilks' test of independence, are extremely complicated in theory and application; for that reason, only the results will be considered here.[13]

The principal findings were as follows: (1) the average times for elements as well as for element groups were not equivalent for different operators working on the same operation; (2) on the other hand, different operators did have an equivalent degree of variability in their element-group times (measured in terms of the time variances) in a few cases, but only when independence had previously been established. This finding strongly suggested that elements as currently defined, especially in man-controlled operations, will not usually be the same for different operators.

Considered together, these three sets of studies have extremely important implications regarding element standard data. First, they show that for all practical purposes man-controlled operations, at least, should be considered in terms of element groups rather than elements. Also, these element groups should be independent of one another, which means that they should be few and they should be large.

But even with element groups, the likelihood is quite small that two or more operators will have (statistically) equivalent element-group times. In standard data work, however, it is not enough to find operation subdivisions that are common (in the sense of having equivalent time

[11] A. Abruzzi, op. cit. This work also describes in detail the operations, the plants, and the other empirical characteristics of the studies made.

[12] The theoretical aspects of these test procedures are discussed in Wilks, "Certain Generalizations in the Analysis of Variance," Biometrika, XXIV (1932), pp. 471-494.

[13] The full details can be found in A. Abruzzi, op cit.

values) to all operators working on a single operation. These subdivisions must also be common to many different operations. This additional requirement makes the problem much more difficult, and it becomes increasingly difficult as more operations are compared.

When operations are being compared, an even more important limitation arises as a result of the grouping procedure introduced to achieve independence. This procedure combines the elements of a given operation into groups that only rarely will be found in other operations. Thus, the process of developing element standard data is a self-defeating process, especially with man-controlled operations. To meet the independence requirement, a small number of large element groups must be constructed. But this makes it almost impossible for different operations to have element groups that are even descriptively comparable.

But even if these extremely formidable difficulties could be overcome, a number of other questions have to be answered--if the objective is to predict the time required to perform a new operation. Thus, the new operation must have element groups which: (1) are descriptively comparable to those given in the standard tables, and (2) have the same averages and variance values. But the test results showed that likelihood of achieving this is extremely small. In fact, the only safe way to check this question is to subject the new operation to a series of test studies like those considered here, which would eliminate the need for making a prediction.

Assuming, just for the sake of argument, that all these difficulties could be overcome, there remain two major questions to be considered. The first is that the empirical value of a prediction, expressed in terms of its range of error, depends on the number of observations and on the variability of the observed data. The second is that the average times of elements and element groups decrease gradually as a result of improved methods and skills. This means that even though it were possible to answer every other question, a new set of standard data would have to be developed at periodic intervals by the same tedious and hazardous process as before.

Thus, element (more properly element-group) standard data is apparently an impossibility for all operations in which the workers exercise an appreciable influence on the work method and the work pace. The fact is that only for machine-controlled operations is there even a remote likelihood of developing standard data of this type.

In view of these findings, it is at once clear that none of the procedures currently recommended for developing element standard data is valid. Some of the specific shortcomings are that: (1) element standard data are often developed from observed data by using (statistically) invalid or inefficient measures of central tendency; (2) in many cases, so-called "abnormal" readings are discarded in advance on subjective grounds; (3) little or no attention is paid to the variability of production rates; (4) the question of whether relationships exist among elements is never taken into account and rarely even recognized.

In fact, almost all time-study texts implicitly assume that production rates are essentially constant; also, that each element is a completely independent unit, apparently because it has a unique verbal definition. These texts also seem to assume that the time required to perform a new operation can be estimated without error. In any event, sample sizes and variability values, which determine the range of predictive error, are never recorded on standard data-tables. Another essential difficulty is that all these texts deal with elements rather than element groups. As currently defined, however, most elements are not independent, to say nothing of their other deficiencies for predictive purposes.

A supplementary point of interest is that all current procedures require that the observed element data be rated subjectively. This practice is completely meaningless, however, unless the elements being rated are first established to be independent.

It also follows that the argument of consistency, upon which so much emphasis is placed in the literature, is completely unsubstantiated. In fact, the question of consistency does not even begin to have meaning unless and until: (1) it is established that the elements involved are independent; (2) the data are obtained and treated according to the test procedures discussed above. Quite aside from its lack of validity, arguing that standard data have the advantage of consistency implies that ordinary time studies, which would otherwise be used, give inconsistent results. This gives the argument a rather amusing footnote, since ordinary time studies are used to develop the basic standard data values. The over-all conclusion is that the results of current standard-data procedures are in most cases meaningless and in any case, have little or no predictive value.

These research studies also produced a number of other empirically important conclusions, only one of which can be touched on here. Many time-study texts and some leading labor unions take the position that only the elements directly affected by a change in method, material, or design are to be observed in restudying an operation.[14] The preceding material makes it clear, however, that the effect of such a change will generally not be confined to such elements. Instead, it must be expected that an operation change will produce a totally new element structure. The only completely reliable way to deal with the problem, then, is to determine the full effect of any given change, using the test procedures mentioned above.

Another group of research studies was made on motion standard-data and related problems. Both the test procedures and the results were essentially the same as they were in the element case. Accordingly, only the highlights will be presented here. In this case, time analyses were made from film records of certain laboratory operations, which meant that only a limited number of observations could be obtained on each. The timing instrument used was the so-called "wink-counter," which gives readings to the nearest two-thousandths of a minute when used in a camera field. It might be added that film studies of this type require so much "staging" that they can all be classified as laboratory studies, even when they are made in the factory.

One of the first findings obtained was that there is no justification for the rather common belief that the times required to perform so-called fundamental motions are constant within reasonable limits.[15] What actually happens is that constant readings are obtained only when the motions (or elements) are not much larger than the smallest unit of measurement. However, the readings cease

[14] See, for example, "The UAW-CIO Looks at Time Study," The United Automobile, Aircraft, and Agricultural Implements Workers of America, July, 1947, p. 30

[15] See, for example, A. B. Segur, "Motion Time Analysis," Proceedings of the Time and Motion Study Clinic, Industrial Management Society, Nov., 1948, pp. 40-48.

to be constant when more sensitive measuring instruments are used. This means that inadequate measuring instruments are responsible for constant readings, not the basic motions or elements. To avoid such difficulties, (and also to achieve independent motions or elements), it seems advisable to adopt the following criterion: consider only motions or elements lasting at least five times as long as the smallest measurement unit.

As with elements, it was found that relationships often exist among fundamental motions as currently defined. However, independence can be achieved by combining these motions into motion groups which are smaller in number and larger in size. It was also found that the pattern of the relationships among the motions was different for different operators and changed after a (short) time even for the same operator. It seems safe to conclude from this evidence that these relationships would also vary from operation to operation and, more generally, from plant to plant.

These statistical results were corroborated by empirical evidence obtained by a detailed scrutiny of the films. This scrutiny showed that the motion structures of the operators differed greatly; also, the motions were performed in groups rather than as isolated units. This finding suggested that workers develop their motion structures as a whole rather than as a sum of separate and distinct motions.

It was discovered also that each worker's motion structure can be broken down into two distinct components. The first can be defined as the expected, relatively constant, and usual motion pattern, including a set of relatively fixed relationships among the motions. When a special situation arises, however, such as difficulty in engaging moving parts, the worker uses another motion pattern. This can be defined as the unexpected, varying, and occasional motion pattern, in which the relationships among motions are also changed. The nature of the occasional motion pattern depends on the nature of the situation encountered and on the worker's adjustment to it.

The test results showed further that for all practical purposes meaningful motion standard data can be developed only from operations divided into a small number of large and independent motion groups. But even for independent motion groups, the likelihood of obtaining equivalent motion structures (in terms of average and variance values) for different operators is remote, especially when the number of operators being compared becomes relatively large. The test results also strongly suggested that it will be almost impossible to find descriptively comparable motion groups even in almost identical operations. Thus, very few operations will have motion groups that can even be compared, to say nothing of having equivalent statistical properties.

Even then, it would not be enough for established operations to have comparable motion groups with equivalent average and variance values. The new operations for which the predictions are intended must have comparable motion groups with the same average and variance values. These facts, however, can safely be determined only by obtaining and analyzing data from the new operations--a procedure that would make predictions unnecessary.

Sample sizes and variability values must also be such that the predictions will be empirically useful, i.e., their ranges of error will not exceed predetermined limits. It will be extremely difficult to meet this requirement in view of the limited sample taken in the usual motion study.

The likelihood of overcoming all these difficulties is even smaller for motions than it is for elements; the reason is that motions are influenced by the operator to a much greater degree than are elements. This finding also points up thje fact that motion structures will not remain constant for very long. A new set of standard data would have to be developed, then, at relatively frequent intervals, assuming, of course, that all the other difficulties can be overcome.

Accordingly, the likelihood of developing meaningful motion (more properly motion-group) standard data is even more remote than it is for elements. In any event, it will be impossible to obtain motion standard data that can be used in all industries or even throughout one industry. This puts the problem of developing motion standard data up to the individual plant. The cost of making the required film studies under these circumstances would appear to be prohibitive, especially since the prospect of success is so meager.

The preceding material also makes it clear that all sets of motion standard data claiming general applicability--and almost all of them do--are invalid. The reason is simple and direct: they just do not apply to the motions considered in these research studies. In fact, probably it is precisely because different motions are used in different types of operation that the published sets of motion data differ so much from one another. This fact alone, as Gomberg correctly warns, is sufficient to raise a serious doubt about their validity.[16]

Quite aside from this, current motion standard-data procedures have all the weaknesses of element standard-data procedures. For example, nowhere is it acknowledged that fundamental motions are likely to be correlated or that there is a need to develop independent motion groups. The result is that every set of motion standard data currently available is completely unacceptable for predictive purposes.

The research studies also led to supplementary findings concerning two basic notions related to the standard-data notion. Thus, the generally accepted notion that there is only a limited number of fundamental motions (between 15 and 25 are usually considered) is directly related to (and probably responsible for) the equally accepted notion that motion standard data could be developed for universal application.

The evidence obtained in these studies, however, showed that a limited number of definitions cannot possibly apply to all the motions encountered in industrial operations. Some writers, such as Gillespie and Fairchild, have attempted to solve this problem by developing more comprehensive definitions.[17] However, the motion patterns of different workers will differ in an almost infinite variety of ways. No matter how carefully they are made, then, descriptive definitions will never be completely satisfactory for making estimates and predictions. To identify a motion uniquely, it is also necessary to state its chief statistical properties by recording its average and variance values.

The research studies also showed that the "one best way" notion has the same shortcomings as the standard-data notion. This is only natural, since the standard-data notion represents an attempt to give physical meaning to the "one best way" notion. Thus, rearranging or

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[16] W. Gomberg, op. cit., pp. 156, 159-160.

[17] James Gillespie, "Dynamic Motion and Time Study," Paul Elek, Ltd. 1947, and Mildred Fairchild, "Skill and Specialization I." Personnel Journal, IX (1930), pp. 28-71.

revising element or motion structures, as the "one best way" notion requires, will produce an entirely new element or motion structure with unpredictable statistical properties. Another basic shortcoming common to both these notions is that little or no attention is paid to the question of variability in performance.

Editor's note: There was considerable reaction to Dr. Abruzzi's talk at the close of Friday's Session in Berkeley. In response to this reaction, Mr. Douglas Watson of McKinsey & Company, San Francisco prepared the following questions which were answered by Dr. Abruzzi at the beginning of the Saturday morning session.

Question: From the practitioner's viewpoint, how can reasonable tolerances of precision and predictability be defined? Dr. Abruzzi: The degree of precision and predictability (in terms of the range of estimating error) must be determined by the economic and other empirical requirements of the plant. Precise estimates may be required, for example, when time study results are to be used to make important decisions about production costs, etc. For most cases of this kind, 5 per cent seems to be a reasonable choice for the maximum range of estimating error.

Question: Recognizing the importance of an overall economic approach, how much precision should we sacrifice in approaching the practical problem of providing incentive coverage? Dr. Abruzzi: Basically, the answer to this question is the same as the answer to the first one. How much precision is needed depends on the use to which the time study data will be put. Much more precise results will be required in general for making valid cost estimates than for incentive standards. In the latter case, relatively non-precise estimates may be acceptable as empirical reference points to both management and labor, provided that they are clearly recognized to be such by both parties.

Question: Standard data, such as the MTM system, has a history of reasonable success in establishing standards of acceptable precision as measured by careful time studies using current techniques. Recognizing their lack of scientific validity, can we afford not to use these methods in practice? Dr. Abruzzi: There are a number of important reasons why the usual methods of checking the predictions of standard data against time study results are unacceptable. First, both sets of results are rated which the MTM people admit brings them somewhat closer together. Besides, each comparison of this kind is made under circumstances which enable the ratings to be manipulated either consciously or unconsciously so that the final results will be close to each other. It is worth repeating that, in any event, the practice of rating element or motion data has no meaning unless the elements or motions involved are established to be independent. As we have seen, this is not usually the case with elements and motions as currently defined.

Another reason why the checking process used is unacceptable is that the published comparisons of standard data and time study values are usually analyzed incorrectly. A correct analysis often shows that the results being compared are actually quite far apart rather than quite close. In one example from the MTM book, the average difference reported was less than 2 per cent whereas further analysis showed that the average difference was actually over 7 per cent.

The plain fact is that standard data do not give results that are scientifically valid in the sense of precise prediction. In fact, these results usually have an unknown degree of precision. In practical terms, this means that the current use of standard data has empirical value in the following restricted sense. Standard data can provide reference points which are acceptable to management and labor as usable guides within the framework of collective bargaining. They should thus be labeled as usable empirical guides, and no claim should be made that they are either accurate or precise.

It should be added that direct time study estimates are vastly superior to standard data estimates in any case. Even though they too give relatively non-precise results, direct time studies have the crucial advantage of reflecting actual work performance. An average cycle time value obtained in this way can at least be said to have some direct relation to the "true" cycle time value. Even then, all that is obtained are reference points that are usable in an empirical sense rather than precise in a scientific sense.

Question: In view of your earlier comments, are we to conclude that you doubt the worth of incentive-wage plans for increasing production effectiveness? Dr. Abruzzi: There is no doubt that incentive-wage plans generally increase both production effectiveness and worker earnings, sometimes substantially. However, it is also important to realize that such plans have only a limited and temporary incentive value. Thus, the incentive may raise the average output by, say, 25 per cent and average earnings by a corresponding amount. But once the full incentive effect has been realized, no further substantial increases take place and both production and earnings become stabilized at a new level, which workers and management come to consider the expected normal level.

This means that industrial engineers should seriously consider the use of non-financial incentive plans in addition to incentive-wage plans. Such plans are much more likely to be continuous in their incentive effect, especially when they bring out the worker's interest in his work, workplace, and product. It is only by creating such a continuous incentive environment that industrial engineers can obtain truly optimum production effectiveness.

PRESENTATION AND INSTALLATION OF PERFORMANCE STANDARDS AND INCENTIVE

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San Francisco, California

Mr. Chairman and guests, I am indeed honored in having this opportunity of speaking to you. The subject selected by your general chairman, Presentation and Installation of Performance Standards and Incentive, is a challenge. It directs our attention to an important practical matter rather than the highly technical aspects of our profession.

I intend to highlight some of the problems connected with the subject of discussion. Principal emphasis, however, will be directed to the procedures utilized in the United States Steel Company in our endeavor to minimize these problems and make our incentive applications effective. The thoughts to be presented are not applicable only to one form or philosophy of wage incentive. I believe that the policies and procedures we apply are suitable for the application of any form of incentive plan.

I sincerely hope that you may find our experience helpful and of practical application in your own work.

Completion of a wage incentive application involves a tremendous amount of skilled technical work. This effort is expended, of course, for the purpose of attaining substantial benefits for the employees and company alike. However, I am certain that many of you have shared our suspicion that all too often the end results of such effort were less than satisfactory; that too many good facts remained undemonstrated, and consequently unsold; and that intended benefits were not realized because of failure to demonstrate that the incentive application and work involved were fairly conceived and fairly concluded. Clearly, the incentive application emerging from such exacting form of work warrants most careful attention in its subsequent processing to insure that the desirable objective is realized and the effort not wasted.

United States Steel Company's objectives in this matter of performance standards and incentive are threefold, namely:

1. To present the pertinent facts in a manner that will facilitate their review and approval by members of management charged with this responsibility;
2. To present to the employees and Union representatives, in a concise and understandable form, such information as may properly be required to demonstrate the fairness of the proposal and its mode of operation; and
3. To secure benefits of reduced unit costs and increased employee earnings through successful application of an incentive wage plan.

The last stated objective is self-explanatory; it is generally attained, however, only to the extent that the first two objectives are realized.

Let us consider the referred to presentations in their order of occurrence. The first need is to display the results of industrial engineering effort for management review and approval. Such action is necessary to insure that the application:

1. Has been developed consistent with policy and procedure of the Company's established incentive practice;
2. Meets the requirement of the Labor Agreement and can be installed properly;
3. Meets the needs of accounting application and administration; and
4. Is subject to proper maintenance.

Assuming the standards to be fair and properly developed, of next importance to the eventual success of the wage incentive is the matter of presentation to the employees. Presentation and application of the performance standards and related rates of pay provisions require handling in such manner as to afford:

1. Adequate advance explanation to Union representatives and employees affected;
2. Reasonable review as to the fairness of the performance standards if such questions are raised; and
3. Current information to employees regarding their performance and earnings under the incentive.

In order that management and employee reviews can be accomplished with a minimum of administrative burden, adoption of a standard form of presentation is necessary. This procedure insures that the pertinent information is presented in a concise and understandable form. Standardized presentation sets the stage for portraying the facts and telling the industrial engineer's story effectively; it enhances the likelihood of acceptance of the proposal on the part of all concerned.

In our Company, the proposed performance standards, referred to as standard time values, and details of application, are assembled in a brochure. This brochure consists of standardized sections uniformly providing certain essential information. While the form and order of presentation could be altered for personal preference, we believe the essential content is relatively fixed in nature.

Slides have been prepared illustrating our incentive application brochure. As each brochure section is shown on the screen, we can examine its purpose and typical content. Our example is developed in terms of a nail keg assembly operation, but we will direct our attention principally to the basic information required for each section.

The first slide pertains to the Identification and Statement of Contents, which appears as the first page in each application. Its use and purpose is self-evident; it identifies the Company, Works, and Department involved as well as the particular equipment or unit to which the incentive applies. The Statement of Contents identifies the substance of each brochure section and is uniform in each application. The installation date of each application is entered upon its determination.

The reverse side of this sheet is used to set forth the basic principles and philosophy of incentive which have been adopted for use. The merits of any particular philosophy are, of course, not under consideration here, but the

INCENTIVE APPLICATION

No. 869-01B

ABC STEEL COMPANY

Any Plant

Wire Products Department

Nail Manufacturing - Keg Assembly

Date of Installation August 17, 1951

CONTENTS

1. **Description of the Application.**
2. **The jobs and their respective job classes.**
3. **The standard time values.**
4. **The units of production and method of reporting.**
5. **Calculation of performances and earnings.**
6. **Information regarding performances at various rates of production.**

SECTION 1

Description of the Application.

A. This application applies to the manufacture of nail kegs and covers a crew of one man per turn assigned to each keg assembly work station.

B. Standard time values have been established to reflect the time required to produce 100 kegs of a given size and to change the keg assembly equipment from one size keg to another.

C. The standard time values are multiplied by the actual units of production to obtain earned standard hours. Performance and earnings are dependent upon the relationship of earned standard hours to actual hours worked.

D. The average qualified employee can attain a performance of 135% and hence, earn 35% in excess of the standard hourly rate.

E. The purpose of this application is to attain performances which will provide lower unit costs and increased employee earnings.

practice of setting forth the principles adhered to by the Company is highly recommended. Such statement aids in conveying full information and understanding as to the principles by which the Company is guided. The Company, by this action, indicates its willingness to proclaim and stand by principles which it believes to be fair and proper.

Section I, which we are now viewing, provides a general description of the application. The intent here is to set forth a simple and concise narrative description of the scope, basis and purpose of the application.

This section provides in brief and general terms the following information:

1. The operation and crew to which the incentive applies;
2. The expression of standard time values and their means of application to the actual production accomplishments;
3. The expected performance and earnings for the average group of qualified employees; and
4. The purpose of the application which is to reduce costs and increase earnings.

SECTION 2

The Jobs and Their respective Job Classes.

Job Title	Code Number	Job Class	Standard Crew Per Turn
Assembler, Cooperage	86918	5	1*

*1 Assembler per keg assembly work station

Section II identifies each job covered by the application as illustrated by the Assembler-Cooperage job in this slide. This section requires a listing of:

1. The official job title;
2. The job code number;
3. The job class, which identifies the job's standard hourly wage rate and base rate under the incentive in accordance with Labor Agreement provisions; and
4. The standard crew for the specified set of conditions to which the performance standards are applicable.

Section III lists the standard time values applicable to the defined units of production for a specified set of conditions. These standard values apply only to the standard crew identified in the preceding section.

You undoubtedly have noted the Section III caption of standard time values. This terminology, which is employed in United States Steel, is synonymous with the terms of performance standards or standards as used by other companies.

As may be noted, this section provides information, such as:

1. A concise statement of the standard time value per unit of production or per occurrence of a job function, tabulated in the form most convenient for proper understanding and application;
2. A brief description of the standards in terms of the operation covered; and
3. The circumstances under which the standards are applicable as identified by the official Methods Description.

Since various references to Methods Descriptions will be made in following comments, it is appropriate to examine the content of such a description at this time.

SECTION 3

The Standard Time Values.

1. Keg Assembly:

Key Size Diameter	Standard Hours per 100 Kegs
10-1/4''	1.25
11-1/4''	1.28
12"	1.35

These standard time values cover all work required of a standard crew from obtaining shook from substorage to placing assembled keg on the chain conveyor.

2. Size Change:

Standard hours per complete change = 0.126

This standard time value covers all work of a standard crew to change the keg assembly equipment from one size keg to another.

****

Note: The above standard time values: (1) are established for the conditions specified as of August 17, 1951 in Methods Description No. 869-01B; (2) will remain unchanged as long as all of these conditions prevail; (3) shall become null and void when and if these conditions are changed; and (4) will be replaced by new standard time values reflecting the change of conditions.

Any set of performance standards are accurate and reliable only for the particular set of conditions and method of operation upon which they are developed. The purpose of the Methods Description is to set forth the specific methods or standard practice and related conditions comprehended by the standards. In our usage, this description identifies the methods for the use of men, machines, and materials. Accordingly, the description states the raw material specifications, the equipment specifications, the process requirements and sequence, and the product specifications for the operation, by cross reference to other records covering these matters; it also provides a diagram of the equipment layout and product flow, a listing of the supervisory, direct or indirect standard labor force, and a description of the method of operation in order of the occurrence of the work elements involved.

We now turn to Section IV, which defines the units of production to which the standard time values apply; it also specifies the means by which the reports of production will be secured. By examination of this slide we can conclude that this section provides information and statements as to:

1. The units of production, weight, count or other measure to be used for application of the standards;
2. The handling of such matters as defective product and unmeasured hours of work; and
3. The manner of obtaining records of the actual production of a crew, and the responsibility for determining and recording such production and other related data.

SECTION 4.

The units of production on which the standard time values are based and the methods by which reports of production will be secured.

1. Units of production

   A. Standard Time Values for keg assembly are based on the unit of 100 kegs of a specified size; they are to be applied only to production which meets the established inspection requirements.
   B. The Standard Time Value for size change from one keg size to another is based on each occurrence of such required equipment change.
   C. Time spent on work not covered by Standard Time Values, if any, shall be identified as unmeasured work and approved by the Turn Foreman. Such hours worked shall be added to the earned standard hours in the calculation of earnings.

2. Reports

   A. Mill Accounting shall compile the report of production and is responsible for its accuracy.
   B. Production of each crew shall be measured by counter on the chain conveyor.
   C. The report of production shall include for each standard crew:
      1. Number of prime and reject kegs by keg size.
      2. Number of size changes.
      3. Actual hours of unmeasured work, if any, as approved by the Turn Foreman.
      4. Assembly equipment number.
      5. Man name, check number, job title, and total hours worked as approved by the Turn Foreman.

By referring to Section V, an assembler, his foreman, or the mill accounting clerk can find instructions regarding the method of calculating performance and earnings. Please note that the information is complete with regard to:

1. A statement of the period of time for which performance and earnings shall be calculated, such as turn, day, week, or pay period;
2. Definitions of the terms used in the calculations, such as earned standard hours, and index of pay performance; and
3. An example of the method of calculating performance and earnings for representative production during the stated period of incentive measurement.

This section is essential for a clear understanding as to what is meant by the terms involved and how earnings are to be calculated.

Our assembler job provides a simple illustration of the content of Section VI. Here we set forth information as to the composition of the standard time values and the performance attainments that are anticipated of the average group of qualified employees. This kind of information is portrayed for a representative cross-section of the types and sizes of products involved in the operation. In the case of machine or processed controlled opera-

SECTION 5. Calculation of performance and incentive earnings.

1. Calculating Period

   Performances and incentive earnings shall be calculated on the single turn basis.

2. Method of Calculation

   The performance and incentive earnings for a turn shall be calculated as follows:

   a. Total earned standard hours = units of production multiplied by the appropriate standard time value.

   b. Total hours of unmeasured work, if any = total man hours of a crew spent on work not covered by standard time values.

   c. Total hours worked = total man hours of a crew on the job.

   d. Index of pay performance = (total earned standard hours plus total hours of unmeasured work, if any) divided by total hours worked.

   e. Index of measured performance = total earned standard hours divided by (total hours worked minus total hours of unmeasured work, if any).

   f. Total earnings = standard hourly wage rate x hours worked on the job x % pay performance (if performance is 100% or more).

3. Illustration

   Suppose the record for a crew on a given turn is as follows:

Item	Units of Production		Standard Time Value	Earned Standard Hours
11-1/4' keg	613	@	1.29/100	7.908
12" keg	205	@	1.35/100	2.768
Size Change	1	@	.126	.126

a.	Total earned standard hours	= 10.802
b.	Total unmeasured hours reported	= 0
c.	Total hours worked	= 8
d	Index of pay performance (10.80 + 0) + 8	= 135%
e	Index of measured performance (10.80) + (8-0)	= 135%
f.	Total earnings = $1.51 x 8 x 1.35	$16.31

SECTION 6. Information regarding performances at various rates of production.

The following table lists representative conditions as to composition of the standard time values and expected index of performance.

Unit	Work & Attention incl. Rest & Personal Allowances	Delay Allowance	Total Std. Time Value	Expected Kegs Per Hour	Expected Index of Performance
10-1/4	1.23	.02	1.25	108	135%
11-1/4	1.27	.02	1.29	105	135%
12	1.33	.02	1.35	100	135%

tions, the expected performances are representative of capacity operation of the equipment, taking into account reasonable delay experience. In all instances, the standard time values include reasonable allowance for rest and personal needs. This detail is not segregated here due to the complexity involved, since such allowances are applied on an elemental basis and they vary as between elements comprising a standard time value.

In addition to the brochure sections just viewed and described, other information may be included which legitimately is of interest only to management. For example, in a given instance it may be desirable to provide a brief history of past wage payment practices on the jobs or operation. Detailed accounting control procedures which set forth responsibilities and methods of verification or audit may be appropriate. Information as to the administrative expense is usually significant in obtaining the necessary approvals. All such factual information as may be deemed necessary is supplied for the purpose of facilitating the required management review and approval.

We have examined the content and format of the incentive application. Let us now consider "how" the application is presented and the industrial engineer's place in the activity of presentation and installation.

Presentation to management and their subsequent review for approval is, of course, important and here the industrial engineer provides an essential service. He is called upon to explain the source and development of the data, and to develop any other related information required to facilitate such review and approval. However, of more interest to us at the moment, is the industrial engineer's function as related to the presentation made to the employees.

Presentation of the incentive to the employees is of serious import to the industrial engineer responsible for its development. The way in which his work is accepted is the principal determinant as to whether he shall have the satisfaction of seeing his efforts put to gainful purpose. The work he has accomplished is of an exacting form. If properly developed and fully understood, the employees and Company will share profitably in the benefits intended.

The first required action is to submit the application brochure for discussion with the Union representatives of the employees. This discussion is initiated by the department superintendent with the grievance committeeman. The superintendent is usually aided by the valuable assistance of the general foreman or turn foreman involved. The industrial engineer is also a party to these discussions. I should also like to add that in our opinion the industrial engineer is well qualified to participate in these "on-the-firing-line" discussions.

In the course of making the studies and determinations involved in developing the application, the industrial engineer acquires an intimate understanding of the operation and of the facts underlying the standards. If he performs his job properly, his close association with the employees concerned should enable him to command their respect and engender confidence in his fairness. The prestige thus earned is most helpful in the satisfactory completion of the phase of activity now under discussion.

Accordingly, it is clear that the industrial engineer can be of real assistance to both the department superintendent and representatives of the employees. His job is to explain the basis of the data, to describe the studies taken and determinations made, and to answer any question that will further proper understanding of the proposal. The industrial engineer can also assist the review considerations by developing any additional information required which is of legitimate interest to the employees.

I do not intend to imply that the industrial engineer should or can take over the responsibilities of the department superintendent or industrial relations department in matters of negotiation. Under our procedures, the presentation of an incentive application is not a question of negotiation. The activity is looked upon as a straightforward submission of factually determined data incorporated into the established pay procedure. Such factual data is expected to stand on the merits of its accuracy and fairness; across the board "horse trading" on standards is not tolerated. It should also be noted that no point of dispute or grievance is yet involved. Accordingly, this phase of activity is conducted solely by the department superintendent, assisted by the industrial engineer and by other line supervisors as required.

These explanatory discussions with the employees are directed at obtaining mutual agreement regarding the fairness of the performance standards and installation of the incentive. If such agreement is reached, installation can be made immediately.

At times, however, it proves impossible to secure such mutual agreement at this point in the deliberation. Stated differences of opinion will exist and further investigation, without practical testing of the proposal, will prove fruitless. If this conclusion is reached after a period of reasonable review with the employees, installation is clearly in order. Frequently, on-the-job experience with the incentive will dispel any concern or questions held by the employees.

How, then, is installation accomplished when mutual agreement is not reached?

Under the terms of the Labor Agreement, management has the right unilaterally to install an incentive in certain situations and is compelled to do so in others. For example, this agreement provides that at management's discretion, an incentive may be installed:

1. On new jobs or jobs not presently paid on an incentive basis; and
2. To replace an incentive currently in effect, which was installed prior to April 22, 1947, and wherein earnings have become submerged because of the higher standard hourly wage scale.

In addition, management is required to replace an existing incentive when changes are introduced in the manufacturing process or methods, equipment, manufacturing or quality standards, job methods, etc.

For purpose of discussion let us assume that mutual agreement has not been reached on an incentive application wherein management has the right to proceed under the contract provisions just described. Installation is then made unilaterally with full explanation given of management's rights in this regard.

The employees may accept and agree to the provisions of the application after a period of actual experience under the incentive. If so, no problem exists.

On the other hand, the employees may continue to question the incentive and the fairness of the performance standards. If so, the employees are amply protected by the terms of the referred to Labor Agreement. They may file a grievance regarding the fairness of the standards and equity of earnings any time within the period of 30 to 60 days following installation of the incentive.

In order to follow the course of the industrial engineer's activities in these matters, we shall assume that a grievance is entered within the stated period. This hypothetical grievance only states that, in the employee's opinion, the application fails to return equitable incentive compensation.

Here, of course, the services of industrial relations play the dominant role in dealing with the employees and processing the grievance. However, their efforts and the eventual resolution of the problem are very much assisted by the industrial engineer. Not to be overlooked in the handling of grievances, is the valuable contribution made by line supervisors, particularly the foremen, in their day-to-day contacts and discussions with the employees. There is no intent to minimize the importance of their function, but in this instance we are more concerned with the industrial engineer's activity.

Discussions conducted by industrial relations are directed at isolating the specific points held in question by the employees. If these questions can be identified readily, the task is simplified. The industrial engineer will be put to work investigating the claims and developing such factual information as will prove or disprove their validity.

Frequently, however, the employee's concern runs to an over-all suspicion of the results, or stems from lack of understanding of all the factors involved. In this case, industrial relations may suggest a comprehensive review of the entire body of supporting data to pin-point questions of real significance to the employees. Again, the industrial engineer is called upon to assist in such review. He will compile and present all required detail of data necessary to further understanding. Additional analyses will be made and other information developed if the need is indicated. Check time studies may be undertaken to verify the original findings or to substantiate the accuracy of a particular elemental time value or delay allowance.

In all of this effort the industrial engineer makes a valuable contribution. His patient review and development of facts will do much to enlarge the area of agreement and narrow the points of dispute. Hopefully, the items in dispute will be isolated to some few points. If so, the reasonability of each side's position probably can be tested by facts. If management's proposal is found to disclose errors or oversights, it can be adjusted accordingly. Likewise, the employees may become convinced of the fairness of management's proposal and drop further processing of the grievance.

There is always a possibility that a point of difference cannot be resolved in the grievance procedure, particularly if it concerns policy or an interpretation of the Labor Agreement. Many contracts provide for resolution of such differences by arbitration. If this step is taken, the work and accumulated data prepared by the industrial engineer is usually helpful in formulating the Company's case.

The foregoing comments elaborated principally upon the function of the industrial engineer in the processing of grievances stemming from installation of an incentive. Reference was also made to the development of various data and the disclosure of a substantial amount of information for the purpose of obtaining agreement on the performance standards and incentive. It would appear advisable now to direct some attention to a consideration of how much information, and the kind of information that should, or could, be submitted for employee review.

One school of thought claims that presentation of the performance standards, a statement of the rules for their application, and an example of the method for calculating earnings is all that is required of management. Under this line of thinking there is reluctance to provide much, if any, additional information in support of the fairness of the standards, should such a question be raised. Concern is expressed that, through careless handling of such data on the part of employees and Union representatives, management may inadvertently disclose for uncontrolled circulation, confidential information regarding operating practices, processes, and costs.

There is obvious merit to this point of view, and the expressed concern is warranted. It must be recognized that it would be quite normal and logical for a Union representative to use and reveal such available information from one company in support of the Union's contention in an incentive dispute of similar circumstances in another company. Certainly, it is undesirable to promote loose distribution of confidential information which primarily is of legitimate interest to management only.

On the other hand, it is difficult to come to grips with the employee's questions and allegations unless all such pertinent data is disclosed and utilized in demonstrating the fairness of the Company's position. Foreclosing this avenue of approach to the issue forces adoption of a most unsatisfactory procedure. The Company must then take the position that standards are to be accepted or argued without regard for the facts involved. This attitude invites the negotiation of standards and their adjustment to resolve issues without any basis of fact in support of the positions taken or conclusions reached. Some people hold to this approach on the basis that, since the development of performance standards is a management function, the employees have no proper interest in the basis of standards development or the facts upon which they were founded. To reject this philosophy, we need only reflect upon the axiom that it is the unknown and uncertain in the problems we face which cause most alarm and unnecessary conjecture.

We in United States Steel Company believe it is proper to permit review of all information reasonably required to obtain understanding of the Company's proposals. We believe such information can be developed, reviewed and judged in a manner that does not jeopardize its confidential nature. We believe that such presentations are necessary to the acceptance and satisfactory operation of an incentive.

In presenting information regarding equipment, processes and operating methods, it does not follow that the data must be released for indiscriminate handling. For example, the Methods Description referred to earlier contains a substantial amount of confidential information. It relates to specifications of the equipment and material used, and provides much detail on operating methods and techniques with respect to speeds, temperatures, drafting practice, etc. This record provides accurate information of conditions on the jobs and operation as well as a process flow diagram of the equipment layout; photographs may also be used.

This description is important in establishing an accurate record of the conditions to which the standards apply. It also serves as the basis for demonstrating the nature of any subsequent changes made to the specified conditions, in order that the performance standards may properly and defensively be adjusted to reflect the extent of change.

This record, as we have seen, is identified in the incentive application brochure. It is available for the employee's review but it is permanently retained by management as an official record and cannot be removed from the plant by unauthorized personnel.

Time study records are frequently reviewed in the discussions previously mentioned. In fact, we always volunteer to review the time study detail with the employees. This practice removes much suspicion which otherwise would prevail. Obviously these comprehensive records of determined facts are important to any analysis of the fairness of performance standards; they must be permissible of review if such review is requested. In similar fashion "recap" and summary information of time study results is reviewed jointly with the employees. Such review is proper and necessary in order that the employees may appraise the reasonability of the many elemental time values, delay allowances and rest allowances going into the composition of the performance standards. Such joint review of official company records is not apt to endanger the confidential nature of the company's information, since the time studies and related data are retained in the industrial engineering department files.

The method of conducting check time studies and reviewing results therefrom is quite important. The studies are generally initiated by an employee request for the purpose of testing or verifying the fairness of the company's proposal. It is not uncommon for representatives of the employees to participate as observers in the conduct of the studies. In such capacity, the observer notes all items recorded by the time study man and he may check the time readings. He has the opportunity of appraising the time study man's leveling or rating as compared with actual performance on the job studied. Following the completion of the studies, the observer may sit in on the recapitulation of the elemental time values, and the development of all data and standards emerging from the check studies. Surely this openhanded procedure is conducive to selling the incentive proposal and it is in no way harmful to the company's protection of its confidential records.

Statistical records providing information such as the product mix and the frequency of delay occurrences by type are also helpful in the discussions. Pertinent information of this sort can be abstracted from official records in summarized form without releasing significant confidential data which also may be contained in the same records. If requested, employees may review the official source records retained by management to verify the accuracy of the abstracted data.

The incentive practice of many companies is to make payment only for prime product. Accordingly, the performance standards reflect a reasonable expectancy of unavoidable rejects and yield loss in the operation. Where such practice is followed, the employees logically are interested in the way such lost production time is taken into account. Any such inquiry usually requires a review of yield results and the amount of product normally rejected for failure to pass the inspection requirements. Historical data and the results observed during the studies are helpful in answering such questions. This type of data is also subject to treatment in a manner that safeguards the company's interests.

One other aspect of the installation of performance standards warrants our attention. My reference here is to the publication and follow-up of incentive application results in a manner which serves the employees' interests and the company's need for control reports.

Previously, a statement was made that the company should supply current information to the employees regarding their performance and earnings. In our opinion, publication of such data is necessary to continued good results, and it is essential to selling the proposal during the time it is subject to question in the grievance procedure. Obviously, understanding of the application's mode of operation and results therefrom are essential to the attainment of maximum performance.

In recognition of this fact, the accounting department publishes promptly the results of incentive performance. The interval of publication is the same as the period of calculation defined in the application, i.e., by turn, by day, by week or by payroll period. Such publication advises the employees and supervisors of the following information, as a minimum, for each standard crew:

1. The number of units of production attained;
2. The indices of measured performance and pay performance; and

3. The earnings realized by each job as compared with the guaranteed earnings of the standard hourly wage rate.

The other type of reporting mentioned pertains to the company's need for reports serving control purposes.

The attainment of maximum performance, capacity operation and minimum costs as well as the proper maintenance of the standards, requires constant analysis by management of the results of application. Clearly, reports designed to facilitate a follow-up of results to insure continued success of the application are in order.

Two different types of monthly reports are recommended for this purpose. The first report should portray detailed information on each individual application. Emphasis here is placed upon the needs of operating supervisors and industrial engineers with respect to complete detail for analysis and trend usage. At other levels of management interest runs more to summarized over-all results totalized by departments, plants and the company. The second report should be designed to evaluate the results of management's effort on their incentive program.

Certain information recommended for presentation is common to each report, differing only in the portrayal on an individual application basis in the one report versus a totalized and averaged basis by department or plant in the other.

This information common to the two reports should provide a comparison of current performance with the performance in the reference period immediately preceding installation of the incentives.

The actual labor cost per standard dollar should also be provided in each report for the current period and reference period. These figures are directly expressive of the direct labor cost and performance results realized. Cost per standard dollar is determined by the ratio of the actual labor cost per earned standard hour to the standard labor cost per earned standard hour.

The effect of paying guaranteed base rates when performances are less than 100 per cent occasions labor costs to exceed one dollar per standard dollar. Accordingly, it is also recommended that both reports indicate the total dollars of such measured losses paid for performance not realized.

Also of interest in both reports is the extent to which product was produced or hours worked where no standards were applicable. The desirability to reduce this figure to zero, if economical to do so, is clear.

The form designed for reporting on an individual basis must provide, of course, appropriate identification of the operation and application number. In addition, this report should specify the expected performance at capacity operation and the standard labor cost per earned standard hour. A trend effect can be accomplished by publishing the cost and performance results of consecutive payroll periods on a single report.

The management summary report should also provide information over and above that previously referred to as common to both reports. For example, other items of interest are the number of applications in effect by department and plant, and the extent of incentive coverage attained of all wage roll man-hours worked.

Such a summary report of performance analysis lends itself to the portrayal of another type of significant information. It is possible to identify the actual payroll for measured production and compare it with the payrolls that would have resulted if all current performances less than 100 per cent were eliminated, or had all reference period performances less than 100 per cent continued unimproved. This comparison discloses the direct labor savings yet to be accomplished, and it also evaluates the total direct labor savings actually realized.

These recommended reports of results have been described briefly and in fairly general terms. It is not intended to imply that they warrant little attention. Actually, they are quite important and necessary to the continued suceess of an incentive program. Such reports point up the need to direct attention to particular situations for any corrective action indicated. In this manner, they aid in securing optimum performances with related benefits of improved costs and employee earnings.

At this point, it may be helpful to summarize the ideas I have endeavored to convey regarding the subject of discussion.

1. Statement was made that the intended benefits of incentive application are sometimes not realized for want of developing clear understanding with the employees regarding the fairness of management's proposals.
2. It has been suggested that understanding may be facilitated by use of a standard form of presentation setting forth certain required information.
3. Presentation and installation involves two important steps. The first requires review by management for necessary approvals, and the second step involves review and acceptance of management's proposals by the employees.
4. Considerable emphasis was given to the importance of the industrial engineer in explaining the application and related facts in order that proper understanding may be attained.
5. An argument was advanced that it is essential to utilize all information reasonably required to accomplish understanding on the part of employees, in the interest of securing agreement to management's proposals.
6. The use and disclosure of pertinent information required to realize understanding and agreement can be made without harm to any confidential nature of management's data, and
7. The final suggestion offered pertained to the necessity for issuing reports of results designed with regard to the interests of the employees and the needs of management, in order to insure the continued success of incentive application.

The importance of the subject considered here today, as it relates to minimizing some of the problems encountered in an incentive program, needs no special emphasis in this group. You are all well aware of the need for utilizing thorough and orderly procedures to attain the benefits of an incentive program for the common good of the employees and company.

Clearly, proper handling of incentives does much to improve employer-employee relations and the successful improvement of these relations is most necessary. The degree to which skilled handling of fair incentives contributes to these desirable employee attitudes is directly reflected in employee performance attainments. We can all agree that improved performance with increasing output from industry's costly tools of production is a prime need today for the continued profitability of industry, for the good of our national economy, and for the furtherance of our defense effort.

I appreciate having had this opportunity to relate my viewpoints on this subject. Thank you for your kind attention, and I trust you may find the foregoing comments of interest and value.

PERFORMANCE RATING OF WORK MEASUREMENT FILMS

John G. Carlson
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The people attending the Industrial Engineering Institute at Los Angeles were shown Work Measurement Films* RB530, RB540 and RB580 with two main objectives in mind: (1) to give those in attendance an opportunity to exercise their judgment of performance level and to participate in the "Work Measurement Survey of the Los Angeles Area" by Ralph M. Barnes and W. E. Carroll, reproduced elsewhere in the Proceedings.

Since time was limited it was not possible to show the audience the introductory Work Measurement Films nor to describe the operations shown in the films. Because of this, the average ratings summarized below may not be entirely representative of the group.

Performance rating is perhaps of greatest interest and value to people regularly engaged in time study work. However, we encourage everyone in business and industry to become better acquainted with the methods and techniques of Work Measurement. Operator performance rating is an important one of these techniques and must be given considerations in setting standards.

RESULTS OF WORK MEASUREMENT PROJECT

Film No. RB530
Miscellaneous Factory Operations
Study III

Film Code No.	Amount of Time Study Experience: None	2 Years or Less	Over 2 Years	National Average
G300	115	110	114	122
G305	88	87	90	92
G310	70	68	67	69
G315	122	123	129	135
G320	99	100	104	103
B400	123	116	122	129
HC500	119	120	126	132
MDC600	114	114	124	131
Number of People Making Rating				
	76	33	48	

Figure 1--Results of Performance Rating Survey. The table above gives average ratings of each of the three classifications of people attending the Industrial Engineering Institute at Los Angeles, namely, (1) people with no previous time study experience; and (2) people with 2 years' experience or less; and (3) people with more than 2 years' time study experience.

RESULTS OF WORK MEASUREMENT PROJECT

Film No. RB540
Miscellaneous Factory Operations
Study IV

Film Code No.	Amount of Time Study Experience: None	2 Years or Less	Over 2 Years	National Average
A1300	130	129	135	128
DF1400	116	115	126	121
F1500	117	116	121	117
B1600	93	97	106	109
FP1700	105	106	107	108
P1800	132	132	135	134
C1900	118	115	123	126
HL2000	106	107	114	111
Number of People Making Rating				
	74	33	47	

Figure 2--Results of Performance Rating Survey. The table above gives average ratings of each of the three classifications of people attending the Industrial Engineering Institute at Los Angeles, namely, (1) people with no previous time study experience; (2) people with 2 years' experience or less; and (3) people with more than 2 years' time study experience.

RESULTS OF WORK MEASUREMENT PROJECT

Film No. RB580
Assembling Two Cast Iron Plates - Method C
Study VIII

Film Code No.	Amount of Time Study Experience: None	2 Years or Less	Over 2 Years	National Average
C6000	106	105	103	113
C6100	91	90	89	98
C6200	108	111	112	122
C6300	122	124	125	142
C6400	72	73	72	82
C6500	82	86	84	88
C6600	95	96	97	100
Number of People Rating				
	74	34	47	

Figure 3--Results of Performance Rating Survey. The table above gives average ratings of each of the three classifications of people attending the Industrial Engineering Institute at Los Angeles, namely, (1) people with no previous time study experience; (2) people with 2 years' experience or less; and (3) people with more than 2 years' time study experience.

The "National Averages" shown in Figures 1, 2, and 3 are the average ratings made by experienced time study men from many different industries located in the East and Midwest.

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STUDY OF SYSTEMS OF RATING

People With 2 Years' Time Study Experience or Less

System of Rating	No. of People	Percentage
a. POINT SYSTEM	2	5
b. WESTINGHOUSE	8	20
c. 100% PLAN	26	67
d. OTHER PLANS	3	8

The above table shows that of the people in the category that had two years' time study experience or less who attended the Los Angeles Institute, five per cent used the Point System of rating; twenty per cent used the Westinghouse System (rating skill, effort, conditions and consistency); sixty-seven per cent used the 100% plan, and eight per cent used other plans.

People With More Than 2 Years' Time Study Experience

System of Rating	No. of People	Percentage
a. POINT SYSTEM	12	17
b. WESTINGHOUSE	11	15
c. 100% PLAN	34	48
d. OTHER PLANS	14	20

The above table shows that of the people with more than two years' time study experience who attended the Los Angeles Institute, seventeen per cent used the Point System; fifteen per cent used the Westinghouse System; forty-eight per cent used the 100% plan; and twenty per cent used other plans.

Figure 4

STUDY OF METHODS OF RATING

People With 2 Years' Time Study Experience or Less

Method of Rating	No. of People	Percentage
a. OVER-ALL STUDY	10	26
b. EACH ELEMENT	20	51
c. EACH WATCH READING	9	23

The above table shows that of the people in the category that had two years' time study experience or less who attended the Los Angeles Institute, twenty-six per cent rated the Over-All Study; fifty-one per cent rated Each Element; and twenty-three per cent rated Each Watch Reading.

People With More Than 2 Years' Time Study Experience

Method of Rating	No. of People	Percentage
a. OVER-ALL STUDY	7	13
b. EACH ELEMENT	34	62
c. EACH WATCH READING	14	25

The above table shows that of the people with more than two years' time study experience who attended the Los Angeles Institute, thirteen per cent rated the Over-All Study; sixty-two per cent rated Each Element; and twenty-five per cent rated Each Watch Reading.

Figure 5

*For a description of the Work Measurement Films see "Work Measurement Manual" 4th edition, pp. 15-52 by RalphM. Barnes, Published by Wm. C. Brown Co., 915 Main Street, Dubuque, Iowa.

PRESENTATION OF THE SOCIETY FOR ADVANCEMENT OF MANAGEMENT TIME STUDY RATING FILM

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You engineers and managers attending this Fourth Annual Industrial Engineering Institute are a unique group. You are now going to have the distinction of being the first group of this size and character on the West Coast to see one of the reels of the Society for Advancement of Management's controversial film, "The Rating of Performance." When this film was first shown publicly last April at the Sixth Annual Time Study and Methods Conference in New York City, it created quite a debate over its merits and shortcomings. It is not our intention here today to enter into this controversy. Nevertheless, we are pleased to be able to present to you the highlights of a study that has undoubtedly devoted much effort in searching for the answer to that perplexing question, "What constitutes a fair day's work?"

Many of you, no doubt, have followed the development of this project over the past five years and have anticipated the time when the film would be ready for public display. A few of you may have been members of one of the participating companies and may have personally contributed to the original data through your performance ratings of the operations under study. I am sure that all of you are interested in this very recent and important contribution in the field of performance rating.

Shortly after the end of World War II, in recognition of the evident need for intensive study in the field of performance rating, the Society for Advancement of Management established a Committee on Rating of Time Studies. Under the guidance of this committee, a contract was made with New York University to conduct the study and a full-time project engineer was engaged.

As the result of several years of intensive effort, motion picture films were made of 24 different operations, most of which are quite common in the industrial occupations of today. A few operations, such as "deal cards" and "transport marbles," were chosen as highly representative of many jobs encountered in industrial and clerical work, although they themselves are not common industrial occupations. The 24 operations were divided into eight groups of three each, and each group was filmed on a separate reel. It is one such reel that we are going to see this afternoon. At the beginning of the film are explanatory scenes that demonstrate the methods of performing the operations. In addition, there is a script to be read aloud to the raters as this explanatory portion is being projected. (I shall read to you the explanatory notes pertaining to the three operations we shall witness, although no rating will be done.)

Continuing with the development of the film, after the presentation of these introductory scenes, 15 views of the three operations were presented (five scenes for each operation). All of the scenes for one operation were not shown consecutively, but they were alternated with scenes of the two other operations. A short interval was provided between each scene to allow the rater time to record his opinion of the operator's performance level. In some of the operations, two or more different operators were filmed. However, in most of the operations, all of the scenes were performed by the same operator. All of the changes in performance were real and were produced by having the operators work at a slower or faster rate. The scenes were shown in random fashion, and none of the scenes were necessarily what might be termed the "normal" rate. Most scenes were shown only once, but a few were duplicates.

After the film had been edited, these eight reels with their explanatory instructions were circulated throughout all areas of the country. Over eighteen hundred industrial engineers in more than two hundred different companies rated the performance of the operations. In all, the study took over fifteen thousand man-hours to complete. The rating method and system of allowances (personal, fatigue, and delay or conditional) for each of these participating companies were analyzed by the contract group at New York University. Through a process of averaging, one overall time value was determined, which was expressed as the "allowed time for the average of qualified incentive operators."

Finally, a manual (1) was published tabulating these time values. The booklet also included instructions on how this film could be used to evaluate the performance rating of a company's time study engineers. As I mentioned previously, we have neither the time nor the inclination to engage here today in a discussion of the merits and shortcomings of this film. However, so that you may have a better understanding of it, we should like to present one reel at this time. The reel you are about to see was chosen as quite typical and representative of the operations filmed in the study.

[At this time, Reel Four was projected on the auditorium screen. The three operations involved were: (a) forming an impregnated paper cup on a hydraulic press, (b) cutting cork tubing with a rotating disc knife, and (c) deburring a small steel roller.]

In concluding, it might be appropriate to state what the Society for Advancement of Management (2) claims are some of the advantages to companies that use its film:

1. Creates a better understanding and appreciation of industrial problems as a whole.
2. Improves human relations in industry by reducing controversy in the work measurement process.
3. Allows one company to compare its concept of a fair day's work with another company.
4. Provides a guide for formulating what is an acceptable performance.
5. Improves consistency and accuracy of performance rating.
6. Achieves more uniform and consistent time values among departments.
7. Provides procedure for training in time study rating.
8. Simplifies the rating process and provides objective bench marks for reference.

Contrasted with these claims is the comment which appeared in Fortune (3) that Walter Reuther, President of the United Auto Workers (CIO), has issued a memorandum to his officers and department heads that "the S. A. M.'s rating film should be given no status in any of our plants, and that it should under no circumstances be accepted as an objective standard for the settlement of time-study disputes."

Finally, we have the comment of William Gomberg of the International Ladies' Garment Workers' Union (AFL), who made the following statement at this same rostrum during our Institute (4) a year ago: "It is therefore sheer nonsense to talk about measuring a fair day's work independently of the wages or wage system."

Having presented these conflicting points of view, we leave you to form your own conclusions.

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INDUSTRIAL ENGINEERING RESEARCH SESSION

Session Chairmen· E. P. DeGarmo, Berkeley, February 1, 1952
C. L. Taylor, Los Angeles, February 4, 1952

STATISTICAL DESCRIPTION OF WAGE INCENTIVE SYSTEMS[1]

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At the present time, evaluation of an incentive system is usually based on only the average productivity of the group of workers involved. This average is compared against a desired average figure and conclusions are then drawn as to the relative effectiveness of the incentive. This average is inadequate since it provides no means of evaluating the time standard used or the motivation of the group. The purpose of this paper is to present a more adequate means of measuring the effectiveness of a given wage incentive plan's ability to stimulate worker performance.

The major tool to be used is the frequency distribution curve of worker productivity. In statistical theory, if you are able to get a large enough group of workers and measure a capacity or ability, your findings will distribute themselves as a normal curve similar to the light bell shaped curve of Figure 1. This means there exists a

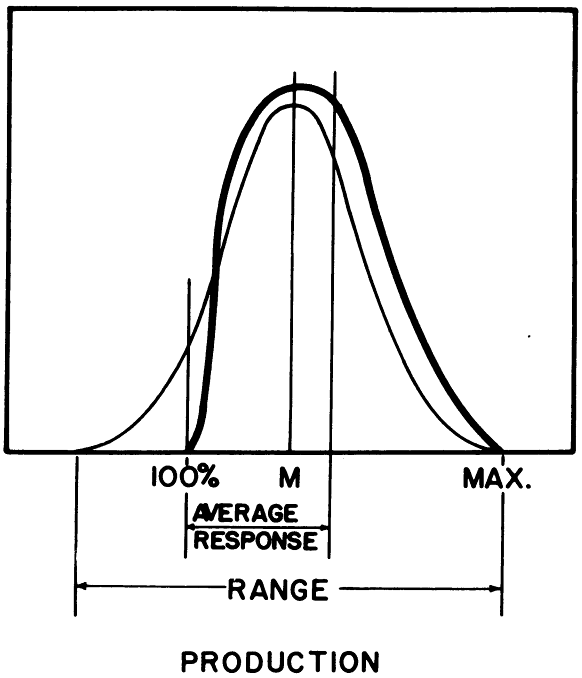

Figure 1--Frequency Curve Representing Effectiveness

normal population of workers possessing any trait we desire to measure. For this discussion, let a "normal" population be defined as 99.5 per cent of the total population which excludes the freaks of the population, namely, 0.25 per cent of the most highly skilled and 0.25 per cent of the most incompetent workers. An employer then draws on this normal population for his workers. An example of a normal population would be all the experienced lathe operators in a given vicinity, which will include both very poor lathe operators and very good mechanics. From this group of experienced operators, management desires to have only the best or the upper portion of the normal curve. However, as can be seen from the curve, the better workers are percentage-wise few in number and management must be satisfied with the large group of average employees. By means of aptitude tests, interviews, etc., management is sometimes able to eliminate some of the very poorest workers.

Let us assume that for a particular job, management hires workers from the normal population. This hired group is a sample from the population and if the workers are selected without tests, etc., its distribution curve will plot itself in a normal fashion. (This is true since the population is normal--then a sample from the population will distribute itself normally.) Since management usually pre-selects its workers in some degree in an effort to secure the better employees, the distribution curve will plot itself as slightly skewed or top heavy to the left. Once the workers are on the job, there is a further weeding out of those unable to make standard and a continual hiring of new workers to replace those weeded out and to replace those lost due to normal turnover. The final result is a skewed distribution, as shown by the heavy curve of Figure 1. Note here that the distribution of the workers' production is all to the right of the 100 per cent or standard line. The average response is the average amount above standard produced by the group and is greater than the population average response, M, as shown in Figure 1. Most standards of work are set with the average worker in mind and are established to produce a certain average response. The figure that experts agree to be the most effective for an average response is 30 per cent.

The skewed curve of Figure 1 represents, therefore, an excellent condition in which employees are producing over standard and the average response is greater than the population average response. However, this is true only if the group is motivated to produce beyond standard. If motivation is lacking among the employees, then the curve will have a tendency to spread to the left of the standard and the average response will be less than the population average as in C of Figure 2. If the standard is too loose, the curve will appear as in D of Figure 2. It is apparent, then, that the curve's shape

[1]Abstracted from M. S. Thesis performed under the direction of D. G. Malcolm.

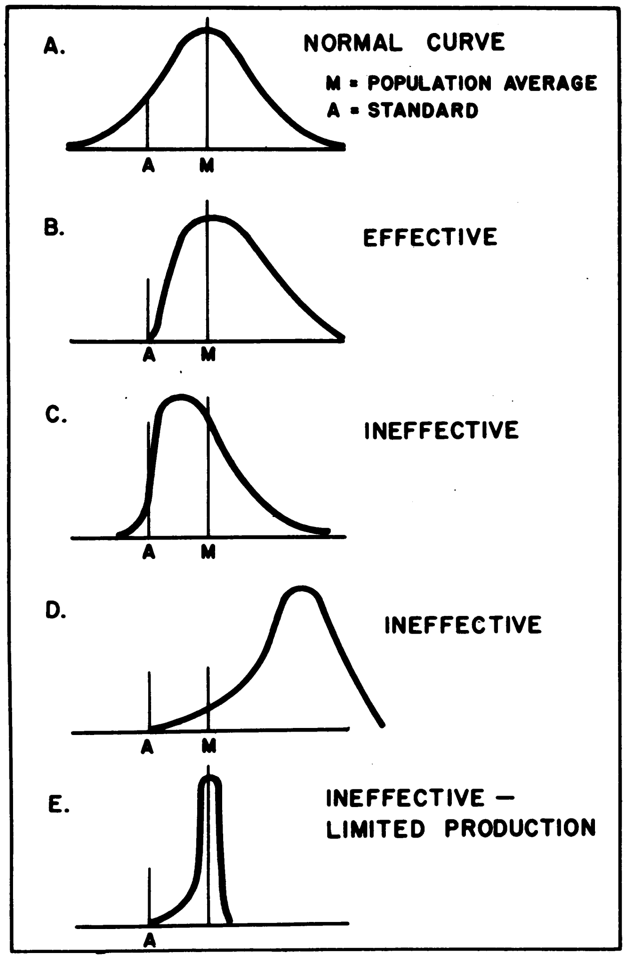

Figure 2--Frequency Curves Describing Effectiveness

and the average response are criteria for evaluating incentive plans.

However, before a complete evaluation can be made, there remains one more item to be investigated, and that is the range or spread of the distribution curve. For our purposes, the range will be defined as the ratio of the highest value over the lowest value on the abscissa taken over definite limits of plus or minus three standard deviations (99.5 per cent). As an example, for a normal population covering six standard deviations, if the best production is 180 per cent and the lowest 90 per cent, the range is 2:1 or 2. The most important factor for consideration when working with the range is that it increases with job or task difficulty, i.e., the more difficult jobs will have greater spreads between the poorest and best productivity than the simpler tasks. It follows, then, that to evaluate any group working on a job, its range must be determined and compared against a standard. Unfortunately, there are no true basic standards established, but only broad classifications, such as 3.5:1 for extremely difficult jobs and 1.5:1 for very simple jobs. However, Figure 3 shows a plot of population ranges against the maximum productivities obtainable (using 100 per cent as standard) from the very best workers of a normal population for various average responses. These particular curves are helpful in evaluating wage incentives in that they determine the maximum production obtainable by the best workers for a given population range and a desired average response. Thus, if a worker produces 180 per cent under a plan designed for 30 per cent average incentive with a task having a range of 2.5, it does not necessarily mean that a loose standard exists, but rather that such a productivity is possible and even desirable that the very best workers achieve this output.

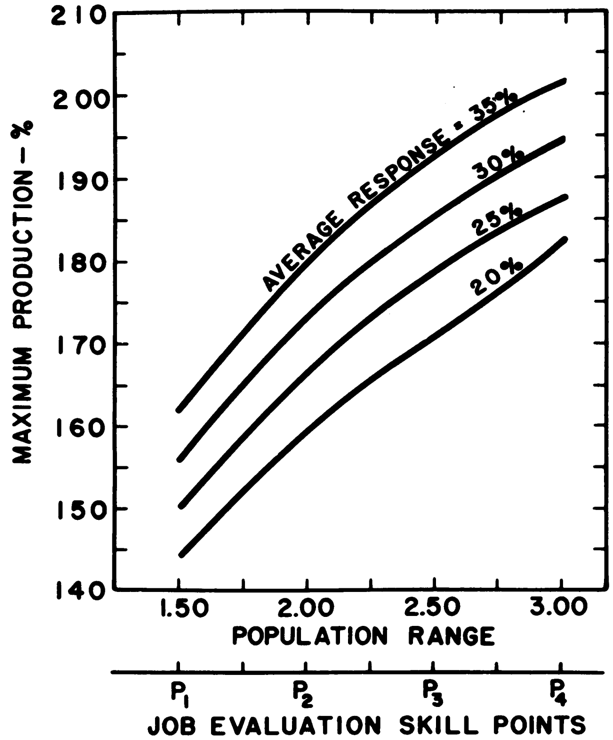

Figure 3--Population Range and Job Evaluation Points vs Maximum Production for Different Average Responses

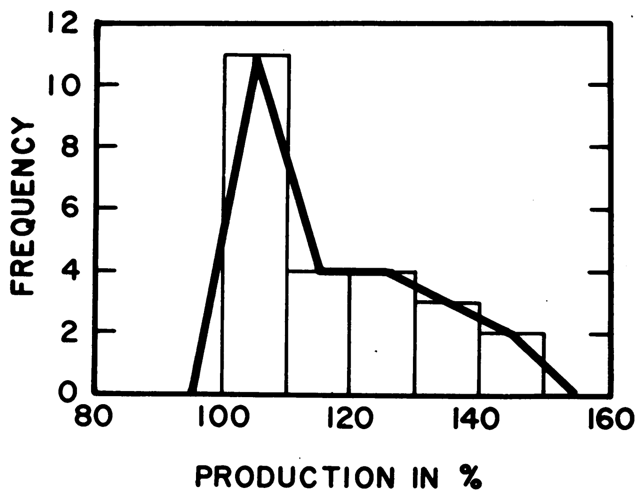

Figure 4--Frequency Curve of Company A

Another possible abscissa for the curves of Figure 3 is to use job evaluation points instead of population ranges. This would fit in well with the many firms who employ weighted points job evaluation plans. However, the values of P_1, P_2, etc. are only the skill components of the total wage evaluation points for any particular task. As each job is evaluated and the points established, the tasks can be grouped according to their skill points which correspond to their difficulty. Therefore, the points along the abscissa represent the wage evaluation points for skill which are directly related to the population range.

In summary, to evaluate a group under an incentive plan, it is first necessary to plot a frequency distribution curve of productivity. Since in practice, group sizes are usually relatively small and do not lend themselves to plotting of smooth curves, the best curve for critical evaluation is a frequency polygon superimposed on a histogram as in Figure 4. This curve's shape, its position relative to the standard, the group's average response and the range, are the factors used for an evaluation of effectiveness. The basic curves of Figures 2 and 3 can be used for comparative purposes. Any abnormalities that come to light, such as a loose standard or poor motivation, can be investigated for information and remedial action taken. The concepts and curves outlined in this discussion were presented as additional tools for management in evaluating wage incentive plans. It is by no means complete and exhaustive, as there are many points that require further investigation. However, it is hoped that the introduction of these new concepts will be of use to management and also bring about further studies in this field.

EVALUATION OF A MULTIPLE-IMAGE TIME STUDY RATING FILM

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Of all the problems encountered in the field of time study, none is as controversial in nature as that of performance rating. In spite of the fact that much research has gone into attempts to find an objective approach to this problem which would be acceptable by labor and management alike, the fact remains that today, performance rating, practiced in a dozen different ways, is still a hotly contested issue on the industrial scene and probably will remain to be a trouble spot as long as subjective judgment is required for the determination of work standards.

The basic difficulties of performance rating rest in its two inherent problems, the validity of a normal rate of performance established within the as yet unknown physiological and psychological limitations of the human body, and secondly, the reliability of rates set by time study engineers in reference to a valid or assumed normal rate of performance.

This study was undertaken to probe further the second only of these two problems, that of reliability, in an attempt to find an objective rating technique which will permit time study engineers to rate more accurately and consistently with respect to a previously established standard rate of performance. The approach followed in this study was to develop and evaluate a multi-image rating film. The multi-image film (IE-2) used for this test showed six simultaneous images of the operation to be rated, these being at the 70-85-100-115-130-145 per cent paces, where 100 per cent is defined as the normal pace of performance for this study. The operation to be rated was the loading of an indexing plate with two steel bearings. This operation simulated the placing of a part into the nest of a dial plate of an industrial dial feed type punch press. The same operation was shown in 30 varying performance paces on another film (IE-1).

Two tests in all were made. Test #1, which was designed to evaluate the multi-image rating film as a training device, was made during the Third Industrial Engineering Institute of the University of California.[2]

[1] Abstracted from M. S.-Thesis performed under the direction of D. G. Malcolm.

[2] Proceedings of Third Industrial Engineering Institute, University of California, Berkeley, 1951. Results of the above test are included in article "Time Study Rating Films" by D.G. Malcolm and E.S. Valfer, pp. 45-47.

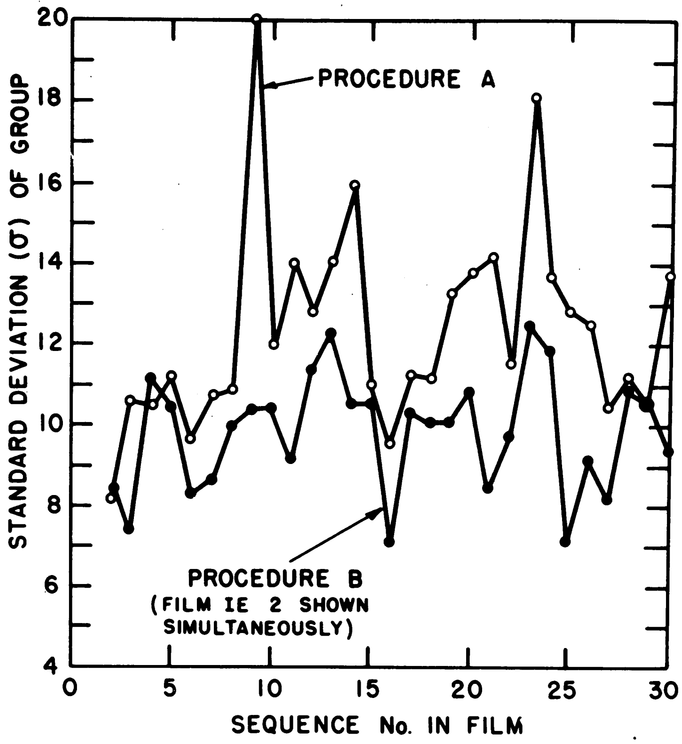

Figure 1--Group σ vs actual rating Film IE No. 1 Combined Data (Proc. A & Proc. B)

The engineers who attended that Institute were the subjects of Test #1.

Test #2 tested the hypothesis that more accurate and consistent ratings can be made if the time study observer is shown a constant visual multi-image reference while rating an operation. One hundred and two subjects from Bay Area industries and the University of California were tested in this part of the study. Each subject was tested under two procedures, A and B. In Procedure A the group rated the 30 sequences of film IE-1 after it had first familiarized itself with the six performance paces shown in film IE-2 (the multi-image film). This testing procedure was identical to that given group #1 during Test #1 referred to above. In Procedure B the multi-image film IE-2 was projected on a second screen simultaneously with film IE-1. By this procedure, the group was given a continuous reference while rating the 30 sequences of film IE-1.

Table I shows the results of Test #2. The analysis of this data indicates a significant improvement in rating consistency at the 5 per cent level of confidence (or better) on 19 of the 29 rated sequences for Procedure B. The rating consistency for both procedures as indicated by the standard deviation is shown in Figures 1 and 2. From Fig. 2 it is evident that the greatest improvement in rating consistency was exhibited in the high and low ranges of the rating scale. The most consistent rating for Procedure A is indicated slightly above the 100 per cent pace of performance. This fact is in agreement with the findings of Test #1. Figure 3 shows the group standard deviations for all four testing procedures of Test #1 and #2 vs. the actual rating. Although Procedure 2 Test #1, and Procedure A, Test #2 were identical testing procedures, it is noted that the two curves do not exactly coincide. This is due to the fact that different subjects participated in the two tests. Making allowance for this fact, it is seen that the progress of improvement in rating consistency flattens the profile of the standard-deviation curve from the U shape exhibited for Procedure 2, Test #1, unaided rating, to a straight line with a slope of approximately 8° for Procedure B, Test 2, (the simultaneous use of the multi-image film).

Fig. 4 depicts the average ratings for the groups under Procedures A and B of Test #2. As in Test #1, there was no significant difference in the rating accuracy of the group means. This is due to the high original accuracy of the group means which limited possible improvement. Improvement of rating accuracy of some individuals is indicated in this study by the improvement in group consistency, since a better group consistency indicates that more individual ratings fall within acceptable rating limits, and therefore, the accuracy of some individuals must have improved.

This study also indicated that ability to pace rate an operation new to an observer does not seem to depend on the length of rating experience of the observer. In fact, more consistent ratings were obtained from a group of completely inexperienced time study observers than from four groups of experienced engineers.

Results of this study indicate the following possible industrial applications for multi-image rating films:

1. Test #1 indicated that the use of multi-image rating films for training of time study engineers tends to improve their ability to rate more consistently as a group, and hence that some individuals will rate more accurately.

2. Test #2 indicates that the use of the multi-image reference film simultaneously with the film of an operation to be rated, should tend to insure more consistent ratings. This application should be studied.

3. Test #2 also seems to indicate the feasibility of developing a rating technique in which the time study engineers use a multi-image reference film at the plant location where the time study is to be made. This application of the reference film should be studied in the actual line situation.

It may therefore be stated that this study has shown that further exploration of the use and application of visual reference techniques in time study may help to achieve more consistent and accurate ratings and as such, contribute to establishing a more reliable rating technique.

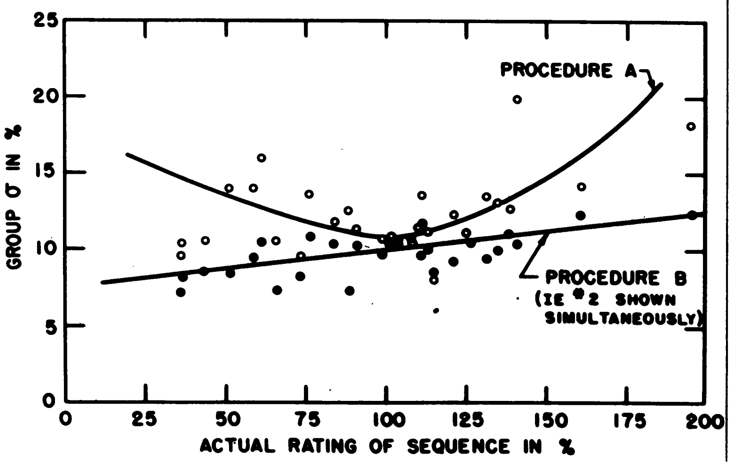

Figure 2--Group σ vs actual rating Film IE No. 1 Combined Data (Proc. A & Proc. B)

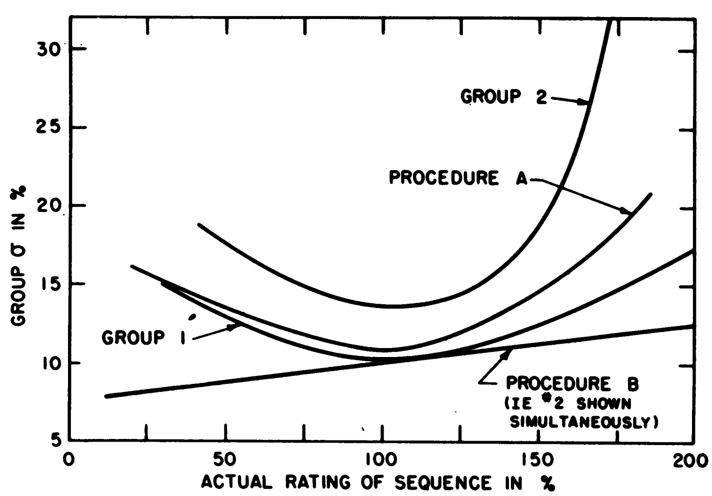

Figure 3--Group σ vs Actual Rating Film IE No. 1

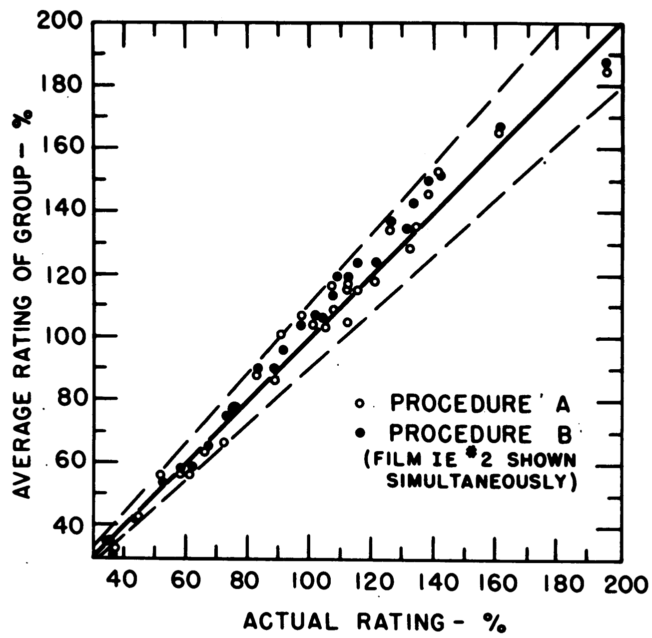

Figure 4--Plot of Average Ratings of the Combined 5 Groups and ± 10% Error Lines Film IE No. 1

TABLE I

GROUP AVERAGE RATINGS AND STANDARD DEVIATIONS FOR TEST #2							
		Test Procedure A		Test Procedure B			
Sequence No.	Actual Rating %	Average Rating %	σ_A	Average Rating %	σ_B	$F = \frac{\sigma_A^2}{\sigma_B^2}$	Level of Significance of F Test %
1	100	-	-	-	-	-	-
2	115	115.6	8.2	123.9	8.5	-	-
3	66	63.8	10.7	65.3	7.4	2.09	½
4	108	116.9	10.5	120.1	11.2	-	-
5	126	134.1	11.3	137.9	10.2	1.21	-
6	73	67.8	13.0	74.8	8.4	2.42	½
7	44	42.3	10.7	43.0	8.7	1.52	5
8	98	107.5	11.0	104.8	10.1	1.21	-
9	142	153.0	17.7	152.1	10.4	2.88	½
10	84	89.4	12.0	89.9	10.5	1.33	10
11	59	57.8	14.1	58.6	9.1	2.40	½
12	139	147.0	15.1	149.6	11.2	1.83	½
13	162	164.5	14.2	167.4	12.4	1.32	10
14	62	56.6	16.1	58.5	10.3	2.43	½
15	102	104.0	11.1	106.8	10.6	1.11	-
16	36	35.7	9.5	35.9	7.2	1.79	½
17	91	101.2	11.3	97.1	10.4	1.20	-
18	113	117.6	12.0	118.9	10.1	1.45	5
19	135	137.4	13.3	144.4	10.2	1.74	1
20	76	77.8	14.2	78.0	10.1	1.96	½
21	52	55.9	14.2	54.5	8.6	2.75	½
22	111	116.9	11.6	117.2	9.8	1.39	1
23	196	184.8	18.1	186.8	12.5	2.10	½
24	112	105.4	13.7	117.1	12.0	1.32	10
25	89	87.7	12.8	90.8	7.2	3.17	½
26	121	119.0	12.5	125.0	9.2	1.85	½
27	37	32.4	10.4	31.3	8.3	1.57	2½
28	108	109.5	14.0	113.3	11.0	1.62	2½
29	104	103.4	10.6	106.4	10.2	-	-
30	132	129.4	13.8	135.6	9.6	2.06	½

TESTS FOR INSPECTION TECHNIQUES

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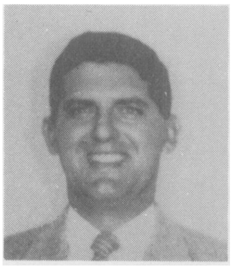

Often industrial work methods are set up with little thought given to how such methods will affect the operator or the operator's performance. Partly responsible for this neglect is a lack of adequate information. This report is a summary of an investigation of different work methods used in the visual inspection of surface defects, and is an outgrowth of an investigation originally undertaken at the University of California and reported in the Proceedings of the Third Annual Industrial Engineering Institute.[2]

Basically, this study concerned itself with the ability of an individual to visually inspect material as it moved on a conveyor belt. It proposed to study how the ability of an individual to inspect was affected by the manner of presentation of the material, by the position of the inspector relative to the flow of material, and the size of the material.

Inspectors worked at a specially designed conveyor table which imparted a rotary motion to cylindrical inspection specimens as they traveled on a conveyor belt. Defective specimens, indicated by a mark on the periphery of the cylinders, were removed from the conveyed material as it passed by the inspector. The criterion used to measure an inspector's performance was termed "inspection efficiency" and defined as the ratio of defective units removed by the inspector to the number of defective units in the sample, expressed in per cent.

Two positions of the operator relative to the flow of material were investigated. One position required the operator to stand at the side of the conveyor and the material flowed in a lateral direction. The second position had the operator standing at the end of the conveyor belt and the material flowed directly towards him. Contrary to expectations, the results showed that the direct approach of material was a less efficient position of work. Inspection efficiencies at the side position were consistently higher than those at the end position. Generally, the operators experienced a greater difficulty in grasping cylinders from the end position because of the oncoming motion of the cylinders.

Tests were conducted to determine the effect of presenting material in various manners. Cylinders were passed by an inspector singly, two abreast, three abreast, and four abreast. Inspection efficiencies dropped off as the number of specimens abreast increased, however, not by proportional amounts. Obviously, as the number of specimens abreast increased, the time to inspect a given number of specimens decreased. To adequately evaluate and compare the different tests, time and efficiency must be reconciled against each other. In some industrial applications, time may be more important than efficiency over a limited range.

When two or more cylinders abreast were presented, the end inspection position produced better efficiencies than the side inspection position. This reversal of the previous tests may have been due to the ease with which the inspectors could reach over wider portions of the conveyor belt from the end position.

Previous investigations with 2-1/2" diameter cylinders seemed to indicate optimum efficiencies when the cylinders rotated at approximately 80 RPM as they traveled past the inspector. Tests with 1-1/3" diameter and 3/4" diameter cylinders did not yield similar results but gave high and constant efficiencies over a wide range of rotational speeds. A better correlation was found between efficiency and the number of revolutions of the cylinder per foot of travel on the conveyor table. As seen in Fig. 1, at about two-thirds of a revolution per foot, efficiencies seem to reach a maximum, regardless of the diameter of the cylinders being inspected.

This study has provided answers to some problems involved in the visual inspection of material. It has also served to raise other problems which need to be investigated.

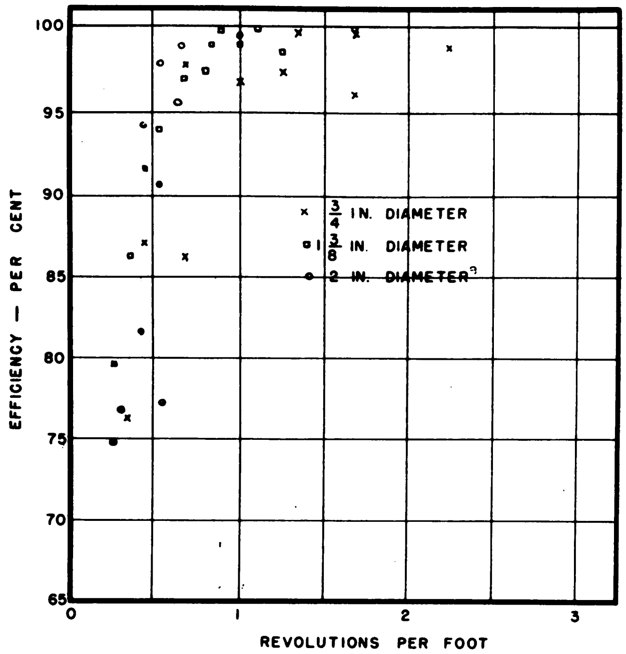

FIG. 1--Mean inspection efficiencies for Tests E and F as a function of the revolutions per foot

[1]Abstracted from M. S. Thesis performed under the direction of E P. DeGarmo.

[2]DeHart, A. L. "Visual Inspection of Cylindrical Surfaces in Combined Translation and Rotation"--Proceedings of Third Annual Industrial Engineering Institute of the University of California, Berkeley, 1951.

AN ANALYSIS OF FATIGUE IN A MANUAL OPERATION

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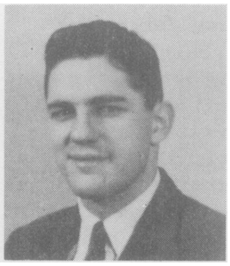


This study reports an investigation made of the variations in worker productivity and work habits throughout the day in a particular plant and for a specific type of operation. It has been noted quite often that a worker's production rate decreases toward the end of the day. Assuming that he is a well-trained and qualified worker, what actually causes this decrease in production? Does he take more and longer rest periods as he becomes more fatigued? Does he change his work methods from those he had been trained to use? Does he slow down all of his manual motions uniformly?

Up to the present time, not much is known about the variations in the operator's work habits throughout the day. Many more investigations had been made on the various types of work output curve characteristics of different types of jobs. A work curve of a job is the production rate versus the length of time at work. The commonest type of work curve found in industry is the work decrement type in which the production rate in both the morning and the afternoon work spells gradually increases to its maximum and then falls off; the overall production being less in the afternoon than in the morning. This work decrement curve is often called the industrial fatigue curve, fatigue being defined as the decrease in quantity and quality of work from the maximum values.

The purpose of the investigation was to determine what factors account for the decrement in work which is considered typical of many types of industrial operations. It is to determine what change or changes appeared in the operator's work habits to cause the decrease in production.

EXPERIMENTAL DESIGN

The study consisted of observing two middle-aged female industrial operators and covered a period of six months. The selected plant was a medium sized metal fabricating plant employing 700 workers. Both operators performed the same task and were paid on a non-incentive time payment basis. The working conditions were pleasant, clean, and quiet. The operators worked a 5-day 40-hour week with two ten-minute rest periods each day.

The selected task was a man-controlled, manual, repetitive operation combining many different manual motions. It was a semi-skilled, light assembly operation in which the operator punched wires into slots and soldered the wires. There was ample opportunity for the operator to change her work method if she so desired. The average cycle time (time to complete one unit) was 4 minutes and the daily production averaged 70 to 80 units.

In order to determine the representativeness of the behavior of the operators during the test period with non-test periods or average factory conditions, the experiment was divided into three separate parts: a pre-test, test, and post-test period. The pre-test and post-test periods were representative of non-test periods or average factory conditions. The criterion used to compare these three periods was the all-day production average, since production is directly dependent upon motivation, the most important variable factor between these periods. Since there was no significant statistical difference between the all-day production averages for the three periods, it can be inferred that the test period was representative of the non-test or average factory conditions.

The data was collected by two principal methods. 1. All-day time studies. During these time studies the production rate, speed of work, and the magnitude and types of delays were recorded. 2. Motion pictures. Motion pictures were taken periodically throughout the day of representative work cycles and were used to record the finer and more minute variations in the operator's work methods than those obtained in the time studies.

RESULTS

1. Actual Work Curves of the Operators--Typical Work Decrement Type. The actual work curves of the operators were of the typical work decrement type in which there was 15 per cent less production in the afternoon work period than there was in the morning period. The top curve in Figure 1 shows the actual average production per hour of the day for one of the operators studied, Operator A.

2. No Significant Slow Down in the Speed of Work. There was no significant slow down or change in the actual working cycle time or any of the element times during the day. The actual working cycle time was the actual working time taken by the operator to produce one unit of work. It did not include the stoppages in work for personal or other necessary reasons, and the time was not adjusted or "rated." The average cycle time was computed every half hour of the day from the all-day time studies. For both operators the average cycle time in the afternoon was only 2 per cent, or about .10 minute slower than it was in the morning. The middle curve in Figure 1 shows the average cycle time per hour of the day for Operator A. It can be seen that the cycle time is relatively constant throughout the day and that there is no discernible trend of the time increasing towards the end of the work period. This shows graphically that the operator's work motions did not slow down and cause the great decrease in production which was described in the previous section.

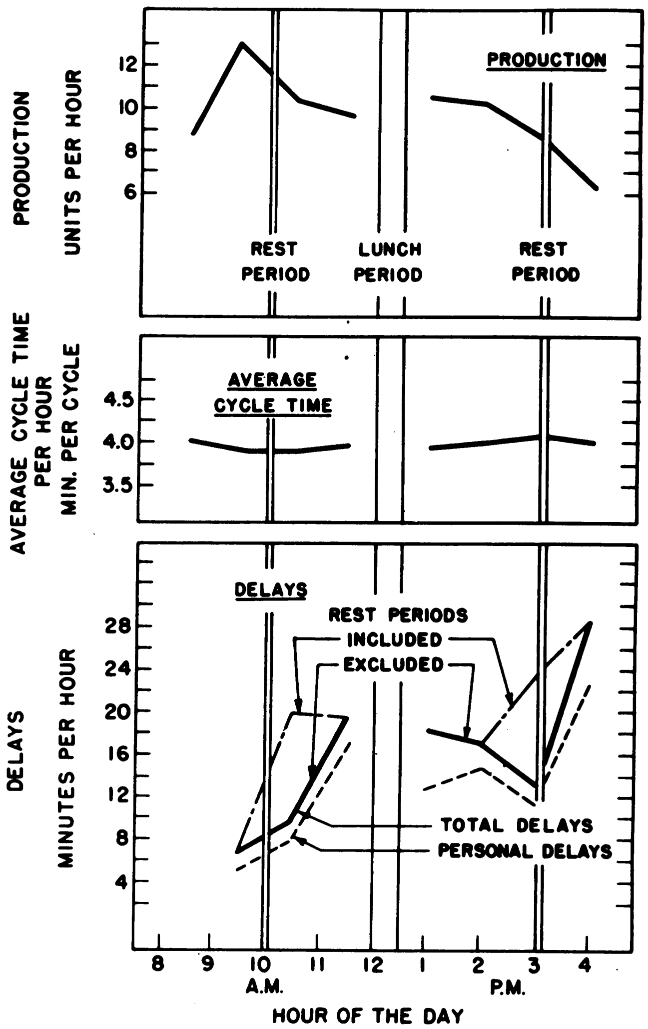
3. Non-Productive Working Time (Personal and Necessary Delays) Much Larger in the Afternoon Than in the Morning--Principal Cause for Decrease in Production. These delays covered all the non-productive working times except the two ten-minute rest periods and the lunch hour. For Operator A the delays in the morning averaged 20 per cent of the 4-hour period. In the afternoon, the delays almost doubled in time value and averaged 34 per cent of the 4-hour period. Comparable values were obtained from the other operator observed. The lower curves in Figure 1 show the average total and personal delays in minutes per hour of the day for Operator A. The great increase in the delays in the afternoon as compared to the morning and in the latter

[1] Abstracted from M. S Thesis performed under the direction of L. E. Davis.

half of each work spell, is clearly seen. The total delay is the sum of the personal and the necessary delays. The personal delays are defined as all the stoppages in work for personal reasons.

4. No Observable Change in the Work Methods Used by the Operators Throughout the Day.

5. Cumulative Loss in Productive Working Time Often Considerable. The cumulative loss in productive working time due to delays and work stoppages is often considerable although the loss in time on any one occasion is generally small. In this study, this loss amounted to 30 per cent of the working day. This value of 30 per cent lost time is corroborated by an investigation in England in which the average lost time amounted to 28 per cent. (Myers, 1930).[2]



6. Personal Delays Averaged 25 Per Cent of the Working Day. The personal delays averaged 80 per cent of the total delay or 25 per cent of the working day. These delays were much larger in the afternoons than in the mornings. They consisted mainly of talking and going to the restrooms.

CONCLUSIONS

1. Work Decrement Curves Not Caused by Slow Down in Motions, but Rather by a Great Increase in the Delays. In many non-incentive, manual, repetitive jobs of the type studied in which production does follow the typical work decrement pattern, the decrease in production is not caused by the operator slowing down his motions or changing his work method, but rather is caused by the operator taking more and longer rest periods. Figure 1, which has been described previously, illustrates this conclusion very well. These curves show clearly that the decrease in production is not caused by a slow down in the speed of work (cycle time) but rather is caused by a great increase in the delays (non-productive working time), principally the personal delays.

It should be noted that this conclusion applies only to non-incentive man-controlled operations in which the operator is able to stop working whenever he so desires. Perhaps, if the task were one where the worker could not stop work to rest, he might slow down his work motions or change his work method. Additional investigations should be made on this type of job.

2. Cumulative Loss in Productive Working Time is Often Considerable. The delays and work stoppages of industrial workers although each instance is often small accumulate and mount up to a large portion of the working day.

RECOMMENDATIONS

It is highly recommended that executives in industry re-examine very carefully the non-productive working times and activities of their factory personnel. Because of the large value of this lost time as shown by this and other investigations, it seems that this area should prove to be a fertile field for improving the overall efficiency of many industrial plants.

[2] Myers, C. S., (Editor), Industrial Psychology, London, Thornton Butterworth, Ltd., 1930.

A STUDY OF THE EFFECT OF MECHANIZED HOSPITAL BEDS ON THE TIME REQUIREMENT OF NURSES

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The mechanical hospital bed described in this paper has been developed over a period of the last eight years under the leadership of Dr. Marvel Beem.[1] The efforts of many engineers have also contributed to the development of the bed which now includes the following specific functions.

1. A self-contained tray, adjustable for eating or reading, with 500 cubic inches of space for the patient's personal items. This tray has pushbutton control panels for both the patient and the nurse. These panels will be described later. Inside the tray is a key-locked compartment containing individual cut-off switches for each of the functions available to the patient. This makes it possible to inactivate any or all the mechanized parts upon doctors' orders.
2. Full-sized flush toilet; sewer connected; adjustable at any angle; beside the patient in twelve seconds. The toilet is so linked to the bed that it can be used outside the bed in an ordinary bathroom position, for ambulatory patients. A novel patented jet provides complete emptying of the toilet at ordinary water pressure with less than a gallon of water.
3. Lavatory with hot and cold running water available from a concealed position in the bed; beside the patient in eight seconds.
4. A self-contained stretcher which eliminates the necessity of purchasing a special guerney or cart for the bed, or of having to move the patient on to and off the cart.
5. Variable elevation in the bed so that the patient can be ambulatory without any help from a 23-inch height which is standard for non-hospital beds, or so that the bed can be 32 inches from the floor, the standard hospital height, for the working convenience of the attendant.
6. Mechanized head, knee, and foot lifts.
7. A self-contained retractable trapeze bar extending the full width of the bed, which is available to the patient so that he can change his position without assistance. This trapeze has a reading light and a standard for intravenous and enema use.
8. An automatic electric timer-controlled oscillation circuit which can cause the bed to oscillate back and forth a total travel of 10 inches about a horizontal axis running along the width of the bed. This oscillator feature has therapeutic value for prophylaxis of embolism in post-operative and obstetrical cases.
9. Two cabinets 12" x 12" x 20" are available for storage of linens.
10. A central hydraulic power plant; a one-half horsepower, 110 volt, single phase, continuous duty, 1750 RPM motor operates a quiet reciprocating pump, which provides about a gallon of hydraulic fluid a minute at pressures four or five times that required to operate the bed.
11. A simple connection through the head of the bed to the roughed-in utilities in the wall makes this bed adaptable either to new hospitals or old installations.
12. The push-button control panel on the nurse's side of the tray which is not available to the patient, consists of buttons for variable elevation of the bed, for disengaging the cart from the bed, for the head and knee and foot lifts, for total off and on power control for the bed, for ambulatory toilet position, and for control of oscillator feature of bed.
13. The push-button control panel on the patient's side of the tray consists of buttons for the flush toilet, trapeze, variable positions, and the lavatory.

The objective of this study was to determine the effectiveness of the bed from the standpoint of reducing nursing time requirements. The hospital selected for this study was the Valley Hospital in Van Nuys, California. This is a privately-owned general hospital of sixty beds. At the outset, a discussion of the research methodology to be used was held with Dr. Ralph M. Barnes, Saadia M. Schorr, a member of the College of Engineering Faculty, and other faculty members interested in the field of work measurement. Then a meeting was held with the Administrator of the Valley Hospital and all the members of the nursing staff, in order to explain the objectives and methodology of the study.

All the nurses on all three shifts were asked to prepare a list and description of duties which they perform regularly. From these lists were selected eight elements or duties which the mechanized bed would eliminate entirely or on which the bed would effect a saving in time. These elements were listed on cards which were given to nurses assigned to the medical, surgical, obstetrical, and orthopedic departments in the hospital.

The eight elements selected were:

1. A.M. Care - This includes the time required for procuring and disposing of bed pans and urinals, bathing the patient, procuring drinking water, and ambulating the patient.
2. Bed Pans and Urinals - time required to procure and dispose other than at A.M. care or P.M. care.
3. Ambulating Patients - time required to help patient get out of and into bed.
4. P.M. Care - Time required to procure and dispose of bed pans and urinals, wash water, and drinking water.
5. Bring patient drinking water.
6. Adjusting patients' position in bed.
7. Transfusions and Intravenous Treatments - time required to procure, set-up, and dispose of special standards for holding the apparatus used.
8. Transport Patient from Bed to Surgery and Vice Versa - time required to procure guerney or cart, pick up patient from bed and place on guerney and vice versa.

In order to determine the average frequency or average number of times each element was performed by a nurse on each of the three shifts, each nurse was requested to keep an exact record of her performance by placing check marks on the aforementioned cards each time she performed an element. These data were obtained for a

[1] A Los Angeles physician, surgeon and member of the American College of Surgeons.

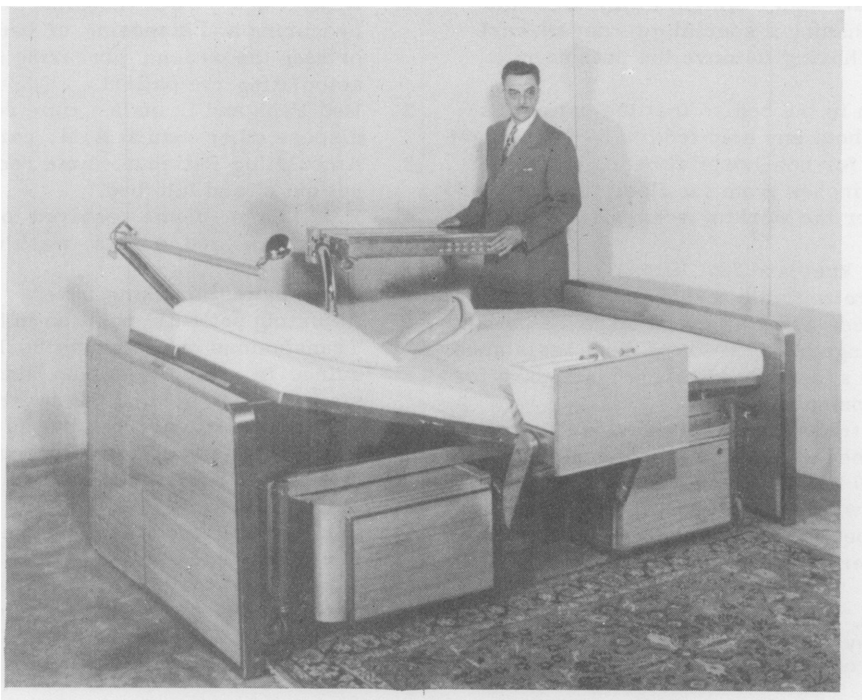
period of seven consecutive twenty-four hour days. The average time required to perform each element was then determined by asking each nurse to record the actual elapsed time for each of the elements listed on the cards. These data were also obtained for a period of seven consecutive twenty-four hour days. The number of nurses who participated in the study were: thirteen on the day shift, twelve on the afternoon shift, and five on the night shift.

The tabulated results indicate that if the mechanized beds were installed in the hospital, a saving in nursing time of approximately forty-six per cent could be realized. In this study, the assumption has been made that all patients in the Valley Hospital could make use of the mechanical features of the bed. However, this is not actually so. Hospital administrators estimate that approximately seventy-five per cent of hospital patients could make use of a mechanical bed. A study to determine accurately this percentage is being planned. It is also planned to establish more firmly and define the limits of accuracy of the results obtained in this study by use of advanced work measurement and statistical techniques.

TABULATED RESULTS

	Column I			Column II	Column III	(Col. II x Col. III)	Column V
ELEMENTS	Average Frequency per Nurse Shift 7-3	3-11	11-7	Total Average Frequency per Nurse per 24-hour Day	Average Savings in Time per Element (in Minutes)	Total Average Savings in Time per Element per Nurse per 24-hour Day (in minutes)	Total Average Savings per Element (Percentage of 24-hour Day)
1. A. M. Care	7	0	0	7	25	175	12. 2
2. Bed Pans and Urinals	12	14	15	41	4	164	11. 4
3. Ambulating Patients	10	10	2	22	5	110	7. 5
4. P. M. Care	0	9	0	9	10	90	6. 3
5. Bring Patient Drinking Water	10	10	6	26	2	52	3. 5
6. Adjusting Patients' Position in Bed	10	12	9	31	1	31	2. 2
7. Transfusions and Intravenous Treatments	6	2	1	9	3	27	1. 9
8. Transport Patient from Bed to Surgery and Vice-Versa	2	1	0	3	5	15	1. 0
						664	46. 0

TOTAL AVERAGE SAVINGS IN TIME PER NURSE PER 24-HOUR DAY: $\frac{664}{60}$ minutes = 11 hours; $\frac{11}{24}$ = approximately 46%



A MOTION AND TIME METHOD FOR THE EVALUATION OF PROSTHETIC DEVICES

M. S. Gottlieb *

Introduction

Since the inception of Artificial Limbs Research, under the auspices of the National Research Council, motion studies have been used for purposes of fundamental research and evaluation. There can be little doubt as to the pertinence of motion analysis since the job of restoring the function of an amputated limb by the prosthetic device involves first, a study of the motions of the natural limb and second, a comparison of prosthetic movement and natural movement.

The present report is concerned with the evaluation of upper extremity artificial limbs. A survey of the literature on prosthesis evaluation indicates that a successful evaluation technique must consider many experimental problems. The foremost problem is the selection of valid criteria upon which to base the evaluation. A second problem is to develop a methodology which enables the experimenter to control the variables which influence the evaluation.

Summary and Classification of Criteria and Methods Previously Used in the Evaluation of Prostheses.

1. Kinematics of displacements, velocities and accelerations. University of California at Berkeley (U. C. B.) applied this technique to lower extremities. University of California at Los Angeles (U. C. L. A.) has employed a similar technique for upper extremity prostheses. This method has the great advantage of measurement objectivity. However, the data reduction requires considerable time.

2. Judgment of the appearance of the performance. New York University (N. Y. U.) has used the concepts of rhythm, body english and economy of motion. International Business Machines Corporation (I. B. M.) rated performance on a six point scale of quality. UCLA employed a four point scale based on naturalness of movement. All of these measures are highly subjective and none of the investigators has reported reliability coefficients.

3. Appraisal of function with respect to the accomplishment of the task. IBM utilized a six point rating scale, based on the facility of the performance. NYU employed the criteria of grasp and release failure and whether or not the task is normally accomplished by the remaining hand. UCLA used a three point scale, based on facility of performance. These judgments, like the preceding judgments of appearance are also of a highly subjective type. Reliability coefficients are not reported.

4. Measurement of time required to accomplish the task. This measure has been used extensively by NYU. The investigators caution others to avoid using time as the sole criterion for evaluation. Time has the advantages of physical measurement, i.e., measured on a ratio scale, but it is, likewise, very sensitive to variations in non-measurable conditions, i.e., motivation, fatigue, etc. From this statement it is apparent that the reliability of time measurements is important. None, thus far, has been reported.

5. Judgments of performance based on miscellaneous subjective criteria. NYU has employed as criteria, fatigue, overt signs of frustration, and lack of motivation. Reliability coefficients are not reported and as in the case of all subjective criteria, the effectiveness of measurement is questionable.

The advantages of the measurements based on a physical scale are apparent. The main disadvantage is the time involved in analysis and data reduction. The disadvantages of qualitative measurements are the difficulty of quantification, the ambiguity of definition and the unreliability of results. NYU concludes that there are two desirable directions in which their work on evaluation of prostheses can go. "The first is the development of more objective methods of evaluation; and secondly, a better definition of the qualitative variables which are necessarily associated with skill in the use of a prosthesis."

The Use of a Classification of Movements as a Basis for Evaluation.

One of the basic problems faced in establishing the method to be described in this report was the choice of appropriate criteria on which to base an evaluation. Many of the principles employed in the previously mentioned reports have been incorporated into the present paper. It was deemed advisable to seek additional methods and criteria for classifying movements and in a manner which would be feasible in terms of analysis time and at the same time have validity in distinguishing one prosthesis from another. The following is a brief survey of selected literature on the classification of movements.

Theoretically, one of the logical criteria for classifying movements is the criterion of energy expended in making a movement. When the arm is moved, muscles are working and energy is transformed. Since the machine for human movement is not one hundred per cent efficient some energy is also dissipated as heat. If the dissipated heat as well as work could be measured, the movement could be classified according to the total amount of energy transformed in making the movement.

At present there is no practical method for measuring the energy transformations involved in single movements. Calorimetric techniques have been employed in experimental situations where activities are carried out over a period of some hours, but the error involved in calorimetry does not permit its application to the problem of classifying single movements.

The importance of measuring body energy transformations is perhaps illuminated by the effect of fatigue. An individual can go through two mechanically identical movements and yet experience more effort in the one carried out under fatigue. Bartley and Chute present a comprehensive discussion of this subject. They point out that observations of fatigue at the psychological level of description have not had satisfactory correlation with observations at the physiological level. It is conceivable that a classification of movements on the basis of body energy transformations may be related to the subjective

*Abstracted from unpublished report, M.S. Gottlieb and C. L. Taylor, A Revised Method of Motion and Time Analysis for the Evaluation of Prosthetic Devices. Engineering Artificial Limbs Research, University of California, Los Angeles.

experience of work. Few such classifications have been attempted and the progress to date has failed to evolve a system which can handle all of the events concomitantly.

Other methods of classifying movements have had greater practical success. These methods employ criteria which may have hypothetical correlation to energy transformations and in some cases they are employed as substitute criteria.

Since the classical works of Taylor and Gilbreth, industrial management has been increasingly motivated to classify movements in order to study the patterns of movement necessary to do a job in the most efficient manner. This led to the "Therblig" system originated by the Gilbreths, which is commonly used today. This system describes the manipulation of objects by the hand i.e., grasp, transport empty, etc., and has used the criterion of time as an adjunct in the evaluation of these manipulations. Typical therblig studies have established characteristic times for various job motion elements and the analysts by modifying the motion elements, have usually succeeded in securing a convincing reduction in time.

Another method of classifying movements is based on Kinematics. The movement in this method is classified according to the Kinetic energy involved in making the movement. The basic difficulty is in analyzing large amounts of data due to the involved experimental and mathematical techniques.

Electromyography has also been used as a technique for classifying movements. Whether or not it will ever be a valid measure of the amount of energy transformed in movement remains to be seen. Shortcomings of the E.M.G. technique involve the instrumentation and the interpretation of records. As yet, there is lack of agreement as to the correlation of E.M.G. with tension developed in muscles and no evidence concerning the correlation of E.M.G. with body energy transformations.

Methods and Criteria Selected as the Basis for Evaluation

It was decided to employ the following methods and criteria as the basis for evaluation:

1. Energy expended in completing a task: The literature review indicated that direct measurement of energy expenditures is unfeasible. The method presented in this paper uses time and extent of movement as substitute criteria. It is assumed that these variables will be correlated substantially with body energy transformations.

2. Appearance of the subject in accomplishing the task: Extent of movement is assumed to be correlated with gracefulness and non-awkwardness.

3. Manipulations involved in completing the task: The therblig classification and associated therblig times are used to describe the manipulations involved in completing a standard activity. It is assumed that manipulative patterns are indicative of prosthetic function.

The method employed is as follows:

The test subject is photographed within a three dimensional grid. A side and top mirror, inclined at approximately 45 degrees to the grid, complete the three views. Coordinate strings across the front, top and right side of the grid supply reference points for estimating extents of movements. A Mitchell* camera photographs the movements at a speed of 24 frames per second. A 50 mm. lens frames the three dimensions from the distance of twenty-five feet.

After developing, the negative is analyzed from the screen of an editing projector.** Therbligs with their respective times and extents of head, torso, shoulder, arm, forearm and hand movements are recorded on a modified SIMO chart by a trained analyst.

Types of Activities on Which to Base an Evaluation

The selection of test activities on which to base an evaluation is a more critical problem than appears at first glance. The upper extremity amputee must be able to perform a variety of activities which will enable him to achieve independence in the motion requirements of vocations, avocations and personal care. While it is true that a prosthetic device can be designed to suit the prosthetic device, it appears a less fruitful objective to think in such terms than to attempt to fit the amputee with a prosthesis which will enable him to meet as many needs in as satisfactory a manner as is possible. This concept of general utility has been the underlying philosophy of upper extremity artificial limbs research.

Granting the appropriateness of this philosophy, evaluation must be based on performance battery which includes all the activities that an amputee should be able to perform. Due to time limitations, thirteen activities have been selected to comprise the motion and time performance battery. These activities are believed to represent an adequate sampling of the types of motions essential for amputees.

The Importance of Reliability and of Controlling Variables

The previous evaluation techniques have not conducted reliability studies. NYU, although they did not investigate the reliability of the qualitative criteria they established (i.e. lack of rhythm, etc.), had four judges rank the subjects (N = 10), in order of their proficiency in the use of their prostheses. The reliability coefficients obtained ranged from .45 to .95.

The aforementioned studies have not stated, specifically, the point of view which is the basis for the motion and time method. Although they have indicated the importance of controlling variables which influence the evaluation, there has been no concise statement of how extensive the control should be. The motion and time method attempts to control all the variables external to the prosthesis while varying known features of the prosthesis. Only if this is done can performance differences be attributed directly to the prosthesis. If factors external to the prosthesis are allowed to vary in an uncontrolled manner, the results will be confused since it is not known to what extent these factors contribute to performance differences.

Accordingly, careful steps have been taken to insure against spurious results. The performance battery has been standardized. All of the test equipment and their position for use have been standardized. Performance plateaus are established before the test subject is photographed in order to control the effects of practice. The test activities are performed at a casual pace of submaximal rate in order to minimize the influence of individual abilities.

*Mitchell high speed 35 mm. camera on loan from the U. S. Veterans Administration. Acknowledgment is made with appreciation.

**Model DVP, Moviola Manufacturing Co.

Purpose of The Motion and Time Method

Regardless of the reliability of the results obtained from motion and time studies, the question of validity cannot be answered before the prostheses to be evaluated are subjected to extensive field testing. Only when a large population of amputees concurs in its appraisal of a prosthetic design, can that design be deemed worthy or unworthy. The motion and time method represents an attempt to predict the results of the ideal field test by conveniently bringing a few amputees into the laboratory and controlling all variables except the prosthetic variable. It is hypothesized that when these variables are controlled, the obtained results will approach those of an ideal field test.

Because of this hypothesis, the generality of obtained results are limited accordingly. Therefore, the immediate purpose of the motion and time method is to establish whether or not a design objective has been attained under the standardized conditions of the test.

Sample Motion and Time Study

Subject L. Q., a below-elbow amputee with a biceps cineplastic tunnel was trained in the standard performance activities. During the first phase of the study, L. Q. performed the activities using his biceps tunnel to obtain prehension. In the second phase a harness consisting of an opposite shoulder loop was utilized for prehension. Care was taken to control extraneous variables to the utmost.

The purpose of the study was to evaluate the following claims made regarding the superiority of biceps controlled prehension over harness controlled prehension for the below-elbow amputee.

1. Biceps controlled prehension permits the subject to perform the standard activities in less time and with fewer movements.

2. The standard activities can be performed with a smaller extent of movement.

3. The proportion of distal to proximal extent of movement can be increased.

The therblig and extent of movement analyses resulted in the following conclusions: In general, the claims made for the cineplastic prosthesis were substantiated.

1. The average time for performing the activities with the cineplastic prosthesis was significantly less than the average time necessary for the harness operated prosthesis (better than the 0.1 per cent level of confidence). This result was also found in the cases of the average number of movements and the average total extent of movements (total angular displacements) for a given activity.

2. The shoulder and arm segments were responsible for the differences between the cineplastic and harness operated prostheses.

3. The only statistically significant difference in therblig times occurred for transport empty (better than the .1 per cent level of confidence). The averages of nine other therblig times were also smaller for the cineplastic prosthesis but not significantly. The harness operated prosthesis was insignificantly better for the therblig, grasp.

4. An analysis of the average extent of a movement indicated little difference between the prostheses. A graph of the frequency of extents of movement showed that for the arm and shoulder segments the harness operated prosthesis made many more small movements, i.e. 5 and 35 degrees, and that this fact was responsible for the significant differences in the average of the total extent of movement for the various activities.

5. An analysis of the proportion of total number of movements and of total extent of movement contributed by each segment indicated that the cineplastic prosthesis provided a greater proportion of distal to proximal movement.

A METHOD FOR KINEMATIC ANALYSIS OF MOTIONS OF THE SOULDER, ARM, AND HAND COMPLEX

Alfred C. Blaschke and
Craig L. Taylor*

The purpose of this paper is to describe a method of kinematic analysis of the motions of shoulder, arm, and hand.

The need for a practical but precise method for shoulder-arm-hand motion analysis immediately arises from research to establish the functional requirements for arm and hand prostheses. Here, the substitution of mechanical equipment for the lost members, enormously complicated by the limited number of controls available from shoulder harness, muscle tunnel, and accessory mechanical controls, poses for the engineer the perplexing problem of putting the functional regain where it will be most effective. It is necessary, for his guidance, to establish the frequency and extent of motions in the natural mechanism as they are involved in the performance of the common activities of daily living. Such data, therefore, figure prominently in the design and evaluation of the prosthesis.

A workable method of kinematic analysis should not long await application to many fields of human biology. It opens the way to dynamic analysis of all types of manual work. The calorimetric techniques for measurement of the energy in such work have long been recognized to lack the specificity and sensitivity necessary for a scientific formulation of the vast array of light activity types. Hence, it is expected that the physical analysis of biomechanics will contribute in a very fundamental way to the investigation of human energetics in manual work.

The method of kinematic analysis involves six steps as follows:

(1) Measurement and calibration of the standard experimental subject.

(2) Fitting of the subject with visual landmarks.

(3) Cinematography of the subject performing the activities under study.

(4) Obtaining the Cartesian earth coordinates of the visual landmarks from selected frames of the developed film, and correcting these coordinates for parallax.

(5) Analysis of the coordinate data to yield the axes and angles of the idealized kinematic system.

(6) From serial frames, obtaining angular velocities and accelerations, potential and kinetic energies and work of the muscular forces of the members of the kinematic system.

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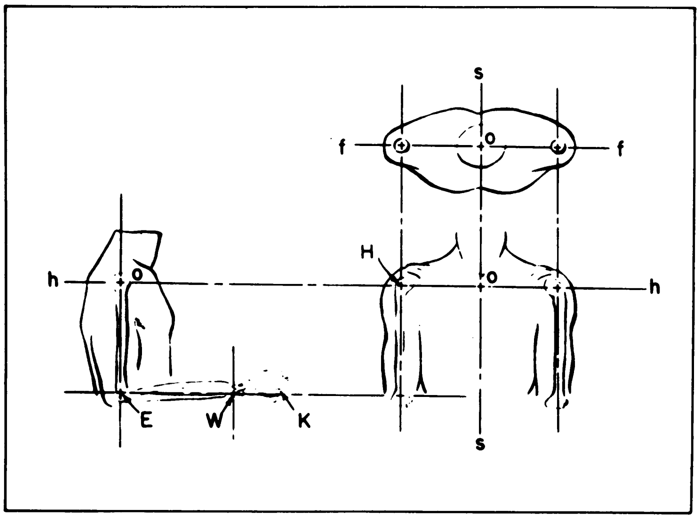


Figure 1--Upper Extremity System in Standard Posture Body reference planes are shown as: ss, sagittal plane; hh, horizontal plane; ff, frontal (coronal) plane. The radial-ulnar wrist axis is vertical through W.

THE IDEALIZED KINEMATIC SYSTEM

Although there are 14 bones whose inter-articulations contribute to the motions in the shoulder-arm-hand complex, an idealized system, composed of four levers, rotating on four centers through a total of nine angles, may be considered to simulate the mechanism. Figure 1 presents the details of this system for the right shoulder, arm, and hand.

The validation of the idealized system depends upon the correlation of information from several sources to picture the various centers and axes.

These sources include: (a) direct measurements of external counterparts; (b) X-ray views of parts of the system to show relationships between visual landmarks and the centers and axes of the idealized system; and (c) plots of the paths made by distal points in the axes while rotating on the assumed centers. In most cases, data drawn from one source may be directly compared with those from another source, thus providing general validation of the assumptions and indicating the limits of motion within which they hold without exceeding acceptable error.

The Shoulder Axis. Center: B, intersection of the humeral center axis (standard posture) by the sagittal plane. Axis: BH, sagittal plane to humeral center. Spherical angles:

This part of the system is the most difficult to define because of the complexity of its skeletal components, which have three articulations, sterno-clavicular, acromio-clavicular, and coraco-humeral, and also the pecular muscular suspension of the scapula. It is beyond the scope of this paper to discuss anatomy in detail, but evidence can be presented to show that, within common limits of motion, the distal part of the system may be taken to act like a hypothetical lever upon a hypothetical center, free to move through two angles. *

The Arm Axis. Center: H, humeral center. Axis: HE, elbow center to humeral center, as established above. Spherical angles: θ_b ; ϕ_b ; t_{HE}, medial and lateral torsion.

The distal end of HE is defined as the midpoint on the axis through the medial and lateral epicondyles of the elbow.

The Forearm Axis. Center: E, the midpoint of the biepicondylar diameter. Axis: EW, axis through wrist and elbow centers. Angles: f_e flexion-extension; t_{EW}, supination-pronation.

The distal end of EW is defined as the intersection of the major and minor diameters of the wrist at the plane of the proximal aspect of the carpal-radial-ulnar articulation. The latter was located in X-ray views.

The Hand Axis. Center: W, at the center of wrist cross section at the plane of the radial-ulnar-carpal articulation. Axis: WM, hand point to wrist center. Spherical angles: θ_b ; $\mathcal{S}_b$.

With W defined above, the only remaining locus to specify is M, the hand center. This is postulated as a point on the palmar pad superficial to the metacarpal-phalangeal joint of the third finger.

THE VISUAL LANDMARK SYSTEM

Since the essential loci of centers and axes of the idealized system cannot be seen, the visual landmarks and their geometric relationships with the system are an indispensable feature of the method. The landmarks are shown in their positions on the subject in Figure 2.

1. The body landmark frame, bearing L_1 and L_2, the lateral axis, and L_3 and L_4, the anterior-posterior axis, is constructed of acrylic plastic components with footings on sternum and thoracic spine allowing freedom of head and shoulders without displacement from the thorax. The standard posture chair, shown in Figure 2, permits the establishment of a definable and reproducible body alignment which serves as the basis of the geometric constructions. The exact setting of the landmark frame, relative to the body, and relative to the body in the chair, established by preliminary measurements, is utilized each time the subject is prepared for motion analysis. The frame is then strapped and taped into position.

2. The shoulder point, L_h, is a simple plastic sphere taped to the shoulder just over the acromic-clavicular point. In our subject, as in most individuals, this point can be located by palpation just lateral to the distal prominence of the clavicle. X-ray views indicate that about 0.25 inch of flesh separate it from the superior margins of the bones. An advantage of this location is the lack of any considerable skin migration on movement which might disturb its relationship to the joint locus.

3. The elbow landmark, L_5L_6, is positioned in the biepicondylar axis just superficial to the lateral epicondyle. Since there is considerable skin migration at this point, caused by forearm flexion, a plastic shell has been fashioned to fit on the dorsal aspect of the forearm, running from the olecranon about 3 inches distally, and turning up the sides to bear over the medial and lateral epicondyles. By strapping and taping in place, this shell holds L_5 and L_6 in their proper locations with negligible variation.

4. Landmarks L_7 and L_8 define an axis through the short diameter of the wrist, normal to EW and in the plane of the radio-carpal joint. They are fixed on a rod which is joined to a molded plastic bracelet.

5. L_M, like L_S, is a plastic sphere taped to the skin. Its location is just over the metacarpal-phalangeal joint of the third finger.

ANGLES AND REFERENCE COORDINATES

Attention has been focused upon the motion of each lever upon its center in relation to the part immediately

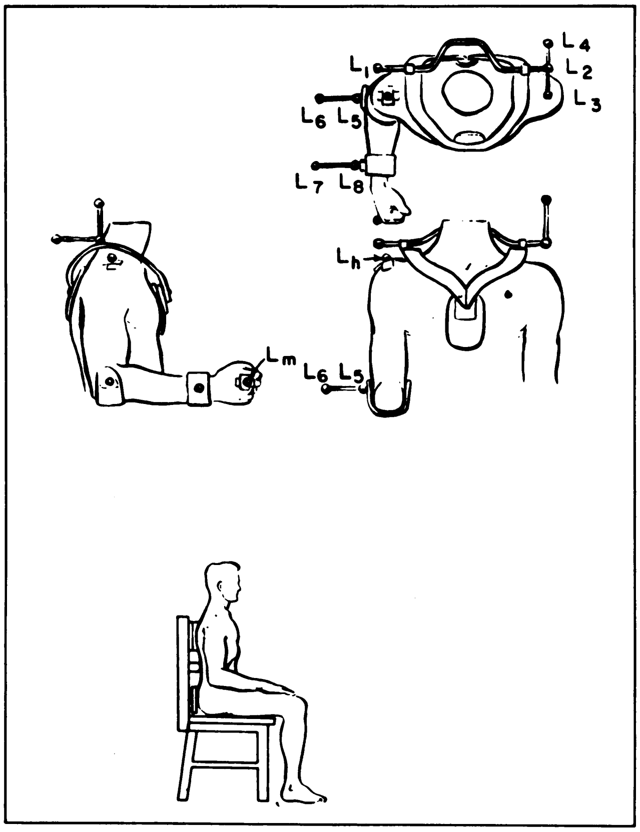


Figure 2--Landmarks and Subject in Standard Posture Chair

proximal to it. This, and the selection of angles, is dictated by a number of considerations:

(a) The muscles of the shoulder-arm-hand complex, with several minor exceptions, are one-joint muscles, and their activity is properly gauged by the movement of a part relative to its proximal part.

(b) The angles $\theta, \mathcal{S}, t$, of the levers are essentially the Eulerian angles of rigid body mechanics.

The basic plan is to construct, at each center in the idealized system, reference coordinate systems to evaluate the axis rotations in terms of the angles made with the coordinate systems. An exception to this is the forearm, which rotates on the elbow as a simple hinge. The constructions required are defined in Table 1.

PHOTOGRAPHY IN THE EARTH COORDINATE SYSTEM

The subject, landmarks in place, is photographed within the earth coordinate system. The details of this setup are shown in Figure 3. By means of a direct front view, and side and top views through mirrors, the position of each landmark in space may be evaluated accord-

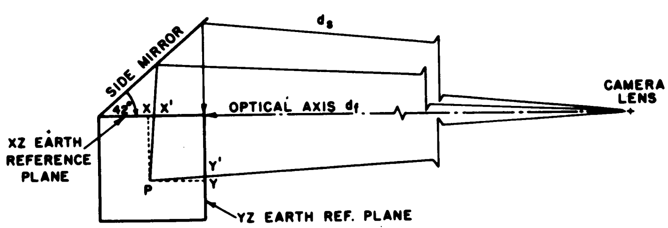


Figure 3

TABLE 1

Axis	Angles	Reference Coordinates (right-handed Convention)
Shoulder	θ_b $\mathcal{J}_b$ (Note: t_{BH} assumed not to exist)	Body coordinate system: Landmark axes L_1L_2 and L_3L_4 become Y_b and X_b axes through B as origin; Z_b is defined as normal to both and passing through B.
Arm	θ_h $\mathcal{J}_h$	Shoulder coordinate system: Z_s passes through H, is normal to BH, and in the plane of Z_b and HB. Y_s is an extension of BH. X_s is defined as normal to BH and Z_s with origin at H.
	t_{HE}	Normal to the plane defined by two positions of HE is constructed. The difference in the angles between this normal and the elbow axis, L_5L_6, in the two positions is the angle of torsion.
Forearm	f_e	Included angle between HE and EW.
	t_{EW}	L_5L_6 is projected upon the transverse plane X_mZ_m of the wrist coordinate system. The angle between this projection and the axis X_m is the angle of torsion.
Hand	θ_m $\mathcal{J}_m$	Wrist coordinate system: Y_m is the extension of EW. X_m is given by the landmark axis L_5L_6 through W and normal to EW. Z_m is defined as normal to Y_m and Z_m and passing through W as origin.

ing to the earth system of coordinates. Two views of apparent coordinates of each landmark are obtained, thus X from side and top, Y from front and top, and Z from front and side. In practice, both coordinates are read when visible. Often, one view is obscured by some body part, so that the availability of the other view is important. When both coordinates are visible, they permit a useful cross-check.

Not shown in Figure 3 are the coordinate scales for each of the views. These were laid off by sighting through a transit, set at the camera position. Thus, the earth coordinate system, as shown in Figure 3, was first constructed, then scales were laid off in two axes for each view, e.g., front, and side and top through mirrors. It should be pointed out that the corrections incorporated in these scales merely serve to establish equivalence with the true earth coordinates at the earth reference planes. Thus, they give values according to the apparent earth coordinates.

From such apparent coordinates, it is then necessary to correct for parallax to obtain the true coordinates of a landmark point. There are 8 possible combinations of apparent coordinates from the three views.

The motions are photographed with a Mitchel camera at 24 frames per second. A lens of 75 mm. focal length frames the three views at the average lens-object distance of 31 feet. After developing, negatives may be read directly or positively printed. The apparent coordinates are read from an editing projector fitted with a rectangular locator upon the screen, so that points in space can be measured from the side scales. Coordinates are read to 0.2 inch.

ANALYSIS BY A MECHANICAL SIMULATOR

In a previous report,* a device known as the Kinematic Analyzer was described. This apparatus has been doubled in size and now is a full-scale system of joints, members, and scales,which is capable of reproducing the major joint rotations of the shoulder, arm, forearm, and hand. Landmarks are places on the analyzer in locations which bear the same relationship to its lever systems which the landmarks of the human subject bear to his skeleton. When the analyzer is adjusted, by use of the coordinates of the landmarks, the angular relationships between its members are comparable to similar relationships in the subject.

Calibration of the analyzer to the pertinent dimensions of the subject required the setting of segment lengths and landmark positions.

The analyzer is positioned upon a horizontal plane table, laid off with rectangular grid lines representing the X and Y of the earth coordinate system. Z distances are found with point locators, set at the appropriate X and Y. With point locators in place, the analyzer is adjusted to bring its landmarks into the indicated locations. To do this, the segments and joints must assume the angular geometry of the original anatomical posture. The analyzer angle scales, scribed to 2 degrees, now indicate directly the desired angles.

ANALYSIS BY CALCULATION

Since the axis lengths of the idealized system are known from measurements given above, the anatomical angles represent the chief goal of the calculation.

Shoulder, Arm, and Hand Systems. The desired angles θ and $\mathcal{J}$ may be calculated after first transforming each axis segment to its corresponding reference coordinate system.

Forearm Flexion-Extension. The included angle between HE and EW may be calculated directly without transformation of coordinate systems.

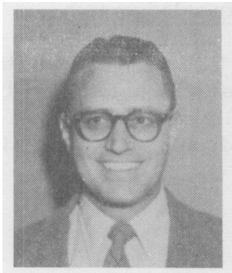
Torsion Angle of the Arm. The change in angle of torsion between any two positions of the arm is equal to the difference between the angles made by the elbow axis L_5L_6 and the normal to the plane containing the two positions.

Torsion Angle of the Forearm. This angle, pronation-supination, is directly obtained from the change in angle between elbow axis, L_5L_6, and wrist axis, L_7L_8, in any two positions.

*"Studies to determine the functional requirements for hand and arm prosthesis," Report to NRC (1947). Department of Engineering, University of California, Los Angeles.

WORK MEASUREMENT SURVEY OF THE LOS ANGELES AREA

Ralph M. Barnes and W. E. Carroll



Purpose of Survey

The object of the study was to determine the operator performance rating, the allowances, and the standard time for thirteen different operations as established by industries located in Los Angeles and vicinity. Only industries regularly using stop watch time study were invited to participate in the survey.

Results

The results of the study (see Table), are of most interest to the participating companies, inasmuch as each company can compare its performance ratings, allowances, and standard times for each of the thirteen different operations with the averages of the thirty-three participating companies. Comparison of performance ratings can also be made with the "national average" for these films.*

Some results of the survey are of general interest. For example, Company 8 rated Operation B1600, Bundle Roofing Shingles at 80 per cent (lowest rating) whereas Company 25 rated this same operation at 135 per cent (highest rating). However, the standard time for this operation was highest for Company 4, due to different allowances which this company incorporated into the standard. Company 8 established a standard time for this job of .68 minute per bundle, whereas Company 4 established the standard time of 1.2 minutes. The average of all thirty-three companies was .95 minute per bundle.

There seems to be no significant difference between the average standard time determined by all companies and that determined by the twenty-four companies using time study as a basis for a wage incentive plan and the nine companies not using time study as the basis for a wage incentive plan.

Participating Companies

All companies in the Los Angeles area known to be using time study were invited to participate in this survey. Thirty-three companies participated and of this number, twenty-four now use time study as a basis for a wage incentive plan, and nine do not use time study as a basis for wage incentives.

*For a description of the Work Measurement Films see "Work Measurement Manual" 4th Ed. by Ralph M. Barnes, published by Wm. C. Brown Co., 915 Main Street, Dubuque, Iowa.

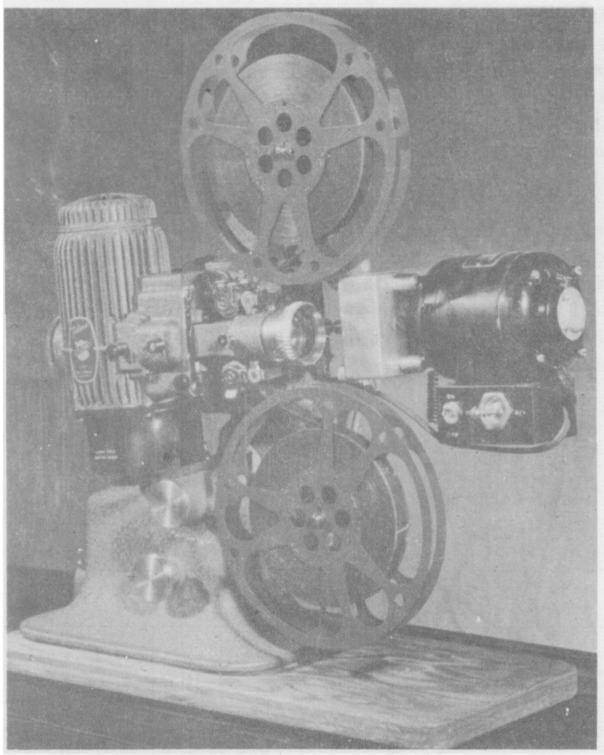


Figure 1--Motion Picture Projector with special synchronous motor drive gives a constant speed of 1000 frames per minute.

Procedure

Silent motion pictures (films RB530, RB540, and RB580) of thirteen factory operations* were projected using a synchronous motor driven projector at exactly one thousand frames per minute. This is the speed at which these films were taken.

The projector, film and screen were taken to the plant of the participating companies and the industrial engineers and time study men were invited to view the films and rate the operator performance level. In some instances, time study men from two or three companies met in the same projection room and rated the films. Each time study man was asked to rate the pace or speed of the operation on the screen just as he would if this job were being performed in his plant. These men were asked to assume that the method shown was satisfactory and to neglect any time required for transportation of material, inspection of finished work, etc. They were asked to rate only the activities shown on the screen. Although all time study men from a given company were invited to participate in the rating part of the study, the chief industrial engineer was asked to select but one answer as the representative data for his company. This was true for operator performance rating, allowances, and standard time.

In some instances, time study men first rated all of the films, then the films were shown a second time, during which the ratings were rechecked and allowances were determined. The films were shown as many times as the chief industrial engineer or time study men requested. Information about each operation was presented

*FP1700, Fill Pin Board was filmed in the laboratory.

and the chief industrial engineer was given the actual cycle time for each operation and the time for each element in the longer operations. Some companies applied the allowances by elements which made it necessary to provide the actual time in this manner.

It should be pointed out that the procedures used in this study have their limitations. In the final report of the project we will describe just how the study was conducted and we will include a copy of the original data which we received from each of the thirty-three participating companies. Since the films used in this survey are available to anyone (on a loan or sale basis) it is possible for a company or group of companies to repeat this study and check the results.

Confidential Data

Inasmuch as we guaranteed to keep all data confidential, we cannot reveal the name of any person or company who participated in this survey. Neither can we reveal the products or any other information that might identify any participating company.

Acknowledgments

The authors want to express their appreciation to all those who participated in this survey and they are especially grateful to John G. Carlson, who assisted with the study and with the analysis of the data.

SUMMARY OF RESULTS OF WORK MEASUREMENT SURVEY

<table>
<tr><th colspan="6">Film No. RB530</th><th colspan="8">RB540</th><th>RB580</th></tr>
<tr><th></th><th></th><th>Grind Casting
G300 to G320</th><th>Bend Copper Tubing
B 400</th><th>Cement Shoe Outsoles
HC 500</th><th>Cut Heel Pieces
MDC 600</th><th>Assemble Carton Cover
A 1300</th><th>Drill Frog for Plow Bottom
DF 1400</th><th>Form Relay Spring
F 1500</th><th>Bundle Roofing Shingles
B 1600</th><th>Fill Pin Board
FP 1700</th><th>Print Carton
P 1800</th><th>Cut Gum Foxing
G 1900</th><th>Label Cans of Meat
HL 2000</th><th>Assemble C.I. Plates
C6000 to C6600</th></tr>
<tr><td></td><td>AT</td><td></td><td>.233</td><td>.105</td><td>.930</td><td>.059</td><td>.443</td><td>.025</td><td>.704</td><td>.453</td><td>.025</td><td>1.11</td><td>.067</td><td></td></tr>
<tr><td></td><td>NA</td><td></td><td>129</td><td>132</td><td>131</td><td>128</td><td>121</td><td>117</td><td>109</td><td>108</td><td>134</td><td>126</td><td>111</td><td></td></tr>
<tr><td rowspan="4">A. Averages for the 33 companies participating in the project.</td><td>PR</td><td></td><td>120</td><td>123</td><td>123</td><td>125</td><td>118</td><td>114</td><td>110</td><td>107</td><td>124</td><td>121</td><td>112</td><td></td></tr>
<tr><td>NT</td><td>.053</td><td>.279</td><td>.129</td><td>1.15</td><td>.074</td><td>.522</td><td>.028</td><td>.775</td><td>.485</td><td>.031</td><td>1.34</td><td>.075</td><td>.294</td></tr>
<tr><td>ST</td><td>.062</td><td>.334</td><td>.150</td><td>1.35</td><td>.086</td><td>.625</td><td>.033</td><td>.950</td><td>.555</td><td>.036</td><td>1.55</td><td>.087</td><td>.341</td></tr>
<tr><td>TA</td><td>69.3</td><td>78.0</td><td>67.6</td><td>71.1</td><td>66.0</td><td>78.6</td><td>65.6</td><td>87.1</td><td>61.6</td><td>66.4</td><td>68.6</td><td>65.9</td><td>65.6</td></tr>
<tr><td rowspan="4">B. Averages for 24 companies using Time Study as a basis for wage incentives.</td><td>PR</td><td></td><td>121</td><td>124</td><td>125</td><td>126</td><td>120</td><td>116</td><td>112</td><td>108</td><td>126</td><td>122</td><td>113</td><td></td></tr>
<tr><td>NT</td><td>.053</td><td>.283</td><td>.130</td><td>1.16</td><td>.074</td><td>.533</td><td>.029</td><td>.787</td><td>.489</td><td>.032</td><td>1.36</td><td>.076</td><td>.295</td></tr>
<tr><td>ST</td><td>.062</td><td>.337</td><td>.151</td><td>1.36</td><td>.085</td><td>.632</td><td>.033</td><td>.958</td><td>.556</td><td>.036</td><td>1.57</td><td>.087</td><td>.340</td></tr>
<tr><td>TA</td><td>69.0</td><td>76.0</td><td>66.0</td><td>69.8</td><td>62.8</td><td>74.8</td><td>62.7</td><td>84.5</td><td>59.8</td><td>63.4</td><td>66.2</td><td>62.8</td><td>63.7</td></tr>
<tr><td rowspan="4">C. Averages for 9 companies <u>not</u> using Time Study as a basis for wage incentives.</td><td>PR</td><td></td><td>116</td><td>120</td><td>120</td><td>123</td><td>111</td><td>109</td><td>105</td><td>104</td><td>120</td><td>116</td><td>108</td><td></td></tr>
<tr><td>NT</td><td>.051</td><td>.269</td><td>.126</td><td>1.12</td><td>.073</td><td>.495</td><td>.027</td><td>.743</td><td>.473</td><td>.030</td><td>1.29</td><td>.072</td><td>.292</td></tr>
<tr><td>ST</td><td>.061</td><td>.327</td><td>.148</td><td>1.32</td><td>.087</td><td>.609</td><td>.032</td><td>.926</td><td>.549</td><td>.035</td><td>1.52</td><td>.086</td><td>.343</td></tr>
<tr><td>TA</td><td>70.3</td><td>83.3</td><td>71.8</td><td>74.8</td><td>74.8</td><td>88.8</td><td>73.4</td><td>93.9</td><td>66.7</td><td>74.4</td><td>75.1</td><td>74.2</td><td>70.8</td></tr>
</table>

AT = Actual Time in Minutes
NA = National Average PR
PR = Performance Rating

NT = Normal Time
ST = Standard Time
TA = Total Allowance

Note: Allowances in minutes per eight-hour shift.

QUALITY CONTROL SESSION

Session Chairmen: A. R. Bailey, Berkeley, February 2, 1952
Don Smith, Los Angeles, February 5, 1952

INTRODUCTION OF A QUALITY CONTROL PROGRAM

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Cluna Lake, California

1. What Is Statistical Quality Control (SQC)?

Whenever a new method or idea has proved successful in several factories, the question naturally arises in the minds of factory managers: Can we use this in our plant? Modern statistical quality control methods have scored some spectacular successes and achieved wide publicity, and have moreover been accepted by the Department of Defense: thus, through defense contracts, they reach into nearly every field of production. It is only natural that factory executives should want to know how this new approach to quality control may affect their enterprises, and what steps they ought to take to secure for themselves whatever benefits it may have for them.

It is first of all necessary to understand exactly what SQC is. It is called statistical because it rests primarily upon the concept of a statistical population. In order to visualize just what a statistical population is, suppose we imagine the process of dealing a hand of, say, five cards from an ordinary pack. We shuffle the pack, deal five cards, note what they are, then return the cards to the pack, deal five cards again, and so on. If we do this many thousands of times, we shall find eventually that a certain average percentage of the hands contains pairs, another percentage three of a kind, and so on for other types of hands. These percentages will remain quite stable if our shuffling is competently done; that is, they will fluctuate slightly, but will never stray very far from an average value which can, of course, be calculated in advance.

The totality of all such hands that have ever been or will ever be dealt from all the packs of cards ever made or ever to be made is called a statistical population. If the packs of cards do not change, and the shuffling is adequate, we say that the totality of all hands constituting the population arises from a constant system of chance causes. The point is that when such a system exists, we can study any convenient segment of the population and infer more or less precisely what other segments will be like in the future. In other words, if a system is statistically stable we can use observations made in the present to predict the future.

All experimental science rests upon the notion of statistical stability. Whenever we test a new type of cutting tool, or take a public opinion poll, or try a new diet for children, or test a new insecticide, we are relying on the stability of nature; we assume that what happens today will continue to happen in the future. Without this assumption, all research loses its meaning. Yet we are all familiar with the possibilities of error that may arise here; samples may be inadequate, and cause systems may change over the years. Thus, the early experimenters with DDT could hardly visualize the gradual emergence of resistant strains of house flies--a change in the cause system that makes prediction impossible.

In some situations, statistical stability is easily achieved. The laws of chemistry and physics appear to have almost perfect stability. Biological systems change due to evolution, selective breeding, mutations, and the like; but such changes are usually slow, and the systems are nearly enough stable for practical purposes. Mechanical and psychological systems may undergo instantaneous transformation; during that instant a man may be overcome with rage or terror, and a machine may be smashed into junk. The great problem of quality control is to attain stable quality despite the inherent instability of the men and machines who turn out the product.

SQC has an approach and a method. The approach is most easily understood by means of a medical analogy. The practice of medicine today is almost wholly confined to the treatment of sick people. A man typically stays away from doctors until his anxiety over his health outweighs his fear of large doctor bills. We can at least visualize a system of medicine in which, through frequent physical checks, the efforts of the doctor would be directed toward keeping the man healthy and arresting disease in an early stage. Typical factory inspection today is like present day medicine; it operates on machines and processes which have become very sick. SQC is comparable to preventive medicine; it seeks to learn so much about the production process, and keep such close check of its operation, that most illness never occurs. If SQC could function in an ideal manner, inspection would be unnecessary.

The method of SQC is much the same as that of preventive medicine. We start with some sick people (or processes turning out inferior product). The illness must be due to something in the environment, or a weakness of the subject, or both. A program of study ensues, from which we may emerge with some such observation as "People from southern states are less subject to tooth decay" or "Children who get plenty of eggs and milk are less likely to have tuberculosis." During this period we keep close watch over as many subjects as feasible, sick ones and well ones too--the doctor with a clinical chart, the engineer with a control chart. We may or may not find the actual cause of the disease, and what we find may or may not lead to practical recommendations for action; many a slum family has felt bitterly ironical when the doctor has ordered for their children plenty of rich, nourishing food. If we cannot arrive at practical preventive or remedial action, our research is unsuccessful; in both medicine and engineering we must accept a percentage of failures. In some cases we shall succeed, either empirically (milk and eggs for children) or fundamentally by finding a cause (fluorine to prevent tooth decay). In one case I know of, production failures were found to arise from faulty illumination; here the cause was discovered, and it was a simple matter to correct the lighting and eliminate the cause. In another case, failures were associated with the presence of a particular individual. Nobody ever found out why, but empirically the problem was solved by transferring him to another area.

2. Importance of Quality Control

The matter of quality control in general (not merely by statistical methods) is becoming increasingly important because of a trend in industry which, if it continues, must eventually lead to a completely new pattern of free enterprise. This trend is towards decentralization of production, together with an increasing utilization of automatic machinery to replace the human hand and eye. If it goes to its logical conclusion, the eventual product of our factories emerges as a series of interchangeable subassemblies, each produced almost wholly by automatic processes and designed in such a way that final assembly into a desired end-product can be accomplished in the home, or in a neighborhood shop with only modest equipment. Our great sprawling factories, with their hordes of restless unskilled labor, will give place to small units manned by a handful of engineers and a floor sweeper. The living of the great majority will depend, not upon factory payrolls, but upon small-scale neighborhood enterprise. The typical purchaser of an automobile may, upon consultation with his service station, buy a Packard motor, a Cadillac transmission, a Chrysler body, and any other units he needs, and either put them together himself or (more likely for such a big job) have the service station do it for him. Right now, with radio-phonograph sets, this is not only possible but extremely easy.

The forces that will bring about this change are obvious. On the one hand we have the fear of war, to which our concentrations of population and industry will be increasingly vulnerable. On the other we have the helplessness of large factories against the pressure of labor organizations. Even if the threat of war does not force us to decentralize our industry, normal social changes will do so--the dispersion of our people into suburban and rural areas, the high land costs in cities, the problems of traffic and congestion, and, perhaps most significant of all, the disappearance through wider education of our reservoir of unskilled and poorly educated personnel, Fortunately, we have developed transportation and communication to a point where dispersal into small unit plants is becoming practicable. The subcontractor system widely in use today is a sort of forerunner of things to come.

If the pattern of production evolves as I have guessed, the needs for standardization of output and adherence to tolerances will become dominating considerations. Our factories today accept the scrap pile as a necessary evil, but if the neighborhood service man gets even one component that fails to work as it should, he suffers a disproportionate loss; his limited volume makes it impossible for him to assimilate many rejects. In such a case, consumer reaction to the source of the unsatisfactory component is certain to be severe. The whole system falls to pieces unless the control of quality of output attains an efficiency much beyond the present day average.

3. Who Needs SQC?

Any executive who visualizes possible future change may choose either of two policies. On the one hand, he can await developments, trying to meet needs when, as and if they arise. On the other, he can begin now to plan and prepare for those needs which he can reasonably anticipate. Assuming that he chooses the second alternative, he must then answer two more questions. One: How much need for statistical quality control can I expect in my plant? Two: Assuming that I can foresee such a need, what steps can I take to supply it?

The question of "How much need" is to some extent relative. The manufacturer who enjoys an advantage that gives him a competitive edge may seek better efficiency to increase his profits, but not ordinarily for sheer survival. Manufacturers with no such advantages need all the efficiency they can get, but this efficiency must be in the large; that is, it must not consist of a gain in one area which brings with it a compensating loss in another. Much confusion has existed in the thinking on SQC and some executives seem to have the notion that the purpose of SQC is to produce only the best product regardless of cost. If there are some quality control enthusiasts who are willing to sacrifice the whole garden for one perfect rose, it is up to management to create such checks and balances that the enthusiasm may be harnessed and directed productively.

If we think of need in terms of overall efficiency, it seems clear that every manufacturing enterprise should at least make some provision to have its needs watched by some competent observer. It will not ordinarily be possible for management to appraise its own needs, nor for that matter can any outsider or low-level employee do so; this job needs the give-and-take of the executive conference. Let us assume that the decision is to expend a moderate amount of effort in the direction of statistical quality control. How should this effort be expended?

4. How Can SQC Be Introduced?

We should begin by recognizing clearly that any new method as far-reaching as statistical quality control cannot be "introduced" in the sense that one might introduce three-shift operation or a conveyor system. The situation is a bit analogous to the "introduction" of the automobile. If by some miracle somebody could have acquired a 1952 Cadillac back in 1902, he couldn't have used it. There were no good highways to drive it over; there was no high-test gasoline to run it with; there were no mechanics who could service it. "Introducing" the automobile had to be a step-wise process, with parallel development of cars, roads, and the service industries. SQC cannot be developed to its full extent without eventual transformations in many of our accepted production and inspection methods. Since we cannot risk upsetting or disrupting our factory organizations, it follows that conversion to SQC must be a carefully regulated operation. If we don't use enough pressure, our plan will be defeated by inertia and conservatism. If we use too much, our total effort will suffer because of the tensions created.

As an example of the kind of difficulty that may arise, consider a practice common in metal working, called "working to the safe side." The general idea is to make every metal part in such a way that, if it fails to comply with the drawing tolerances, it can be made right by additional working. On this theory, plugs are made big and holes small; a plug that is too big can always be turned down a bit, but one that is too small may be irreclaimable scrap. The same argument, in reverse, applies to holes. Now, the general idea is obviously sound, entirely in accordance with SQC; but a good quality control engineer would want a cost study, to determine exactly how far to the "safe side" an operator should work in order to obtain maximum economy. Once the result of the cost study was available, the really hard job would follow; getting the operators to aim for the desired target. Experienced machine tool operators usually resent being told how to do their jobs by college boys, or for that matter, college professors. Two approaches are available: either through the oldest and most experienced operator (if by judicious use of appropriate methods he can be sold on the program) or through a junior operator who may grasp at the chance to outshine his elders. Either method calls for time and tact. If one man can be sold and will cooperate intelligently, he will (if he succeeds) sell most of the others. If there are any die-hards, they may eventually tire of waging a lone battle; in any case they will not live forever. Of course, the method must succeed, and the fact of the success must be demonstrated.

This illustration points up not merely the desirability of a diplomatic approach to the introduction of SQC, or in fact of any new method which requires the cooperation of operating personnel, but also the imperative need for adequate measures of success. It is an axiom of statistical inference that nothing is good unless we can show that it is good, and this means that if we are to demonstrate the usefulness of SQC we must be prepared to devise reasonable and adequate scoring systems in terms of which the superiority of the method can be measured and demonstrated. The quality control chart is such a scoring system, though keeping score is not its main function; moreover, it is not a perfect scoring device, because it ignores costs. In SQC, as in every management situation, we have the problem of communication. The quality control program must include provision for feeding back information, both to management and to the production line, and this information must tell in acceptable language whether the system is doing any good or not. Success is said to breed success, but this is not quite the case; it is really the knowledge of success that does the business.

Eventually, in the initiation by management of any program, there arrives the time when some human being must be given responsibility for its operation. Much depends upon selecting a suitable person. Should he be brought in from the outside, or should the assignment be given to someone in the organization? Should an experienced person be sought, or should the factory train a beginner? What should be his background--engineering, mathematics, or business management? My preference would be for an engineer interested in statistics and management rather than a specialist in either management or statistics. Since the number of mature people with solid and successful experience in SQC is small, and all such people at present have good jobs, it will hardly be possible to hire one; that means training a beginner, not from choice, but from necessity. He will probably need help from time to time, and this can usually be provided by occasional consultation with, say, some member of the nearest engineering faculty. He may be either a junior employee, or a recent graduate hired for the purpose; I don't think senior personnel should be assigned to the job, except possibly for supervision and guidance.

Assuming that we hire a beginner, with some theoretical knowledge and interest but without practical experience, he should be signed on as an apprentice engineer and put to work in production or engineering to learn the factory. He should most emphatically not be singled out for work in quality control at this early stage; the definite assignment should be deferred until the results of the training program become apparent. This program might profitably extend over a two-year period, during which three important benefits could be attained. First, the candidate, by suitable rotation within the organization, could become acquainted with the factory. Second, the factory could get acquainted with the candidate--most important, if he must eventually try to sell them something. Third, management could arrive at a fair appraisal of the candidate's possibilities as a quality control engineer.

Such an appraisal can be based on fundamental questions, most of them easy to answer. Is the candidate a salesman? Is he liked and respected by his associates and others? Does he pick up new ideas quickly? Does he have originality and ingenuity? Is he interested in his work? Does he have an adequate understanding of the theory of statistical quality control? All these questions except the last can be answered by his supervisors; for the last, recourse will probably have to be a teacher or similar professional person, as your organization may not include anyone capable of making this appraisal.

The fact that, once the candidate starts work as a quality control specialist, there will likely be nobody in the organization who can provide him with professional supervision, explains why we need this long program of training and observation. If the candidate is to succeed in starting and developing a program of SQC, he must be given considerable latitude, and on occasion, some support by authority. A mistake in our appointment not only must lead to failure and the loss of time and money, but will almost certainly give quality control a bad name for years to come. If we know our man thoroughly, and if others know him and like him, we can then trust him with a certain amount of leeway.

Once we have decided to give the candidate the quality control assignment, there remains the problem of where to place him in the organization. I think there are two good answers: either he must report directly to the factory manager, or he must work under the superintendent of production. If the superintendent has a friendly attitude, I should prefer the latter, at least for a few years. I think it is a great mistake to identify quality control with inspection. Quality control is exercised during production; inspection comes after production. I have seen several attempts to organize SQC as an inspection function, and with one exception, they have had unfortunate consequences, mainly because the quality control engineer is thereby placed on the opposite side of the fence from production; it is most essential that he be on the same side. Even the lone exception I have in mind (at the Westinghouse plant in East Pittsburgh) in a way proves the rule, since the man in charge is essentially a management consultant, quite different from the typical chief inspector.

Having the quality engineer on the manager's staff has some advantages, especially when his position has been solidified by experience and maturity; so if he is assigned initially to production, the possibility of eventual transfer should be kept in mind. Quality control is a production function, but a competent quality engineer can make effective contributions to purchasing, engineering, inspection, and selling, and these possibilities should not be neglected. I know of one case in which a substantial saving resulted through an improved method of packing which was suggested by a quality study. The choice of assignment necessarily depends upon the man himself. Even if he eventually moves into the manager's office, he should keep one foot in the production department.

For the rest, management can do no more than the gardener does. The soil has been prepared and the seed planted. Weeds will appear, and these must be removed. A bit of fertilizer will be needed from time to time, and maybe occasionally a little support. The rest is up to nature. If we started with good seed, we should at last have a strong plant and an abundant harvest.

PRACTICE VS. THEORY IN SAMPLING INSPECTION

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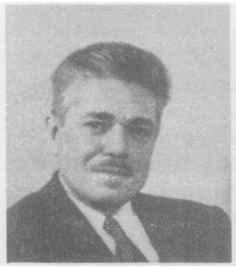

When I was asked to give a talk on quality control as a part of this institute, I suggested a number of possible titles in a note to the general chairman. Among them were "Some Unsolved Problems in Sampling Inspection," "Choosing the Correct Sampling Plan," and the title you find on your printed program. I must confess they all were for the same speech. What I intend to talk about is (a), some of the problems faced by an industrial concern or any other agency that purchases material, parts, or completed product in selecting the best sampling inspection plan for each product and supplier, (b), how, in theory, a choice should be made, and (c), how and why present practice differs from theory.

In sampling inspection, the purchaser or receiver groups submitted products into inspection lots. Then each lot is sampled by drawing at random a number of items. These items are inspected and on the basis of what is found, the entire lot is either accepted or rejected.

Sampling inspection is very widely used for the acceptance inspection of purchased goods and material. In addition, the use of sampling inspection for in-plant quality control is increasing.

Until recent years, sampling inspection was crude and unscientific. One simple sampling plan was used for virtually all applications. A sample whose size was 10 per cent of the number of items in the lot was drawn. The sample items were inspected and if no defective items were found, the lot was accepted. Otherwise, it was rejected. This practice had one virtue--there were no problems of selecting a sampling plan. However, it was seriously inadequate for modern manufacturing methods and products. First of all, it gave almost no protection against the acceptance of bad lots in many of its applications. Second, at considerable inspection waste, it gave too much protection in many more applications. This plan was really satisfactory for only a limited range of acceptance conditions.

Now, a number of sets of scientifically designed sampling plans are available for general use. Each set contains a number of different plans so that a satisfactory one may be selected for the particular technical and cost conditions surrounding any possible application. The first set made available was the Dodge-Romig plans developed at the Bell Telephone Laboratories for use at the Western Electric Company. These are now used in many different firms and industries. Additional sets have been developed under the auspices of different branches of the Armed Services. Military Standard 105-A, the set currently used by all branches of the Armed Services, and the plans published in "Sampling Inspection" which were developed by the Statistical Research Group at Columbia University are examples. These military plans are also widely used by industrial concerns.

The plans in each of these and other available sets are soundly designed. The ability of each to discriminate between lots of different quality has been carefully described. A wide variety of plans to cover a full range of conditions has been made available. In Military Standard 105-A, for example, there are 430 different plans. These plans are for attribute inspection (inspection in which an item is simply classified as defective or non-defective) alone. If a parallel set of plans for variables inspection (inspection in which the property of the item is measured and its quality considered in terms of this measurement) is to be used also, several hundred more plans are added to the collection from which a choice must be made for each application.

The problem now faced by the user, after he has decided on the set or sets of plans he is to use, is to select for each product and supplier the particular plan to apply.

From a cost standpoint, making the right choice is important to both the receiver and the supplier. A poor choice must have one or more of these costly consequences:

(a) The acceptance of a large proportion of the lots that should be rejected.

(b) The rejection of a large proportion of lots that are satisfactory and so should be accepted.

(c) Undue sampling inspection costs because unnecessarily large samples are drawn.

In a full defense or war economy, the consequences represent an unnecessary waste of irreplaceable labor and materials.

When selections are poorly made, the potential value of these carefully designed scientific plans is largely destroyed. Both good plans and the proper use of them are essential for adequate quality control and reasonable acceptance inspection costs.

Forms of Sampling Inspection Plans

Sampling inspection plans may differ from one another in one or more of four basic ways: (1) they may differ in the sharpness with which they discriminate between acceptable and unacceptable lots, (2) they may differ in quality levels at which lots are considered acceptable, (3) they may differ in type of sampling, and (4) they may differ in the type of item inspection required. For each incoming product and supplier, a choice must be made from among the available possibilities for each of these kinds of differences.

In considering these differences, it is helpful to think of each plan in terms of its operating characteristics, a property which may be conveniently described by an OC Curve or operating characteristic curve. For example, if a plan is to draw from each lot a single sample of 75 items, to inspect them on an attribute basis, and then to accept each lot for which no more than 3 defectives are found in the sample, its operating characteristics are as shown by the OC curve in Figure 1. This curve shows that when the percentage of defective items in submitted inspection lots is 2 per cent or less, virtually 100 per cent of the lots will be accepted. If the percentage of defective items in submitted lots is 12 per cent or more, virtually all the lots will be rejected. Instead of reading from the curve the percentage of submitted lots that will be accepted we may, if we wish, read instead the probability of accepting a lot of any quality. For example, this OC curve shows that if a lot is 5 per cent defective, the probability is about 50-50 that it will be accepted.

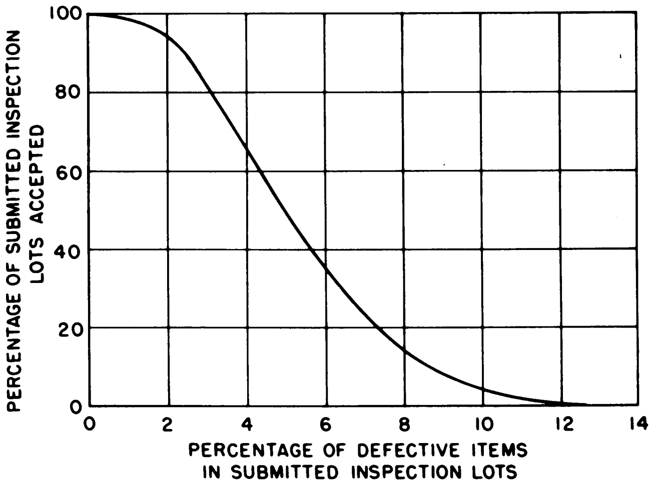

Figure 1
Operating Characteristic Curve when Sample Size is 75 and Acceptance Number is 3.

The ability of a plan to discriminate sharply between good and bad lots--that is, the steepness of its OC curve--depends mainly on the number of items making up the sample. The larger the sample, the sharper the slope of the OC curve and the better the plan can discriminate between one lot quality and another. Note that it is the absolute size of the sample that counts and not its size in relation to the size of the lot. The effect of sample size is shown in Figure 2, which gives OC curves for five plans, each with a different sample size but all of which are designed to accept virtually all lots with 2 per cent defective or less. The dashed line on this figure represents the ideal OC curve. The perfect discrimination it represents can be achieved only by inspecting all the items in the lot.

The quality level at which lots will be considered good--that is, the position of the OC curve from left to right on the percentage of defective items scale--is determined mainly by the acceptance criterion for the plan. In our example, it is determined by the acceptance number, which is the maximum number of defective items that are allowed in the sample for the lot to be accepted. The effect of changes in acceptance criteria is shown in Figure 3, which gives OC curves for five plans, all with a sample size of 75 but with different acceptance numbers.

Sampling plans differ in two ways in the kind of item inspection required. Until recently, all sets of plans generally available were for attribute inspection. A set has now been made available for variables inspection.

Plans also differ in type of sampling. Some require only one sample for reaching a decision to either accept or reject. Others depend on drawing one additional sample or a number of additional samples from lots of doubtful quality. Multiple sampling plans will be described in more detail in a following section.

Objectives in the Choice of a Plan

The choice of a sampling plan depends on the objectives of acceptance inspection. Insofar as quality is concerned, there are two principal objectives. The first is to obtain some immediate protection against the acceptance of unsatisfactory product. The second is to put pressure on the supplier to improve his quality if the general quality level of submitted product is not satisfactory. This last objective is perhaps more important than the first. Very frequently, sampling inspection can be of little help in screening bad lots from good. A third,

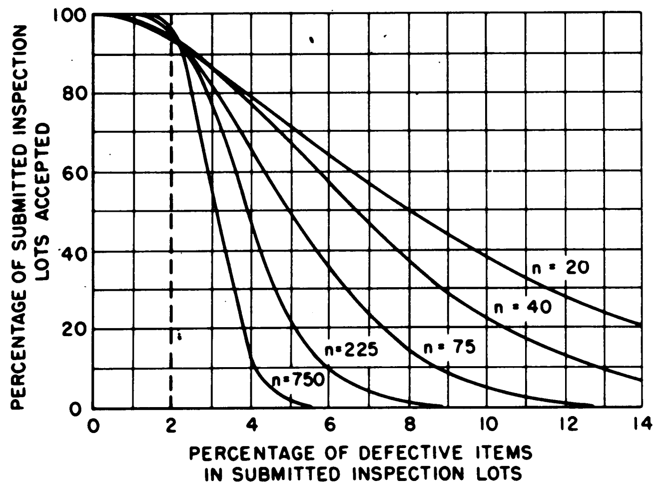

Figure 2
OC Curves Showing Effect of Changes in Sample Size.

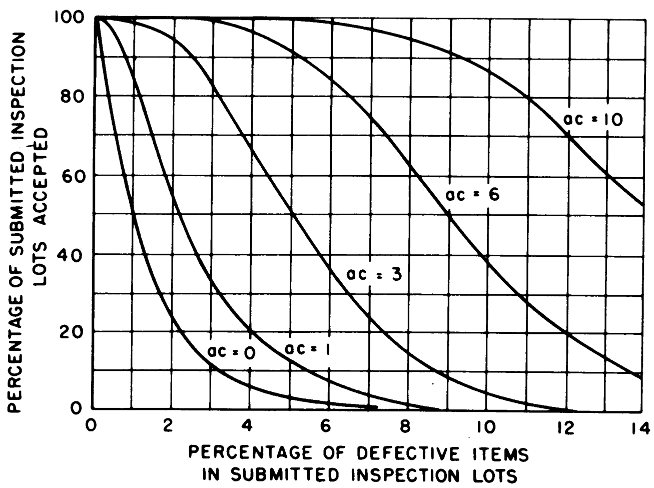

Figure 3
OC Curves Showing Effect of Changes in Acceptance Numbers

and important objective, is to achieve the desired quality objectives in a way that minimizes all the costs that are affected by the choice of an acceptance procedure. These costs include the costs of accepting and using defective items (and particularly the costs of accepting lots with an unacceptable percentage defective). They include the costs--both immediate and eventual--of rejecting lots and returning them to the supplier (particularly if the rejected lots are good), and they also include the costs of acceptance inspection.

The Choice of a Quality Level that is Acceptable

As has been indicated, a specific plan to use for an application is selected, or should be selected, by making a number of decisions. Perhaps the most important one is to select a lot per cent defective which is acceptable. In effect, this means choosing the general location from left to right for the OC curve.

In theory, the person making this selection should first of all determine the costs of accepting and using each of all possible percentages of defective items. These costs should include both the added expense in further processing the materials or parts in his own plant and the tangible and intangible costs of defective items that leave the plant as a part of his firm's product. He should then attempt to determine the costs to the supplier of producing different levels of quality. Finally, he should determine how badly his firm (or branch of the Armed Services) needs the submitted product and the costs of delay if all or part of it is returned. With this information available, he should then choose from among all available possibilities a position for the curve that minimizes all these costs.

It should be apparent that making an optimum choice may be quite a problem. First of all, it is usually difficult to determine and evaluate the costs connected with accepting and using defective items. Many of them are irreducible to money terms, particularly if the receiver is a branch of the Armed Services. How can one determine the costs (in terms of dollars) of accepting a defective gas mask, for example? Also, it is equally difficult to find the relation between cost and quality for the supplier so as to determine how much pressure, if any, to exert for quality improvement. Since eventually the costs of quality improvement must be passed on to the receiver, he must be sure they will be justified. The costs of returning lots when the material is badly needed may be determined reasonably well if the receiver is an industrial concern, but if the receiver is a branch of the Armed Services or a firm producing for them, to do this is difficult in war-time.

Because of the difficulties outlined above, and because of the difficulties of summing up the costs if they were available and making the best decision in a routine way, a simple and practical solution has developed. It is a selection procedure which is used with fair results quite generally by both industry and the Armed Services. Essentially, the procedure is to estimate what the quality of submitted lots will be and if the quality expected is satisfactory, to choose a plan that will accept virtually all lots of such quality. No formal consideration is given the economic factors listed above. An estimate of what incoming quality will be is something that, after some experience, can be determined reasonably well. Hence it supplies a basis for a choice that can be established even though it is not a basis that is fully adequate.

Until recently, the per cent defective to expect for an incoming product was simply determined by an undocumented estimate by some person who had experience with the product and the supplier. A rapidly growing practice in the past few years, however, has been to compile and summarize in written form quality histories for all products and vendors. These histories are mostly a record of past acceptance sampling inspection results. In the absence of any new knowledge to the contrary, it is assumed that future lots that may be submitted will have the same percentage of defective items as those submitted in the recent past.

To aid in selection under this procedure, most sets of plans used in this country have each plan classified or described by a point on its OC curve, called the "acceptable quality level" or AQL. The AQL of a plan, as the term is commonly used, is the percentage defective in submitted lots at which 95 per cent of the submitted lots will be accepted. The AQL of the plan whose OC curve is shown in Figure 1 is 2 per cent. The selection of an AQL thus fixes the position of the OC curve which in turn determines the quality level at which lots will be considered acceptable.

Generally, a plan with an AQL equal (or as close as possible) to the estimate of incoming quality is selected. However, if this level of quality will not be satisfactory in the receiver's use of the product, an AQL at a somewhat lower percentage will be selected. This will result in a plan that will reject a larger proportion of unsatisfactory lots than would otherwise be the case. What is more important, the increased rejections will presumably induce the supplier to improve his quality and send better lots in future shipments. (An interesting problem in this connection is to determine how much rejections must be increased to induce the supplier to make the right amount of improvement.) If the estimate of incoming quality is better than the level that could be satisfactorily used, an AQL somewhat higher could be selected. While this might be in the best interests of both parties, such a practice is seldom found.

Most users of sampling plans who make a selection in the way just described have, as a part of the procedure, a more or less formal routine for making a change in the AQL if incoming quality turns out to be worse than the estimate or if it deteriorates at some time in the future.

A few users have been encountered who make one AQL value, or perhaps two, do for all products and suppliers. Apparently, the reason for this is that information for making a logical choice from among the many values that are available cannot be obtained. One user who is a large purchaser of goods and materials uses an AQL of 1 per cent for approximately 99 per cent of his applications and an AQL of 5 per cent for the remaining 1 per cent. (Round figures like 1 per cent, 5 per cent, and 10 per cent seem to have wide use when bases for selecting a logical figure are not available.)

The selection of a plan in terms of an AQL is advantageous when it is important to accept as much product as possible and when a long-run quality viewpoint can be taken. However, from the standpoint of immediate quality protection, a selection in terms of the other end of the OC curve might be better--the per cent defective in incoming lots beyond which virtually no lots will be accepted. For this reason, most sets of plans have also been cataloged by a point on the low end of the curve--the "lot tolerance per cent defective" or LTPD. The LTPD, as ordinarily defined, is the per cent defective in incoming lots at which 10 per cent of the lots will be accepted. For the plan whose characteristics are pictured in Figure 1, the LTPD is 8.8 per cent.

However, few places can be found in which a selection is made in this way. A selection made in this way must be made mainly in terms of the per cent defective that can be used without too much difficulty, a figure that is hard to determine.

A European method is to classify and select plans in terms of the mid-point of the curve--the point at which the probability of acceptance is 50-50. For the plan in Figure 1, this is at 5 per cent defective. The argument for making a selection in this way is that a selection is found that compromises the conflicting desires of the supplier and the receiver. The supplier wants the position of the curve to be as far to the right as possible; the receiver wants it as far to the left as possible. A value is chosen as a compromise for these views and a plan chosen whose mid-point goes through this value.

The Choice of OC Curve Slope

The next decision that must be made is that of deciding for the application how sharply the plan must discriminate between good and bad lots. In effect, this means choosing the slope for the OC curve.

As previously pointed out, the slope of the curve depends mainly on the size of the sample. The larger the sample, the better the plan will discriminate between good and bad lots. Note in Figure 2 (which gives OC curves for five plans, all with an AQL of about 2. 2 per cent), that if the sample size is 20 about one-half the submitted lots with 8 per cent defective will be accepted, while if the sample size is 225, virtually none will be, for example. The added discrimination of the latter plan, however, is achieved at the cost of a considerable increase in sample size.

The problem, then, is to determine what slope (and thus what sample size) will result in a minimum total cost, considering both the costs of drawing and inspecting sample items and the costs of making wrong decisions. Sampling inspection costs for different sample sizes can be determined fairly well. However, the costs of wrong decisions are difficult to estimate. They include the costs of accepting lots with more than an allowable per cent defective and the eventual costs of rejecting lots that should have been accepted. Also, a part of this problem is to determine the number of lots that should be returned to furnish the right incentive for quality improvement if at any time the quality supplied falls below the acceptable level.

In actual practice, much of the information required for making the best choice of slope is difficult or impossible to obtain. For this reason, a more or less arbitrary choice is made. Most sets of sampling plans are cataloged according to "inspection levels." The choice of level determines the relative amount of inspection that will be required. The middle level is designated as the level most suitable for "normal" use, with the choice of a lower level or a higher level being available for applications for which the cost of inspecting an item is unusually high, for which the acceptance of bad lots will cause considerable difficulty, or for which some other unusual condition makes a different level advisable. It may be observed, however, that the normal level is used for practically all applications.

Actually, the choice of a level (or the consistent use of the normal level) determines a range of sample sizes. Within the level, the specific sample size to use is determined by the size of the lot. For example, with inspection level II in the Military Standard 105-A plans for single sampling, for a lot size of 66 to 110 items, the sample size is 15. For a lot size of 1301 to 3200 items, the sample size is 150.

From the standpoint of protection alone, the sample size for an application should not depend on the size of the lot. The ability of a plan to discriminate between good and bad lots depends on the absolute size of the sample. The relationship between sample size and lot size for this viewpoint--constant protection--is shown by the horizontal line in Figure 4. However, from the standpoint of keeping acceptance inspection costs per unit of submitted product constant, regardless of lot size, the sample size should vary directly with lot size. The relationship for this viewpoint--constant inspection costs per unit submitted--is pictured by the diagonal straight line in Figure 4.

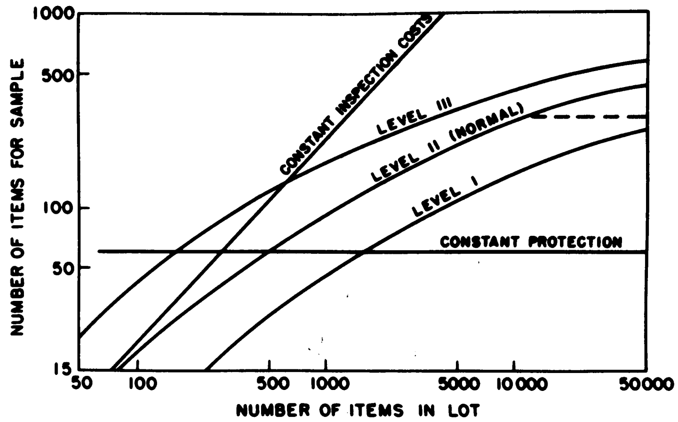

Figure 4
Relation of Sample Size to Lot Size, Single Sampling

In establishing the sample size for each range of lot sizes, the plans' designers work out a compromise between these extreme points of view. The compromise allows some increase in sample size for large lot sizes but not a proportional increase. At the same time, it keeps the sample size for small lots large enough to give a reasonable amount of protection. The relationship between lot size and sample size for each of the three inspection levels of the 105-A plans is indicated in a general way by the three curved lines in Figure 4. (Actually, the sample sizes do not vary continuously. One sample size is used for a range of lot sizes).

It should be apparent that determining a relationship between lot size and sample size that will be best for "normal" use by all branches of industry and the Armed Services is a difficult problem. It is one that seems to warrant further study.

One practice commonly encountered indicates that one aspect of the relationships now prescribed may not be right. This practice is to arbitrarily set an upper limit for a product or a class of products on the size of the sample, regardless of the size of the lot. The effect of this practice is indicated by the dashed line at the curve for Inspection Level II in Figure 4. Arguments for such a limit are (a), that it is difficult to draw very large samples in a random manner, (b), that the inspector becomes fatigued after inspecting several hundred items so that the inspection of additional items is of little help, and (c), that the drawing of very large samples requires the opening of too many containers or in other ways causes unjustified trouble and confusion (particularly when inspection is at the shipping department of the supplier's plant, as is often the case.)

The Choice of Type of Sampling

It is possible to obtain desired operating characteristics by any one of several forms of sampling. In the discussion up to now, single sampling has been described. Two other forms are available as alternatives in the sets of sampling plans generally available. They are double sampling and group sequential.

In double sampling, a relatively small first sample is drawn. It is inspected and if very few defectives are found, the lot is accepted at once or if very many are found, it is rejected at once. But if an intermediate number is found, a second sample is drawn and inspected. On the basis of what is found in the two samples combined, the lot is either accepted or rejected. The group sequential form of sampling is the extension of the double sampling procedure to the possible drawing of a number of samples.

These forms may be illustrated by the following three plans, all of which give approximately the same OC curve:

Single sampling -
- Sample size 225
- Acceptance number 14
- Rejection number 15

Double sampling -
- First sample size 150
- Acceptance number 9
- Rejection number 24

- Second sample size 300
- First and second combined 450
- Acceptance number for combined sample 23
- Rejection number for combined sample 24

Group sequential -

Sample	Size	Combined	Acceptance Number	Rejection Number
First	50	50	1	6
Second	50	100	3	9
Third	50	150	7	13
Fourth	50	200	10	16
Fifth	50	250	13	19
Sixth	50	300	16	22
Seventh	50	350	19	25
Eighth.	50	400	24	25

Multiple sampling plans offer a means of reducing the average amount of acceptance inspection. Very good lots are accepted at once and very bad lots are rejected at once by a relatively small amount of inspection. Additional samples are drawn as needed to make a decision for lots of intermediate quality. For example, with the attribute plans just given the average amount of inspection for each for different incoming qualities, is as shown in Figure 5. If it is feasible to return to the lot and draw additional samples when necessary, multiple sampling plans offer possibilities for real savings.

It appears, however, that single sampling is almost always employed in spite of the savings the other forms offer. One reason commonly given is that quality histories cannot be built up quickly enough if single sampling is not used. Only the first sample in multi-sampling plans can be used if an unbiased estimate of incoming quality is to be obtained. Also, it seems that double and sequential sampling is considered by some to be too difficult to explain and justify. In the double-sampling plan

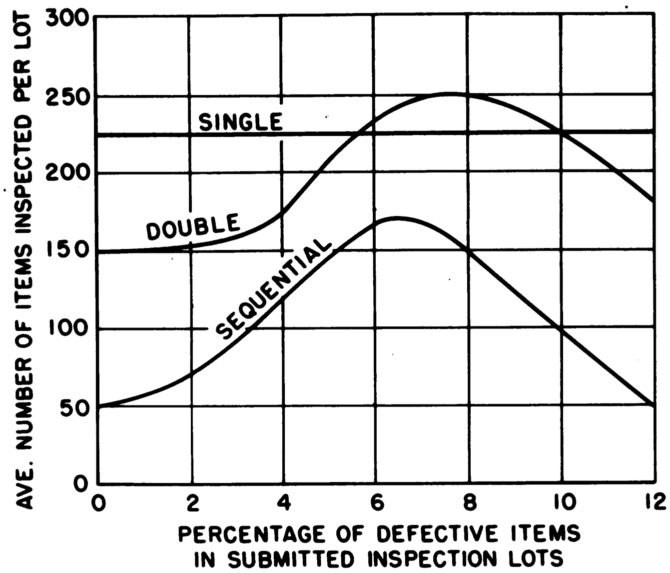

Figure 5
Average Amount of Inspection for Single, Double, and Sequential Plans

shown in Figure 5, to take an example, for a lot 20 defectives might be found in the first sample of 150 items. In the second sample of 300 items, it might happen that only 4 defectives are found. The total number in the two combined, 24, is enough to require rejection, however. Since the lot was not rejected after 20 defectives were found in a sample of 150, the supplier may not understand why it must be rejected as a result of finding only 4 defectives in an additional sample of 300. A final argument in the case of procurement offices of the Armed Services is that it is essential to have uniform and known work loads for their inspectors. Schedules for acceptance inspection, which is usually carried out in the vendor's plant just prior to shipment, must be maintained. In multiple sampling, the amount of inspection that will be required in any specific case cannot be predicted.

In a few places, double-sampling plans are used for a few applications. Also, among the operations I have observed, two large industrial concerns are using sequential plans exclusively. Their experience has been, and this is backed up by extensive records, that most submitted lots are either quite good (which is usually the case) or quite bad. A decision is almost always made on the first, or possibly the second, sample. Since this is so, they have realized appreciable savings in inspection costs by the use of this type of plan. No particular problems have been found. Inspection management in both these concerns are quite enthusiastic about sequential sampling and feel that many other concerns could change to it with profit if they would just try.

The Choice of Method for Item Inspection

Until recently, all generally available sets of sampling plans were for attribute inspection. In attribute inspection, an item is checked by a go- and not-go gauge or other device, and simply classified as either satisfactory or unsatisfactory. However, in a short while a comprehensive set of plans will be available for variables inspection, inspection in which the item quality is measured and recorded in terms of inches, ounces, volts, or some other unit.

The important advantage of sampling inspection by variables is that fewer items have to be inspected than under an attribute plan with the same operating characteristics. More is known about an item if a specific measurement is available than if it is simply known to be bad or good. For this reason, measurements for sample items give more information about the lot than attribute information.

The effect of this practical advantage is indicated by the following examples of sample sizes:

Sample size for attribute plan	Sample size for variables plan: Unknown standard deviation	Sample size for variables plan: Known standard deviation
10	7	5
30	16	9
75	35	16
225	70	28
450	100	36
1500	200	45

The above illustrations are for single sampling. The savings are comparable for double sampling.

The disadvantages in using variables plans are that the inspection of an item may be more costly than under attribute inspection and that the computations required for making an acceptance decision are more involved. However, when the drawing of sample items is difficult, when attribute inspection requires about as much time as variables, and when inspection damages or destroys the item., the use of variables plans may be preferable. The set of plans are matched with an available set of attribute plans so that the two sets may be used on a parallel basis for a complete inspection program. A decision as to the set to use for an application can be made simply in terms of the respective acceptance inspection costs after a decision as to operating characteristics has been made.

The Formation of Inspection Lots

A problem related to those just outlined when applying sampling inspection plans is that of forming inspection lots. In theory, a shipment of goods should be subdivided or grouped into lots that are most suitable for acceptance inspection purposes. In forming these lots, product from different machines, different operators, different dates of production, and the like, should be kept separate so as to maximize the opportunity for difference in quality from lot to lot. If this is done, sampling inspection can be most effective in screening good lots from bad. If inspection lots are all alike, some lots will be accepted and some will be rejected, depending on the effect of chance in the drawing of sample items. The lots that are accepted will be no better than the ones that are rejected. At the same time, when forming inspection lots, the lots should be made as large as possible so that larger samples (with the better discrimination they afford) can be used economically.

For the above reasons, the formation of lots should be an important matter in getting desired protection at a minimum cost. In practice, however, little or no attention is given to this step, apparently. If any one rule is followed, it is to make the inspection lot as large as possible regardless of whether product that may differ in quality is combined. An entire day's production or an entire shipment is usually taken as the inspection lot, no subdivision being made. If acceptance inspection is carried out in the supplier's plant, the floor space available for accumulating the product or the inspector's work schedule may be the determining factor in making up a lot.

Summary

The aim of this discussion has been, first, to show that it is just as important that sampling plans be properly selected as it is for them to be correctly designed. Next, the aim was to point out some of the problems in making a rational choice and how in practice plans are ordinarily chosen.

The intent has not been to speak slightingly of current sampling inspection plans and their use. Their wide employment is with good effect in almost all cases. The scientific approach to quality control through sampling inspection plans and the control chart technique, is one of the most important management developments in recent years. The one thing that to some extent remains to be done is to develop better ways of using these new tools so that the benefits of which they are capable will be more fully realized.

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LUNCHEON SESSION

Session Chairmen: E. T. Grether, Berkeley, February 2, 1952
Neil H. Jacoby, Los Angeles, February 5, 1952

Dr. Neil H. Jacoby

Dean of the School of Business Administration

University of California at Los Angeles

Friends and colleagues: Allow me to introduce myself; my name is Neil Jacoby, and I am Dean of the School of Business Administration here at the University of California, Los Angeles. Yesterday it was Dean Boelter's pleasure to welcome you to the campus, on behalf of the faculty of the College of Engineering. Today I should like, with equal cordiality, to welcome you to our campus on behalf of the faculty of the School of Business Administration. I sincerely hope that you will find your way back to our campus many times in coming years, and that you will feel that your visit here has been worthwhile.

I suppose that many of you have noticed that this Institute is jointly sponsored by the College of Engineering and the School of Business Administration. Some of you may have wondered just how we have worked out the relationship between these two academic units on this campus. Perhaps you would be interested in a word or two on this subject.

The fact that both of these professional schools are jointly sponsoring this Institute, the fact that members of both faculties are participating in the program, the fact, indeed, that some members are joint and concurrent members of both faculties, is proof of the harmony that prevails on this campus. I have no doubt that many of you, as I did, got your university training on campuses where either there was not a Business school and an Engineering school in existence, or if they were both present, relationships between the two were either non-existent or lacked something in cordiality. That is not true on this campus.

Our job in the School of Business Administration, as we see it, is to offer an education for management and for staff specialists in a number of fields of business. Our program involves the requirement that every student master certain basic intellectual tools, as we think of them, notably statistics, accounting, economic theory, and the elements of business law. On the basis of this foundation we require all of our students to take a course in each of the major functional fields of management, which we think of as being production, personnel, marketing, and finance. Finally, we try to synthesize or integrate management principles in all of the functional fields in a senior course in organization and management theory.

Now, I said that all of our students are required to take a course in the elements of production management. It is this course, of course, which brings us into closest contact with our sister College of Engineering. You may ask what, precisely, is the relationship between the production management field in business administration and industrial engineering in the engineering field. I would explain it in this way. We think of production management as one of the functional fields of management, as having to do with the techniques and principles of managing the physical production of the business enterprise. In the School of Business Administration we emphasize the economic, the accounting, the costing, the human, and the organizational aspects of the production process. Our intellectual discipline rests mainly on these bases. The Engineering school, on the other hand, equips its students far more intensively with the physical, the chemical, the mechanical, and the design aspects of industrial production. Now, obviously these fields overlap at some points. I do not think this is a bad thing. In fact, it seems to me that some overlap is a highly desirable thing, because it insures that the same problems are approached by students under the guidance of men who approach them from different directions. Industry needs men trained in both ways.

We are not concerned here at U. C. L. A. with any petty jurisdictional squabbles. We are sincerely trying, in both the College of Engineering and the School of Business Administration, to give our students the best education we can with the resources we have available. We find students in Engineering coming into our school to take courses, and we find, I am happy to say, that some of our students in Business Administration are able to qualify for courses in the College of Engineering. We have several joint appointees in our faculties. Professor Barnes, Professor Salveson, and Professor Carrabino on our faculty, are also members of the Engineering faculty. We have the same broad aims, after all, of trying to increase the flow of well-trained young men--and young women too--into the economic and business life of our area.

Now, I have no intention of imposing on you ladies and gentlemen--by virtue of my power as chairman--any lecture on the organization of the University or our academic aims and our curriculum, I merely thought you might be interested in knowing a little bit about how we have worked out our relationships on this campus.

OVERCOMING BARRIERS TO THE ACCEPTANCE OF NEW IDEAS AND METHODS

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The industrial engineer--the person who is interested in time study, in performance standards, in quality control and inspection, and similar phases of our industrial operations--and the line executive are today frequently confronted with the problem of overcoming barriers in introducing new ideas and methods. Because our technology is changing very rapidly and because we are getting increasing know-how, each of you in your work must be faced with the necessity of dealing with change, of getting people to accept some new idea or some new method which you find it desirable to introduce.

In the past, industrial engineers and line executives--let us say when they are faced with introducing a new wage incentive system--have often thought through very carefully the technical aspects of the problem, but they have minimized or overlooked the human aspects. This is understandable in view of the training which many of them have received. In the past, engineering schools have concentrated almost exclusively on the technical phases of the engineer's work. As a result, the engineer has come out of school as a competent technician, but he has not had adequate training in the humanities. He has not had an introduction to the human problems involved in the work situations he will encounter after graduation. Because of this lack of human orientation, the engineer--as he has introduced his new wage incentive system, his new quality control program, or what not--has very often run into considerable resistance. He has found that the idea or method which he has been trying to introduce has not been willingly accepted by those who have been called upon to deal with the change. He has not taken into account the people who must make his new idea or method work.

Now I would like to bring to your attention a statement that has been made by one of your profession, Mr. J. M. Juran, who was formerly with the Western Electric Company and has written in the field of inspection and quality control. This man has said: "The introduction of any new system of operation faces its greatest obstacles in changing the habits of people ... The human problems exceed the technical problems in complexity and in difficulty. Failure to realize the presence and nature of these human problems creates a high risk of failure for the entire undertaking." Failure to recognize the human problems can lead to failure for the entire undertaking. This being a real possibility, it will be worth our while to examine in detail the entire problem of introducing change.

Let us first look at the barriers which people place in our way as we attempt to introduce change into the industrial setting. We may encounter considerable aggression on the part of the individuals who are subject to the change; they may overtly attack us as we try to introduce the change or in other ways become very hostile to us. We may find that the amount of sloppy or careless work increases; we may find apathy, a disinterest on the part of individuals to do that which they are called upon to do; grievances may increase in number. Where a union is present, we may be faced with numerous slowdowns or even strikes. A few studies have indicated that absenteeism, tardiness, and turnover are very definitely methods used by people to deal with a situation calling for them to change.

I would particularly like to concentrate on one type of barrier which has probably been studied in this context more than any of the others. This barrier involves the restriction of output. Those of you who have dealt with performance standards and wage incentive systems are probably familiar with this phenomenon. The staff expert often exercises great care in timing operations, setting standards, and otherwise working out the details of a wage incentive system; and yet he often finds that at least part of the work group forms into what sociologists call an informal group, under a leader of their own choice. This group decides what a fair day's work is and develops sanctions which keep the nonconformer in line. The individual who starts to respond to the incentive that has been provided is held in check by sanctions which the informal group is able to bring to bear against him. This restriction-of-output device which workers have found useful in combating a wage incentive system has also been used in dealing with other types of change which management has tried to introduce.

Next, let us ask ourselves the question: Why this kind of behavior? Why do individuals set up these barriers in our way making it difficult for us to do the kind of job we think it is important to do in terms of the organizational objectives of the company? In order to get some insight into behavior of this kind, we must first try to understand the needs of the individuals who are actually establishing these barriers. The behavior of individuals, whether it is restrictive or not, results from an effort on their part to satisfy needs which are important to them. These needs lead them to behave in a way that will move them in the direction of what we might call personal goals. Personal goals are those which when attained by an individual will satisfy the need or needs which he feels. Now I would like to contrast for you what I have referred to here as the personal goals of an individual and what we might call the organizational goal of the firm or even of the work group. The organizational goal is that which the manager or line executive is trying to accomplish by getting the members of his work group to behave in certain ways. It often happens, however, that the personal goal of the individual is not the same as the organizational goal. And so we have a motivational system that follows this pattern: the person's boss tells him, "If you do that which is important to us, namely, make possible the attainment of the organizational goal, then we will give you that which is important to you as a personal goal." When people are faced with this kind of a motivational situation, they are rather uninterested in the work that is going on. All that is important to them is that they attain the personal goals that will satisfy their needs. This helps explain why very often workers seem to do the minimum they have to do to get by; and you start asking yourself, as every generation has: "What is happening to people nowadays? Why are they so lazy? They don't seem to care any more. Their standards are going to pot." Well, this is all quite understandable if a person is interested only in attaining a personal goal which is important to him. He quickly tries to figure out the minimum that he has to do to attain that personal goal, to get that pay check or whatever else is important to him; and he does not have any real motivational interest in attaining the organizational goal.

Using this frame of reference in trying to understand why workers set up barriers in our way, let us realize that new ideas and methods almost always at the outset represent a threat to the security of the individuals who will be involved in the change. The individual asks himself as he faces this change possibility: "What does this mean to me? How is it going to affect me?" And this is what is really important in determining his behavior. He starts to wonder: "Have I been doing a poor job? Is the power or prestige which I now have going to be here after the change has been introduced? What about the skill which I have spent years developing, is it going to become obsolete?" These are only a few of the thoughts that tend to arise in people's minds as they try to answer the question: "What does this change mean to me?" The individual is concerned that the change may either make it impossible for him in the future to satisfy certain of his needs or to satisfy them as satisfactorily as he has been able to in the past. And when an individual becomes threatened, he develops modes of behavior (the barriers) to deal with the threat.

There are also certain group implications to what I have been saying. We have to recognize that the behavior of an individual is affected by the impact on him of the group. No individual functions in social isolation; he is always a part of a social group. And very often changes that are introduced have a very important impact on established ways of doing things within a group--on established norms or values which the members of the group have held. When this is true, the group reinforces the feelings of insecurity which the individual has and adds to the problems which we face in introducing change.

This being the basis which we use to explain why people behave in the way they do, let us next face up to the question: How do we deal with these barriers? How do we overcome these barriers in order to introduce more effectively the new ideas and methods which seem desirable?

At the outset, I would like to suggest one generalization. Of very great importance is the human atmosphere that exists between the person or persons who are trying to introduce the change and the individuals who are subject to the change. If mutual confidence is not present, if people distrust each other, the strength of the barriers that will be set up will be greatly increased. When a person has a real sense of trust and confidence in another person, he is much more likely to go along with what that other person is trying to do than would be true in the former case.

For people to accept new ideas or methods, there are probably three different things that have to occur. First, it is important that people come to understand the reasons for the change. They have to get some insight into why a change is going to be brought about. Very often in introducing change, line executives or staff specialists will simply announce the change and say: "Here it is, boys; from now on we behave in this way." There is no explanation, no indication to the people involved as to why the change has to be made. Certainly for people not to set up barriers, it is important as a prerequisite that they have some understanding of the need for the change. Second, people have to see that the change is going to be good for them. This point relates back to the question: "What does this mean to me?" If it is not going to involve something better for the individual--or at least something as good--he is apt to resist the change. He is going to want to be assured that there will not be any reduction in need satisfaction as far as he is concerned when the change is brought about. He is going to want to see that the change will at least leave him no worse off than he is right now; and, even better, that it might improve his present situation. Finally, after the individual has obtained some understanding of the reasons for the change and after he has seen what the change is going to mean to him, then generally some new behavior will be called for on his part. He may have to learn some new skills; he may have to develop some new attitudes; he may have to change his whole frame of reference in order to deal adequately with the new situation. But you are going to have to reach the individual at more than the intellectual level; because generally attitudes and skills are involved, and behavioral changes have to be brought about.

What are some of the methods that might be used by you in bringing about change--methods that have a good possibility of at least minimizing the strength of the barriers that are set up in your way? One approach which is very often used (and I rather suspect most of you use it as your principal method) involves selling. After you have worked out your plans, you try to sell them. Sometimes perhaps you go a bit further; and after you have gone through your sales pitch, you give the boys a chance to ask some questions. You try to answer these as frankly as you can. I would like to suggest that while the sales method does have certain advantages in its favor, it has many strong disadvantages. The selling approach is an approach that is aimed at the intellectual level. You are telling someone else what the answers are. The other person is most often a passive listener--a person who is asked to accept that which you are trying to put over on him. We have a lot of research evidence which indicates that even though you may be successful in reaching an individual at the so-called intellectual level, the likelihood is great that you will not reach him at the behavioral level--that you will not have very much impact on the actual behavior that is forthcoming from him.

A second approach which might be used--one which is better than the selling approach in my judgment--is this: you, as a staff specialist, or a line executive, formulate the new idea or develop the new method in advance of approaching the employees. But you recognize that your first formulation of the idea or method is a preliminary one. You make it clear that it is subject to modification after consultation either with individual employees or groups of them or with the union which represents the employees. Consultation with individuals or with groups of individuals, organized or unorganized, is involved here, with the willingness on the part of the changers to listen to what those who are going to be subject to the change have to say, with the willingness to make modifications in the preliminary formulations of the plan on the basis of the material that you get from the people you are consulting. Now it really takes a big person, a person who is big not in stature but in terms of his total personality, to use this approach. When a person gets into a line position or becomes a staff specialist, he often has a feeling that he is supposed to have all the answers, that he is lowering himself in the eyes of others even to suggest that maybe they might be able to offer something that would improve an idea that was developed by him. Well, there are a lot of people who are small in this respect, who find it difficult actually to consult those who are down on the firing line, the people who are involved in the day-to-day operation, the people who, after all, ultimately determine the success or failure of the change that is going to be introduced. A person who is big enough to use consultation, to recognize that the people on the firing line very often have much to offer that is of value in developing the new idea or method, is much less likely to be faced with barriers than is the seller.

There is a third approach that goes still a step further which I would like to present to you. The second step, already discussed, involves some participation on the part of the people who are subject to the change. The third step involves even more participation. It involves what we might call group decision. It recognizes that if the new idea or method is really going to be accepted, it had better be worked out by the people who are going to have to live with it. It recognizes that if people who are threatened by a change have an opportunity actually to work through from the beginning on the new idea or method in order to assure themselves that their need satisfaction in the future will not be adversely affected, then such individuals will recognize the change as something which is their own, something which has taken into account their feelings in its ultimate design. The point involved here is very well brought out by Alex Bavelas, a professor of MIT, in this way: "The essence of the technique (of group decision) lies in the achieving of acceptance of the change by the group as something that the group itself will do rather than something that will be done to it; and in the establishing of a new frame of reference by decision, and using that decision as the binding force for maintaining the new framework until it 'sets'." The change is something that is brought about by the group, and the group, because of its participation, will be back of the change.

If you think that this is ivory tower theorizing, let me bring to your attention a very interesting research result--one that stems from a study that was conducted about three years ago in a sewing plant of the Harwood Manufacturing Corporation in Virginia. In this corporation, an experiment was set up to try to measure the relative effectiveness of different methods of introducing change. Four groups were selected, four groups that were matched in the important respects. The first group was called a control group. The control group had the change introduced to it in the way which had been customary in the Harwood Corporation. This was the selling approach, with an opportunity for the individuals involved to ask questions. The first experimental group was a group where participation was involved by representation. A few representatives were chosen from this first experimental group. These individuals participated in designing the changes to be made in the job and in setting the new piece rate. After this participation on the part of the representatives of the group took place, the representatives went back to the group, told the group what had taken place and helped train the other members in the new method of performing the work. The second and third experimental groups used total participation. Here every member of each of the groups participated in designing the changes to be made in the job, in setting the piece rate, and in learning the new method of work.

Now, what were the results? Prior to the change, all four groups were producing around sixty units per hour under an incentive system where a unit was defined as one minute of standard work. After the change, in the control group production fell down to somewhat below 50 units, climbed up thereafter to 50, and maintained the level of 50 units per hour for the balance of the experiment which was approximately 30 days. Interviews conducted with members of the control group during the experiment clearly indicated that restriction of output was taking place and that fifty was now looked upon by the group as the new standard which the group was going to maintain. Marked expressions of aggression against management occurred, and there were 17 per cent quits during the experiment. The first experimental group, the one that participated through representation, had its production fall to about the level of 40 units, but it quickly rose until about the fourteenth day it passed 60, and continued on up to about 65 units. The two other experimental groups, the ones under total participation, fell down in production on the first day but immediately recouped to the level of 60 and thereafter continued to show an increase, reaching a level approximately 14 per cent higher than their production before the change. Not only was there an increase in production for the two groups that had fully participated, but there was definite evidence of less aggression toward management and also there was no turnover among those people.

There is one last point which I would like to direct at those of you who are the industrial engineers, the staff specialists. Very often the staff specialist attempts to dictate to people in the line. He thus appears to the people in the line as a real threat. He also often has to make sure that he gets credit for the new idea or method that is being introduced. Now I would like to suggest--and there may be many of you who will strongly disagree with this point of view--that the staff specialist will probably function most effectively if he has a strong passion for anonymity, if he recognizes himself as being an aid or assistant to the line executive, if he measures his success in terms of his ability to get the line executive to accept the new idea or method which he is trying to introduce. He will measure his success by the feelings of security that the line people have in dealing with him. If, on the other hand, the line people look on him as being a real threat to them, then I would say the staff specialist is not functioning effectively.

In the past half hour I have tried to point up some of the principal problems that you face as barriers are set up in your way in introducing new ideas or methods. I pointed out to you the kinds of behavioral responses that are forthcoming from people as you try to involve them in change. We tried to get some insight into why people behave in the way they do; and we tried to see some of the methods that might be used, ranging from the selling approach which is relatively ineffective, to the full participational approach, which research evidence seems to indicate is the most effective approach. Finally, I suggested what seems to me to be the most effective role which the staff specialist can play in his relationship to the line. In conclusion, let me say that as staff specialists and line executives I feel that you cannot overemphasize the great importance of the human factor relating to the problems with which you must deal. Never forget that in every problem which you face--whether it is a problem of change or any other kind of problem in which people are involved--the human factor must be taken into account in arriving at an effective solution.

INDUSTRIAL ENGINEERING PHILOSOPHY

Session Chairmen: H. S. Kaltenborn, Berkeley, February 2, 1952
R. B. Barton, Los Angeles, February 5, 1952

THE TREMENDOUS POTENTIAL OF INDUSTRIAL ENGINEERING

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In correspondence with foreign businessmen, and in contacts with businessmen who have come to this country from some 26 or 27 foreign countries in Europe and Asia, asking questions as to how American Industry and our Company handle management problems, the outstanding remark made by almost all of them in every instance has been that it is clear to them, after a visit to this country, why American Industrial Management is the outstanding management in the world of business today. And they attribute that fact to the universal practice among American Industrial Management people of freely and fully exchanging information regarding management problems and their solution. It is very interesting to me because the more I think about it the more I realize that it is true. The fact that representatives of Columbia Steel, Standard Oil Company of California, East Bay Municipal Utilities District, to name a few companies I see represented here, are willing to meet in public or in each other's offices and exchange information about organization, personnel, research, accounting, advertising, wage and salary administration--and all of the other areas of management responsibility--means that all of us can make progress continuously, based on our ability to give information to the other fellow and in return receive information which adds to our store of knowledge and enables us to do a better job. I think that is the keynote of this Fourth Industrial Engineering Institute.

Professor Kaltenborn referred to the fact that having returned to the land of my adoption I went into the legal profession. Unless anybody now or hereafter raises the question as to why a fat, dull old country lawyer can get up and tell a bunch of industrial engineers how to run their business, I want to say I am not going to tell you how to run your business, but I am going to tell you from some of my personal experiences in corporate reorganization in the law practice, in the reorganization of what was first the U. S. Army Air Force and subsequently the U. S. Air Force, and my work in the Department on Organization in Standard Oil Company of California, things that are basic, that occur everywhere, that are applicable to all types of human endeavor.

It is my personal belief that the man with a profession behind him is the best qualified man to act as a staff adviser to top management in the solution of management's multiple and complex problems. By profession I refer to lawyers, engineers, accountants, chemists, and other similarly trained individuals. I believe that even military men have something to offer. My main purpose is to open to you, particularly to the younger men present, the door to a wider horizon of endeavor in management. I propose to discuss how the application of the normal concept of industrial engineering does not take full advantage of the potential of the professional field of endeavor.

I should like to quote from a definition of industrial engineering given by Professor M. E. Mendel at the I. M. S. dinner meeting in December 1950, courtesy of Professor Malcolm. "Industrial engineering is that branch of engineering where more special knowledge of the mathematical and physical sciences and applied psychology, together with the principles and methods of engineering analysis and design acquired by professional education and practical experience are used in order to solve in a scientific manner the problems of designing, predicting the performance of, and controlling an integrated industrial human group activity, the related physical facilities, and the accompanying pattern of interrelationships." That is a very fine definition.

I think it behooves the industrial engineer to look beyond the confines of that very qualified definition, and in order to illustrate my point I propose to demonstrate briefly to you gentlemen how a broader concept works in industry, and more particularly in the oil industry. Within our industry industrial engineering has a rather limited application. We do, generally speaking, follow the broad principles which are taught and applied in the field of industrial engineering, but when it comes down to the more detailed techniques practiced by the average industrial engineer we find that because of the complexity and the nature of our organization, those techniques do not have wide application. In the design and operation of an assembly line for the assembling of automobiles, such as the Ford Motor Company has at Richmond, industrial engineering plays probably the major role, because the essence of the production technique is uniform, repetitive action conducted at a maximum of speed with an attendant maximum of proficiency. That is how the American business manufacturing game has gotten as far as it has.

Let's take a comparable item out of a large oil company--the light oil distillation unit at our Richmond refinery. The problem is that of processing by chemical means through mechanical equipment lighter fractions of crude petroleum in order to separate out the top fractions for use in gasoline, naphthas, the solvents and thinners, and aviation gasoline, and to leave a residue of lighter oils which may be re-refined into such things as liquid petroleum oil for medicinal purposes, sewing machine oil, and the lighter grades of lubricants that are used throughout industry and American human life. The process is a continuous flow process through retorts and stills; and the operator frequently stands around with his hands on his hips or in his pockets doing nothing but watching a series of gauges. His value to the process is a standby value based on his knowledge of what to do instantly should the process vary from the normal. You can see readily that he has not the same type of activity or responsibility as that of a production line worker.

We do use industrial engineering, for instance, in setting up and measuring the efficiency of such activity in our refineries as barrel washing, the filling and shipping of smaller products, and the operation of our new wax plant. As a matter of fact, we have a plant at Richmond in which we take such great pride that we willingly take large groups of the public through it, upon request, to show them the modern facility layout and planning of a completely automatic system of packaging, filling and shipping, which occupies an area of about three acres and is operated by four men. That includes the filling and delivery to the freight car doors of completed, marked, and filled packages. So industrial engineers are useful to us. But there are more important, highly complex operations in the oil industry which, although they are subject to some form of measurement, are not susceptible to the techniques ordinarily used by the industrial engineer.

Our five basic operating functions are exploration, production, transportation, manufacturing, and sales. Exploration is known as a scientific pursuit, in that it employs scientific knowledge and the scientific approach. The over-all ability to find oil transcends the purely scientific, and in many instances, as wealthy men in Texas will tell you, the secret is the ability to smell it.

The same thing is true in production. Our production involves drilling to the pool, the capture of the oil, and its movement to the surface where it is collected through gathering systems for transportation to the refinery. And as the field grows older and older the gas pressure at the bottom becomes less and less, the problems of capture become greater and greater. We have used certain industrial engineering techniques to improve the efficiency of our production operation. Our Producing Department, by the use of those techniques and study over a period of about six years, has reduced our manpower requirement in producing wells from 26 men per 100 producing wells to 15 men per 100 producing wells. I don't mean to indicate that the Standard Oil Company is always seeking ways to take people off the payroll. That isn't true. If we can reduce the number of men required on a job it leaves us free to utilize the surplus men on other jobs.

The same thing is true of our marine operations, our manufacturing operations, and as I mentioned, the light oil distillation unit, and our marketing activity. We have from time to time called in industrial engineers from outside the Company and from within the Company to make detailed studies of various aspects of our major operations. And in almost every instance we have profited to no small extent from their ability to point out methods of improvement and improved techniques in our own processes.

The industry, although it does not use industrial engineering to a large extent, does apply the basic principles which are involved in industrial engineering to the problems of manpower and organization. We do this in Standard of California in the department of which I am a member, the Department on Organization. We also operate through counterpart organizations within the major operating department which we designate as Organization and Cost Control ~~Divisions~~.

The department has been in this game in our Company for some 20 years. Over that 20 years we have evolved the following philosophy of organization as a function or technique of management. It falls logically into four parts. (See Figure 1.) Organization planning is the architectural design of organization structure for the application of mass effort to the production of goods and services. Concurrent with that sub-function, and closely integrated with it in almost every instance, is the problem of manpower and methods control and cost control. We believe that this is the means of determining by factual measurement the required size of the organization in terms of people.

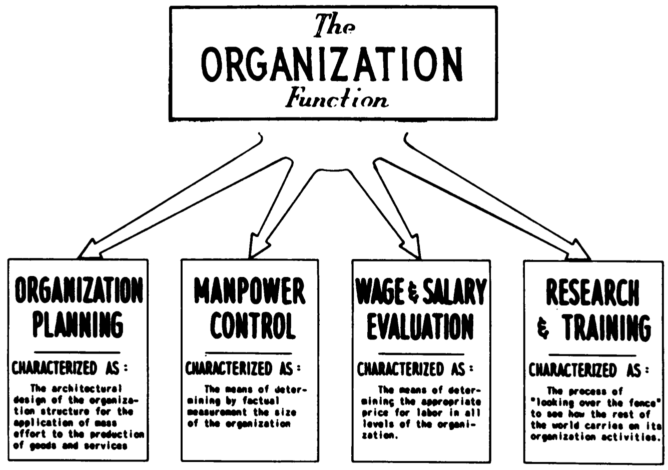

Figure 1

I am sure that those of you who are familiar with personnel work have knowledge of cases that will contradict the next point, although I would like to say in our defense that our 20 years of experimentation have confirmed our original view. I have learned recently that there are other industries and certain branches of the Armed Services that are coming to see this point our way. We believe that wage and salary evaluation, the staff work in support of the administration of wages and salaries by line management, is a proper part of the organization function. It is the means of determining the appropriate price for labor at all levels of the organization.

I was asked last night if we actually applied these principles in our system of job and position evaluation to all levels, and I had to say that we actually do--from the job of roustabout and laborer in the field, and hall boy or office boy in the offices, clear on up to the level of officers of the corporation. The salary and wage structure developed within our Wage and Salary Division are applied in putting a price tag on every job in the Company and all of our subsidiaries.

In order for these three sub-functions to continue efficiently and effectively and to keep abreast of the latest development, we feel that an important sub-function is organization research and training, the process of looking over the fence to see how the rest of the industrial world is solving its problems. The American technique of exchanging management know-how is similar to the training and indoctrination of those people within the Company who are now engaged in, or who are to be engaged in, management and the staff activity under the organization function.

The department in general provides assistance, advice, and consultation to line management in these four phases of the broad function. The normal pattern of such assistance is through policies and programs which are developed as a result of experience, analysis, and study, and recommended to top management for adoption.

Functional guidance is a term that we like to use to describe the peculiar staff relationship between a staff organization and another organization in the line. The Department on Organization assists management and other departments by providing functional guidance on organization matters, and by means of special analyses, studies, and surveys. In conducting this type of endeavor it is possible that you gentlemen will find the makeup of the department of interest. Generally speaking, in fact, almost without exception, the members of our department have come up through accountancy, through mechanical engineering, electronics engineering, mining engineering, law, and in some few instances, military personnel experience. My own belief is that a man who has, as I say, a professional background and a taste of the rigidity of military organization is far and away the best type of man to utilize in this part of our management picture.

The chart entitled, "Department on Organization--Relationships," is an attempt to portray graphically and briefly the relationships of our department with the rest of the Company. The department reports to the President, and on occasion, to the Chairman of the Board. This means that we are subservient to no special interest within the Company. We have no axe to grind, we have no advancement to seek, because we work for the man. It has been tried in the past having the department report to a Vice President, and as I believed to be inevitable, when the department made recommendations affecting another department reporting to another Vice President, there was not a clear-cut acceptance of recommendations. The charge of bias and partiality was apt to be hurled, and instead of solving management problems, the situation was very apt to deteriorate into a dog fight between two Vice Presidents. We have gone back to putting organization directly under the top man. We believe that line management, from the officers down to field superintendents and foremen, carry the inalienable responsibility for sound and simple organization, for proper utilization of manpower, and for the effective exercise of controls over manpower and costs. That responsibility cannot be delegated outside of the line. But we assist the line manager, who may not have time or the know-how to do the thinking and the work in connection with that responsibility by himself, by providing staff groups at each level to be his right hand on the particular subject of organization.

Our department, therefore, works for the President. We take on jobs, we give advice and consultation, and assistance as necessary, to Vice Presidents on request. We are available for consultation to department management at the direction of the President, at the request of the Vice President, or at the request of the department manager himself. And in our major departments there are counterpart staff groups to serve within those departments. Organization and Cost Control Divisions are charged with the same staff functions that our department is, but with the respect to the particular department in which they are located. They answer directly to their department manager. There is a functional relationship between our department and those divisions to ensure that Company policies and programs are uniformly understood, interpreted, and applied. The same is true at subsequently lower levels. I will try to demonstrate that point a little later.

As I said before, a great deal of our work nowadays consists in consultation and advice to line management. In the beginning, 20 years ago, our principal task was putting out fires, going to the field and discovering why operating organizations were not moving efficiently. But over the 20-year period the emphasis has changed from putting out fires to the point where departmental and lower management now come to us and to Cost Control Divisions for advice and consultation before the fire starts, which I regard as a signal mark of progress at least in our management thinking.

RELATIONSHIPS

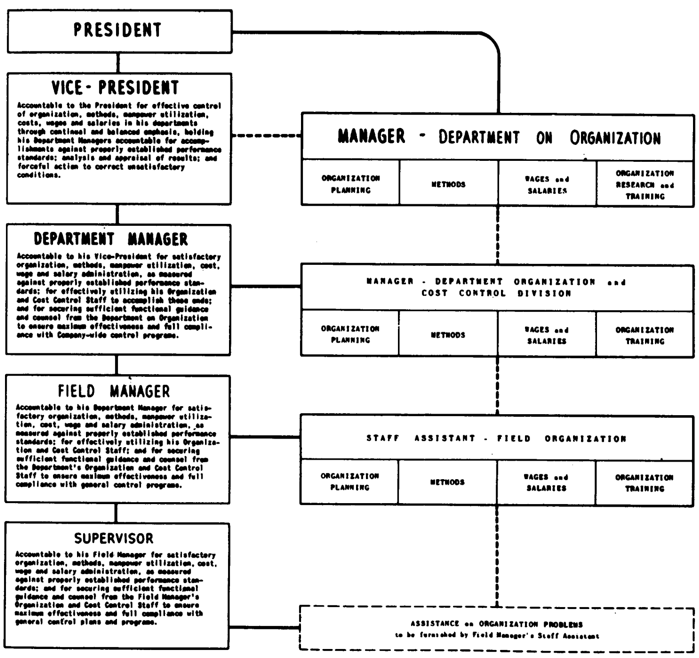

Figure 2

ORGANIZATION CHART

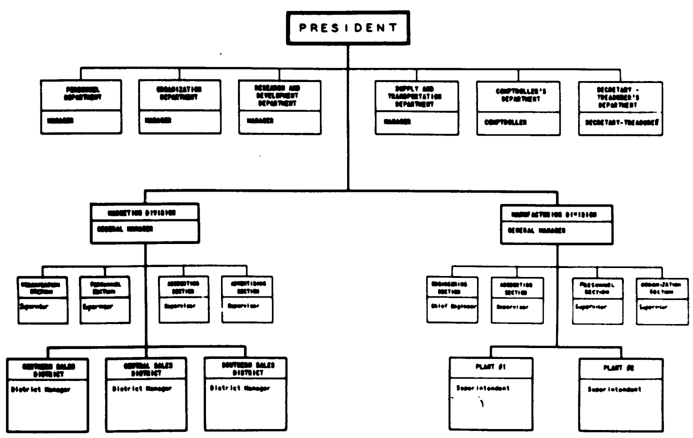

Figure 3

The chart entitled, "Organization Chart," Figure 3, is a highly schematic diagram of the character of the organization of a corporation. I have only attempted to sketch out briefly the character of a company structure here, showing the President, other officers, the principal staff and service departments, and two major operating departments. In order to illustrate the point of responsibility of line management for the organization function I have indicated the Department on Organization as the President's principal staff agency on the subject, serving the President, the officers, and all of the departments in an advisory and staff capacity.

Let us consider the organization of our Producing Department, headed by a General Manager and two Assistant General Managers, with a staff and with three geographical operating divisions as shown in Figure 4. This consists here of Accounting, Personnel, Organization and Cost Control, and Engineering. Observe again that the Organization and Cost Control agency or division is the staff agency reporting to Mr. Big, serving the entire

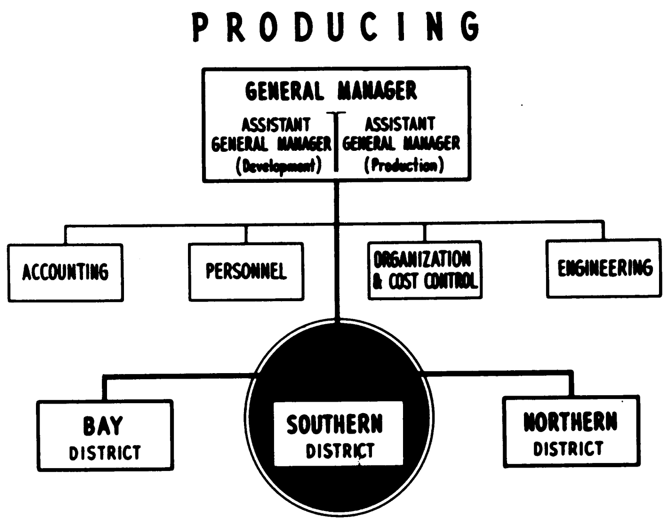

Figure 4

organization of which it is a part. And the three operating divisions have again a similar pattern. Let's take the Southern District.

The Southern District is headed by a Manager and a General Superintendent. It has a staff and three operating divisions. The pattern is identical at this level, as shown in Figure 5. There is an Organization and Cost Control Section, charged with identical staff responsibility, reporting to the Manager, serving the entire organization--the Drilling Superintendent, the Production Superintendent, and the Maintenance and Construction Superintendent. Below this level the staff function is usually part of another job. In our line departments, the concept is that the field superintendent is his own organization and cost control man, because of the essential part the function plays in his management responsibility.

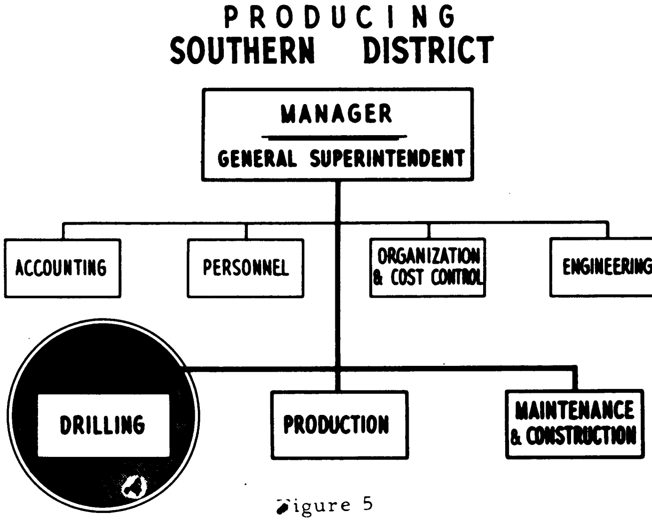

Figure 5

In some departments there may be an assistant to the field superintendent or an Assistant Superintendent who carries the burden of the staff responsibility. But the responsibility is there at all levels, whether there is an organization or component setup especially for the purpose or not.

The corporate organization shown in the chart is that of a company formed for manufacturing some kind of an electronic device which is too complicated for a lawyer to explain or understand. It is a typical pattern of industrial organization. The President, as head of the going concern, is supported by the necessary staff agencies--personnel, organization, research and development, supply and transportation, comptrollership or accounting, and the inevitable Secretary-Treasurer required by corporation statutes.

This corporation is engaged in the manufacture and sale of Clopotrons, so their operations logically fall into manufacturing and sales. The Organization Department serves the President and the whole organization in a manner similar to our department at Standard of California.

This is assumed to be a small corporation. It is highly probable that in some companies the general manager of manufacturing, his personnel supervisor or, in some cases, his accounting supervisor, and in others his chief engineer will serve as the organization consultant to the Manufacturing Division. The same is true of marketing. But here I have assumed that a separate staff agency is warranted. The organization staff agency shown in each of the two operating departments is therefore a departmental counterpart of the Organization Department.

Now let us see what this concept means to industrial engineers.

I believe that the detailed study of industrial engineering techniques provides a know-how and analytical ability that is very difficult to attain in any other manner. The individual who completes his required course of training and graduates as an industrial engineer from a qualified university has had experience in the analysis and evaluation of techniques and practices in terms of results. He should have attained, by the time of his graduation, a realistic understanding of the proper emphasis on the use of detailed techniques. He knows those detailed techniques thoroughly, he has a practical experience in their application to certain problems, and if he is a reasoning human being, he should begin to understand how those small experiences and facts begin to show a pattern of principle and philosophy. During his course of education he has gained an understanding of the development and application of basic management principles and their application to problems of organization and manpower. While not all individuals with industrial engineering training are capable of the broader field of endeavor, industrial engineering as a profession has a wider horizon in American industry than the measurement of detailed efficiency at the lowest operating level.

I say again that my thoughts are principally directed to the younger men here, the younger men in the industrial engineering profession, because the older men have already learned it or being older and somewhat set in their ways in most cases, (my apologies to any toes trodden upon) are unable to adopt new, large-scale ideas. But, if you will take as industrial engineers what you have learned in school and in the initial phases of your industrial experience, and distill from that wealth of detail the common principles applicable to all management, and stand ready to apply them in the broad manner outlined, you will have placed yourself in a position from which you can be of the greatest and most valuable assistance to top management in any industry, whether it is susceptible to the principles of industrial engineering or not.

Discussion following the subject.

Question: Mr. Hall, when you make your job evaluation and fix your salary, do you disclose that salary range to the people or to the individual or to the department, or is that kept secret? Answer: No, it is not secret. It is known as a matter of course to line management and key staff people, all the way down. We have a policy that any employee may inquire of his supervisor and be told the placement of his position and the salary range for that position. We do not fix the salary, it is placed in a group between brackets, and line management fixes the salary.

Mr. Kaltenborn: I might add one of the unusual things about wage and salary administration in this Company, which is very large, with many thousands of employees, as you know. I believe this to be one of the very few large companies which uses the ranking system of job evaluation. And they do it very effectively, although most of you, if you have anything to do with job evaluation, have probably thrown the ranking system overboard for the factor comparison or a point system, or something of that nature. But they do it on a ranking system and they do it very well.

Mr. Hall: I might give just a couple of words of explanation of our firm belief in the allocation of the staff work in support of wage and salary administration to the Organization Department. Our department started out in the depths of a depression when it was a question of cutting operating expenses or going under. We sent a team of four men, two of whom are still in the department, into the field, and they were soon known as the Four Horsemen of the Apocalypse. They were armed with a letter from the head of the Company. He gave them full authority to walk up to a typist typing out an invoice in 12 copies and say, "Stop typing that and don't ever type another one." They worked with the employees in the field. They rode 8-hour shifts with truck drivers. They tagged along after pumper-gaugers around a pumping string. They watched a drilling crew on tour for a full tour. They looked at every job in the field. They talked to all the occupants of the jobs until they were as familiar with the contents of each operating job in the Company as the individual employees were themselves. With the help of the employees they were able to increase the productivity of individual positions by improved methods and techniques. And they were able to eliminate unnecessary or expensive or duplicative effort. Incidentally, with the help of the employees in that very trying time, the reduction in manpower was kept to a minimum because the employees voluntarily accepted a shortened work week in order that the largest number of employees possible could be retained on the payroll. It got down so bad at one point that they were working a 2-1/2 and a 3-day week. But it kept the large majority of our employees working throughout the depression. In doing this job of "efficiency experts," a term I personally abhor, they discovered that truck drivers in the Producing Department were getting a different rate of pay for eight hours work than were truck drivers in the Marketing Department, or the Natural Gasoline Department. They discovered that pumper-gaugers in the Producing Department in the oil fields were getting a different rate of pay than were pumper-gaugers in the Natural Gasoline Department, and so on across the Company. By virtue of their intimate knowledge of the details of each of these operating jobs, they were able, by study and analysis, to arrive at a racking-up of the value of various jobs. In order to get a better wage and salary placement of each of these jobs with respect to all others, a system of vertical ranking within a department, and horizontal ranking or comparison clear across the Company, was developed. The system met the test of fire and sword, because immediately, when the Producing Department found out that Marketing Department truck drivers were now getting into the same salary as they, they raised hell. But the Four Horsemen--and that is now a term of affection, incidentally--were able to demonstrate to the employees themselves that actually the Marketing Department job had just as much responsibility and as much job content as the Producing Department job had. They were able to show pumper-gaugers in the Natural Gasoline Department that the pumper-gauger job in the Producing Department, which had previously been paid the same and was now going to be paid more, was actually a bigger job. The Natural Gasoline Department pumper-gaugers admitted that it was a bigger job after they got through with the explanation and comparison.

We have tried the factor comparison system. We have tried the point evaluation system. We have tried all of the known systems in comparison to our somewhat less than scientific system, and we found in every instance that we could not do a better job by those systems than we do by our own system. And I would like to clinch the point by a remark that I made last night, that our system is acceptable to management, to the employee, to the salary stabilization board, to the wage stabilization board, to the unions. And I will be confounded if I know any other test that is valid.

Mr. Kaltenborn: We are running very close to the time when we will have to adjourn, temporarily, for a brief break. Is there a last question that someone would like to ask now? Later I think after the second speaker is through, if Mr. Hall will still be here, we may have an opportunity to put him back on the floor.

Question: Mr. Hall, there is one question on this organization. You have an awfully lot of duplications down the line. Do the heads of each of these organization divisions belong to the one higher up? Answer: The head of an Organization and Cost Control Division reports to the General Manager of the department.

Question: He is not a member of any other organization higher up? Answer: No, he is not. They do their own house cleaning within their own house, except when an over-all, objective study is needed from an agency such as ours, or when it is a question of the application and interpretation of a Company-wide plan. In such case we come in as the high level experts and conduct a survey, give them the details of a program, and then they are supposed to carry it out within their department. You will understand that out of a large number of departments there are many departments that do not have Organization and Cost Control Divisions. Although there are individuals, members of management who serve as the managers' advisers on that function, in those cases we frequently and most normally do the actual work, where it is required. for them.

Question: I have a question on separation of cost control and your accounting. What sort of a system do you have in liaison between the two departments? Answer: Well, perhaps I better take just a half second to explain what we mean by control. We believe that control is setting up a system of red flags to tell management when something is wrong. It is a means of comparing expectation or planning with actual result. That is what we mean by control. It may be reports, it may be field trips, inspection trips, it may be interviews with individuals. It may be actual comparison of a completed financial statement against a financial forecast. Any means that will bring to management's attention deviation from the normal is what we call control. Cost control is the responsibility of line management. They have the assistance of our department, and the Organization and Cost Control Divisions in setting up controls to tell them when their costs are out of line and why they are out of line. They have the Organization and Methods Divisions within our Comptroller's Department to help them set up special accounting procedures and systems should they desire the help. The Comptroller consolidates the budgets of the individual departments into the over-all Company budget from the over-all point of view as Comptroller and Chief Accountant. He gives advice and consultation to top management and department heads on cost and expense deviations. But the actual control of costs is the sole and again inalienable responsibility of the line manager. Does that answer your question satisfactorily?

Question: Mr. Hall, do you have any trouble with your staff organization getting information to the chief staff organization or the manager? Answer: You mean, do we have difficulty communicating, for instance, between our department and an Organization and Cost Control Division in a major department?

Question: Do the managers ever sit in on their staff organization, so to speak? Answer: Twenty years ago the answer might have been "yes." In 1952 the answer is "no." The reason for the change is 20 years of Company-wide experience. This is a question of what Mr. Hamstra brought up: a matter of integrity, having done a good job, having sold line management as well as the lower staff echelons on the pristine pureness of our motives and the validity of any recommendations that we may have made. It has been a question actually of management education, and the result shows clearly in the fact that, as I pointed out today, the preponderance of our work is in consultation with line management before mistakes are made, rather than having to go back and correct mistakes once they become visible. Is that the information you were after?

Question: Yes.

DYNAMIC INCENTIVES

Col. Alexander Heron, Vice President

Crown Zellerbach Corporation

San Francisco, California

It has been a little bit difficult to phrase a title for the kind of thing I want to say to you today. The people who invited me down here were not deceived into believing that I should be able to contribute anything in the way of superior knowledge of the techniques with which most of you are already familiar. At some time in our process of aging, I think it comes about the time when half the hair is white, we begin to worry about the narrowness of some of the roads that we have been following, the lack of perspective and breadth of view that we may have attained. And so, even though what I say today may be completely unorthodox from your particular Bible, it may induce some of you to balance the scientific knowledge in the field of techniques with--not rules, not facts, not knowledge that I bring to you, but with questions that I hope to leave with you.

In announcing the subject of Dynamic Incentives I should like to interpret my French as far as my faulty knowledge of English will permit. Perhaps I should say that I am going to ask you to be sympathetic to the choice of words to which I have been limited. To do that I want you to think with me of dynamic incentives as something that generates power internally, as distinct from our concept of incentive rewards which from the outside do a hopefully magnetic job of drawing out effort, attention, cooperation from a wage or salary earner. One distinction, perhaps, between what you have been talking about and what I shall talk about today is that I am trying to find out if there is territory to be explored that deals with generation of impulse and power internally in the mind, or conscience, or psyche of a worker, supplemented of course and made worthwhile by the external offers in the form of incentive rewards.

I have an acquaintance, a friend I think, who is the top technician for one of the very large industrial unions in the United States. As a technician I respect him very highly; as a political philosopher I detest him. He is an incisive student and a very troublesome person to deal with from the other side of the table. He has recently written for the International Labor Organization something which would be a much better job than I could do today if I should just take the time to read his paper. The title of it is "Management Attitudes Toward Wage Incentive Systems." In this publication he does a very excellent and factual job of distinguishing between the various attitudes which management at different times, different places, and in different connections has taken toward the general subject, the general function of wage incentive systems. I am not going to attempt to read his paper because it is longer than my talk will be, but I am going to read a few paragraphs for you. He is discussing first a group of management people who approve the theory of wage incentive systems but are reluctant to put them into practice or have not been successful in putting them into practice. Drawing from the comments of this group, he expresses their judgment for them in this way: "As to wage incentives in themselves, they have been unable to implant the spirit of loyalty and devotion to the individual business enterprise or to promote the understanding of and cooperation with plans to promote its best interest." Then in another quotation he says, this time quoting from the writings of technicians in the field of the time study type of incentive wage system, and expressing himself, I think: "A successful wage incentive plan demands favorable plant environment, an equitable wage system, a workable labor policy, stable union relations, and adequate flow of work, standard equipment and materials, and good management performance. A wage incentive system is not a substitute for good management; it requires good management to operate effectively. In dealing with the subject of enlisting the worker -----------* he must be instructed in the purposes, goals, and benefits of the program." Quoting again from this certain critic: "Individual wage incentive programs increase the competitive relationships among workers within the plant and intensify the worker's tendency toward advancing his own self interest rather than the success of the entire establishment. The wage incentive plans do little to implant in the worker an understanding and sympathy for management's point of view, tests for operations, and the essentials for business success."

One final quotation and I shall leave the esteemed gentleman. He mentions that a one approach to gain the worker's loyalty and cooperation in production has been direct communication of the employer's purpose, policy, plans and prospects to the employee. Without quoting I shall leaf forward through a few pages and give you in my paraphrasing the solution to all the problems that surround incentive wage systems. If I have read this article intelligently, carefully, I gather from it that the solution is, to begin the original discussion of an incentive installation, to develop the program, the method, the techniques, and to leave the administration of them at least fifty per cent, with the union that is in the particular establishment. Those of us who have lived through the years with applications of incentive wage systems, those of us who have lived through the struggles and lessons of collective bargaining, have frequently wondered why the obvious economic gains to the individual worker have not resulted in the cementing together of the kind of team in which we are interested, in whose growth, in whose existence we must place reliance. We have seen, most of us, in our own operations various forms of incentive systems ebb and flow in their effectiveness in drawing out worker efforts, worker attention, worker concern over collateral factors such as quality and cost other than labor. We have seen in other establishments, in the complete absence of a direct incentive plan, the achievement of the thing that we have thought could be achieved only through a wage incentive plan.

As I read the program today I felt little twinges of real regret that Mr. Lincoln was unable to be here. However, there is a little comfort in it, too. It is dangerous

*Transcription not clear at this point.

enough for me this afternoon to expose myself to the criticism of people who are religiously committed to certain techniques of incentive systems. But it would be extremely dangerous to expose oneself to the passionate enthusiasm of any adherent of a profit sharing system. In spite of the enthusiasm of the people who live by a profit sharing system, these systems frequently have failed to create the generating force that binds a team together to go through the crisis.

It is a rather curious thing that economists and philosophers and historians and technicians in our own fields have never agreed on a simple fundamental of our American economic system. It seems to me that the acceptance of the first of the ten commandments that may be in our economic system is a starting point for the area of understanding which we are all endeavoring to reach. I am presenting the question to you today that there must be something so simple, so true, that we can all accept it as the underlying purpose of the American economic system. When I say all, I mean wage earners, middle management, supervision, staff people, top management and even theoreticians in universities. If there is such a starting principle it will not be the science of economics, it will not be the interpretation of the American economic system, but it will be something on which we can start together; and in starting together our efforts are more likely to move in the same direction than if we start from a dozen different premises.

Some of you may have heard me say before how much I have been impressed by some rather odd facts that have come to us out of the experiences of George Washington during his first year and a half as president of the United States when the capital was in the city of New York. His private accounts were kept by a man who left a very excellent record and a very interesting and dramatic one. During that year and a half, just as casual incidents here and there scattered about the records, are the stories of purchases which Mr. Washington made--a pair of boots, a pair of house slippers, a set of flat irons for the family laundry, a kitchen range and a bedroom heating stove, a rocking chair, a new dining table; altogether a list of about forty such items. There is nothing dramatic about any of them except for the way in which they were bought. They are the kinds of things which you and your wives would buy across the counter or in a fitting chair in a shoe parlor today. Out of the stock of a merchant you buy these items, or the corresponding items for our modern customs. Every one of them was purchased by George Washington by giving an order personally to a craftsman who knew how to make the particular thing that Washington wanted. That applies to the boots, the shoes, the handkerchiefs, of course, the flat irons, the kitchen range, the family coach, the rocking chair for the bedroom, the dining table for the dining room, every one of them made to order by a craftsman.

The background of the story is that 90 per cent of the adult males in the United States in Washington's time were self-employed in a sense that they possessed certain skills and sold the product of those skills directly to the customer. There was no intervening chain of processes between the man who did the work and the man who bought the finished article which paid for the time of the man who did the work. In these little records in Washington's time a name drops in here and there and one name is in several times--Mr. Jno. Wolf. He made the boots; he made the shoes. Today, in the United States, there are about 700 custom shoe makers who make shoes and boots to order. There are four of them in San Francisco and proportionately there should be about 15 in Los Angeles, I do not know. I have not checked. The four in San Francisco specialize very sharply; two of them specialize in making shoes and boots for skiers and skaters, the other two specialize in making orthopedic shoes to the prescription of a doctor, for people who have foot troubles that need a particular type of shoe. Seven hundred people, seven hundred shoe makers in the United States making shoes to order! On the other hand, John Wolf has left as economic descendants some 250,000 who are workers in shoe factories where your shoes and mine are made. These 250,000 shoe workers do not know you or me. They have not the least idea who is going to wear the pair of shoes on which they are working on some small detail today. They are turning out more and better shoes for everyone of us than George Washington could buy with all the money that he had when he was the richest man in the United States. They cannot go out and sell their skills. Today they require the investment of capital in enormous amounts of machinery; so much so that one of the larger machine industries in the United States is the shoe machinery industry, making machines for the shoe factories where these 250,000 John Wolfs are working. They work perhaps in Connecticut and you buy the shoes in Los Angeles or Beverly Hills or Westwood or wherever it may be, 3000 miles away. And yet, the dollars which you pay for shoes must be carried back in part to furnish the wages for the John Wolfs who are making shoes for us today.

Another illustration of what I think is the starting principle upon which we can all agree in making our American economic way of life a source of dynamics for incentive systems. Up in the states of Oregon and Washington our company and many others employ woodsmen, loggers. The top of that profession is the high climber perhaps, and next to him the faller and bucker, a team of two men. These men "fall" the giant trees. They stand at the foot of a 200 foot hemlock and prepare to bring that tree to the ground. They follow through after the falling of the tree to the work of bucking it, getting the limbs off, cutting it into log lengths. Then their work is finished. Suppose that they were self-employed. How much chance would they have to sell that day's work for twenty-five dollars, which is about what each may hope to earn? How much chance would they have to sell their day's work to the ultimate consumer who is willing to buy what they had produced that day? No one wants to be the world's greatest owner of logs as such. The logs must go from there through a whole procedure that employs hundreds and thousands of men in scores of steps. Finally, you go down to the newsstand and buy a newspaper for ten cents, and your ten cents pays the wages for those loggers in the woods. In that newspaper you find advertisements paid for by the department stores and service stations and the lonely hearts clubs and all the others who use the columns of the paper for that purpose. They did not pay their own money for that advertising in order to see their names or the names of their establishments printed in nice type in the paper. They paid the money that came to them from the customers, the customers who came to them from reading those advertisements.

Is there some way, have we the intelligence, to explain to the man standing at the foot of the hemlock tree the course that is necessary in order to bring to him the money for that day's wages out of the pockets of the purchasers of newspapers in Los Angeles? Out of the pockets of the customers of department stores who provide money which that department store paid to the newspaper publisher? The hemlock tree that these men have cut down found its final market, found its final use in the printed newspaper that was on the newsstand in Los Angeles or in New York or in New Orleans or in Chicago, thousands of miles from where the tree came down!

Ninety per cent of the adult white males in George Washington's time sold their services directly to the customers. They knew who wanted their goods, their services, they knew who paid the money. Today we are working in an economy where eighty-five per cent of us are on somebody's payroll. I should be thoroughly scared if someone told me that beginning tomorrow I had to go out and sell my services, my skills, whatever they might be, my knowledge, whatever it might be, to the ultimate consumer. It is too hard a job for me. Our economy is not organized to work that way and so I sell whatever I have in the way of values to a corporation which takes what I can contribute and mixes it with the contributions of thousands upon thousands of others including these tree fallers and buckers up in the woods. Out of it all comes a going business enterprise which is the salesman for the time and skills, knowledge and services, and efforts of ten or fifteen thousand of us.

I am trying to picture for myself the relationship between the actual purpose in which we are all engaged in our American economy, and the urge upon me to do something as a cooperating member of that economy. In one of our northern mills during the war years they had about 1600 people who stayed on the job continuously. There were about 400 jobs where people were coming and going all the time. To keep those 400 jobs manned, in the course of four years they had to hire 6000 different individuals. They came from all over the United States. I want to mention one who came from what we call the hill country of the Carolinas. He came in the recruiting program in 1943 and in 1948 I had the pleasure of presenting to him a five-year service pin indicating that he was one of those who stayed to fill those 400 jobs. He was a rather small man, with probably less than the average native intelligence. He held on to my hand, shook hands with me in the brief ceremony, and said a few things that set me exploring. I found out these facts about him. His job was that of loading lime rock into little tram cars to be delivered to an acid plant in the pulp mill. This undersized man was lifting heavy "chunks" and loading these little tram cars. As he loaded the tram car he gave it a little push and another one came along and he eventually had loaded a train of them. Then an electric locomotive came along and drew them around a curve out of sight, and some new empty ones came to him. Day after day, empties came in, were loaded with lime rock by his efforts alone, and hauled off out of his sight.

He was a little bit small for the job, but wiry and able to do it. Two or three times they had opportunities to give him slight advancements, one, two, three cents an hour increases, but he insisted on staying on that job. The thing that started me to inquire about him was a remark that he made to me when he got his five-year service pin. He said that he hoped that I would come down and look at his job because it was an awfully important one in that mill. In my questions about him I learned that he had explained in different snatches to people why he was not going to give up that job. He explained to them that this lime rock had to go pretty steadily all through the day shift. It went from here down to the towers, where they made acid out of it, that they used to digest the wood chips. Out of those digested wood chips they made the pulp that went to the paper machines, and of course the paper machines made the paper, and that is what the mill was selling. If somebody got that job of his and did not know how important it was to keep that lime rock moving, if somebody got careless about it or went to sleep on the job, or if somebody could not handle it rightly, there might be a shut down. They might not get enough acid made that day, and there might not be enough pulp the next day, and the following day the paper machines would have to be shut down and the mill would not be turning out any paper!

If we can do consciously, scientifically, studiously for the ten or fifteen thousand people in our company what that unlearned man from the hill country did for himself, we will have achieved the ultimate goal of dynamic incentives. Something was within him that gave him a religious devotion to a task that was worthwhile, not just the task that he was doing, but the task that the whole enterprise was doing, in which his little task fitted.

To me the whole function of the American economic system is expressed in these two things: The first job of our economy is of course to produce an adequate supply of goods and services to meet all the needs of our people as a nation and those are growing needs that are being refined. Equally important and indispensable is the second function of our American system: to furnish to every human resource that we have the outlet for the energies and abilities possessed by that human being who is our greatest resource. To put that crudely in social language, it is to furnish jobs. In a language which I think can be accepted most readily by all of us on both sides of the bargaining table, the second great function, an essential function of our American economic system, is to be the salesman for the time and strength and skills and knowledge of every one of us who cannot reach his customers across the nation; who can no longer sell his shoe-making abilities to the individual customer; who cannot sell the product of the tree that he cut down in northern Washington to the man who wants it in the form of a newspaper on the streets in Los Angeles. These are inseparable functions--to produce an adequate supply of goods and services and, as the basic incentive to get the production done, to do a selling job at a good price for the time, and strength, and skills of every one of us, the eighty-five per cent of us in this country who must be on somebody's payroll.

If we can express that idea across the bargaining table, and if we can plant the seed of imagination in the minds of the Joe Humphreys from the hill country who have those lime rock jobs in our mills; if we can plant in their conscience the ultimate purpose of the particular enterprise and of the economy as a whole; if we can plant it there with the conviction that it is a worthwhile purpose for all of us in America, we have given man a new internal push, a dynamic incentive which will express itself in almost incredible responses to the external incentive rewards that we develop in our technical applications of incentive systems.

THE ROLE OF PSYCHOLOGY IN INDUSTRIAL ENGINEERING

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Editor's Note: Mr. Hamstra started his discussion with a demonstration. Making reference to the fact that need for worker participation had been stressed during the conference, he suggested an experiment. Without further preamble, he asked for a volunteer from the audience. At first, the request was not taken seriously by many, but as time elapsed the realization grew that someone would have to volunteer. Evidence of tension and nervousness in the audience became evident. Eventually, there was a volunteer.

As the audience started to relax, Mr. Hamstra announced that he would need another volunteer. Tension continued to rise in the audience while he proceeded to question the first volunteer along very general lines while awaiting the second volunteer to emerge.

The wait for the second volunteer was somewhat longer than the first. By this time, there was evidence not only of tension, but anxiety in the audience, even though they were only observers.

Each of the volunteers was interrogated in turn. Although there was some tendency to deny the symptoms, each volunteer finally agreed that he had experienced a great deal of muscular tension, accelerated pulse, elevated blood pressure, faster breathing, and feelings of a void in the pit of the stomach. Mr. Hamstra later made the point that these were the physiological symptoms of fear, and that in the demonstration situation, these same feelings were experienced by the observers, even though they did not participate actively. Logically, they should have been completely detached; actually, they experienced all that was happening to the other men. Mr. Hamstra's discussion presented the parallel between the demonstration and the "logical" approach to workers used by Industrial Engineers

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There are a number of things which should be perfectly obvious from this demonstration. We have represented the type of situation that every one of you, as industrial engineers, must deal with day after day, whether you recognize it or not. These situations are just as tight and tense as the one we generated here. It wasn't very pleasant, was it?

Why did these particular men volunteer? The actual reasons are too complex to analyze now. We will accept the reasons they offered, but in each case, it was obvious they felt they must volunteer. So did the rest of you. As a result, everyone was uneasy. The volunteers were on edge. Those of you who were not directly affected, likewise were uneasy and on edge; so was I!

The situation which we created had a property of radiation which none of us desired. In terms of physiological reaction each and every one of us was ready to fight. We had ourselves geared up for action--physical action. Our blood pressure was higher, our pulse was faster, our breathing was restricted. The output of the blood sugar was markedly increased. We were ready, but there wasn't any action; nothing happened. Nobody understood what was going on, why it was happening, or what the outcome would be. And the situation got pretty bad, didn't it?

Probably every one of you creates situations of the sort we have demonstrated every day of your lives. Without this demonstration, you probably wouldn't believe that you do. I think industrial engineering often tends to break down by failing to recognize the reasons for the worker tensions it creates.

My discussion this afternoon will be directed to the problem of unnecessary tensions. Let's review again what happened. First, those who came voluntarily, physiologically were ready to fight. If I had annoyed them far enough, they would have become belligerent. Secondly, what was happening to the volunteers affected everyone in the room. There wasn't one of you that wasn't uneasy in his seat.

This poor human relations approach violated every one of the rules of good management. Serious strikes have been caused by doing what I did. Violating the rules for dealing with others consistently causes the failure of the best engineering plans. No engineering plan can stand on its logical merits where people are involved.

Poor human relations creates a residue of feelings which is almost impossible to dispel. As a matter of fact, in the few minutes of the demonstration, a number of you in this room came quite consciously to hate me! Regardless of how I conduct myself during the remainder of this discussion, some of you will leave with the feeling that you just don't quite like a person who would put on a demonstration of this character.

Engineers usually do not get into trouble for lack of background and training. Rather it is usually a matter of basic personality. A study was done recently in which a very complete psychological analysis was made of a number of topnotch engineers in all fields of engineering. The attempt was to find those characteristics which would differentiate the engineers from the population in general, or from other occupational groups. The tests showed that they were quite normal individually and as a group. Educationally and intellectually they were superior. Physically, they were above average. They tended to have excelled throughout their careers and had made steady progress. Most of them were family men. They were well integrated citizens in the communities in which they lived. In summary, they were good upper-middle class American citizens.

The study showed that the personality characteristics of these engineers were distinctive. It showed that an engineer thinks of himself as a practical thinker, meaning an individual who approaches problems with techniques and methods rather than feelings or impressions. He is a gadgeteer, he always wants another gizmo, and he goes about getting it by a process he calls analysis. He tends to limit his attention to immediate matters; he doesn't have much interest in intangible or unlimited problems. He must work with problems which have a limit, which come to a definite conclusion. He gets a lift out of being asked to do the impossible, so long as he is told what it is. A directive to do anything impossible such as an advertising or public relations man might be directed to do is likely to irritate or discourage or simply antagonize him.

The engineer is independent and self-directing in his work attitudes, and correspondingly is resentful of detailed supervision. He expects to be regarded as competent both by his superiors and his subordinates. Although he resents close control, he has a positive attitude toward authority. He wants to believe that higher echelons are competent and worthy of respect. He works best for a man who is technically competent, someone he can understand and respect. He works less well for those non-technical in background. He makes very little attempt to understand the motives of those working for him. Instead, he assumes that their motives are the same as his. He expects to be looked up to, regards the project he is working on as his personal possession and, accordingly, has difficulty in delegating any real authority for its execution.

These personality characteristics describe an autocrat; an autocrat with high standards of performance who gives precise, orderly directives. He analyzes, supervises and checks systematically. Those are all good engineering principles, aren't they? The interesting thing is that the way in which the engineer works is consistent with the engineering personality. He tries to force work. To get things done, he relies upon monetary incentives or threats of economic attrition. He pokes, he prods, he urges--always creating the atmosphere of people working to please him.

You will recall Mason Haire's discussion last year at this same meeting when he drew a curve of productivity. He listed those forces which were above the curve and tended to restrict production. He also listed the forces which were underneath the curve and tended to force up production. He stated that the point of equilibrium between these forces determined the level of production. The forces with which the engineer attempts to get work done are those beneath the curve; those forces which tend to force up production.

The engineering mind, apparently, has very little comprehension for those forces which are on the top of the curve and which tend to place limits on productivity. You will remember Mason Haire's description of the paper factory in New England where a group of women were doing the job very rapidly. Mason walked up to one of them and said, "I don't understand how you can do that job so fast." And the woman, looking at him with a grin, said, "Oh, that's nothing, watch this!" And she doubled her speed. One simple remark released some of the depressant forces which held her productivity in check. No offers of money, nor appeal for productivity could have gotten the same results. If some of you do not remember this particular discussion, I suggest you review the proceedings of last year. I thought Dr. Haire's discussion was exceptionally good and deserved to be emphasized rather constantly in dealing with engineering problems.

Let us synthesize our discussion and see what it means from the standpoint of industrial engineering. We have said that the industrial engineer, like other engineers, is one who works with gimmicks, with gizmos, with methods--an approach he regards as objective and scientific. He takes a look at a problem, takes it apart and analyzes it, and comes up with a solution. But somehow these solutions don't always work. How many of you have seen strikes precipitated by the installation of new equipment which would actually make the work easier for the workers? Surely this indicates that there must be more to industrial engineering than methods, approaches, and gadgets.

In the noon discussion, Dr. Tannenbaum stressed the value of worker participation in overcoming resistance to change. The principles of participation in any industrial engineering program are very simple. Do you remember the basic philosophy of J.I.T.? "Tell them what you are going to tell them, tell them, and then tell them what you told them." We are not talking about anything different because good training is also good human relations.

Let us re-phrase the job training slogan: First, tell people what you are going to do, completely, not just in part. Second, tell them what you are doing, and finally, tell them what you have done.

Let us use an illustration. I imagine the majority of you are fathers, and I suppose that you have had the experience of taking a young child to the doctor. Did you ever see how your pediatrician handles the child? When the child comes into the office, the doctor doesn't clamp a stethoscope on his chest and start listening. Actually, his methods probably look inefficient to the industrial engineer. The pediatrician hands the instrument to the child while he busies himself with other things. The child plays with it for a while, puts it on his own ears and listens to his own chest. Finally, the doctor puts it on his own ears and he does the listening. The child is fascinated and goes away happy and unfrightened. A lot of waste motion in these methods, perhaps, but if the objective is to listen to the child's chest, it's a pretty efficient way. More motions, but the objective accomplished.

Most of us in our engineering world deal only with physical distances. We measure them, time them and chart them. We must also recognize psychological distances, because the shortest physical distance is not always the shortest psychological distance. Furthermore, where people are involved, you can't cover one without covering the other. And when engineers, industrial psychologists and factory managers stop concentrating entirely upon problems of physical distance and start paying attention to psychological distances, they will discover that more of their attempts at efficiency will get results.

Essentially, the approach of the industrial engineer has been that of the autocrat. He approaches his problem with stop-watch impersonality, busying himself wholly with physical measurements. He analyzes his results, makes his recommendations, and attempts to activate them. Why is this wrong? Why doesn't it work? For exactly the same reason that we encountered trouble with our demonstrations at the beginning of this meeting.

Let us review what happened. First, I gave a short, concise, efficient directive. I asked for a volunteer in an impartial, scientific experiment. Now, you are all scientists, why didn't you volunteer right away? You didn't because in my efficiency, I failed to tell you why I needed volunteers and what would happen. Remember, this is exactly what the person on the job wants to know.

What's so tough about telling what you are going to do unless you are afraid to? Actually, most engineers are afraid to explain what they are doing. They seldom realize that failure to do so creates an even worse situation. Remember the tense, uncomfortable atmosphere in this room during the experiment? I hope you never forget it!

There is another point I want to call to your attention. Even though you take justifiable action in a particular case, if the other people around don't understand the reasons, they will feel as uncomfortable as every one of you felt when I conducted this demonstration. Remember, there wasn't any way in which you could possibly be affected unless you wished to volunteer. Nevertheless, although what I was doing could not possibly affect you, the fact still remains that you were tense and uncomfortable. The feelings of those in the back of the room were as intense as those in the front. The same radiating effects happen all the way throughout your factory, your office, your shop, in exactly the same manner.

Autocratic action, no matter how well justified by logic and anticipated results is disturbing to everyone within the radius of the action. And engineers, by nature of their personality makeup tend to take autocratic action. The characteristics of the autocrat are these: First of all, he keeps all of his plans to himself. Second, he gives only specific and direct instructions, and third, he is the sole judge of whether the accomplishment is good, bad or indifferent. Let me repeat. He keeps all of his plans to himself, he gives only specific and direct instructions and he is the sole judge of the end result.

Now I leave it for you to judge for yourselves whether or not that doesn't describe much industrial engineering. I am not criticizing. Instead, I am merely saying that there are ways in which industrial engineering has to move forward, ways in which the profession must become more mature, and this is one of the most neglected areas for development.

I am not enough of an engineer to tell you exactly how to be less autocratic in your work. The only thing I can hope is to give you a little of the feeling of the operator on the job when somebody pulls a stop watch on him, when a group of poeple come around and start shooting pictures, when a foreman transfers a man to another job without giving him a reason, or when a man is pulled off his job and told he's through. Regardless of what the reason may be, there are other observers sitting out there who are just as much affected as you people were today.

In your industrial engineering work, in your management work, whatever you do, remember that you are dealing with a problem of psychological distance which must be traversed as well as physical distance. Psychological distance can be reduced by remembering that people are important. Tell them what you are going to do, tell them what you are doing, and tell them what you have done.

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Discussion following the subject:

Question: Mr. Hamstra, do I interpret your remarks as a confirmation of our work philosophy that of a hundred per cent effort on a survey, 20 per cent should be spent in sales effort before the survey begins, 20 per cent in sales effort during the survey, and 20 per cent after the survey is completed and before the report is submitted? Answer: Yes, However, I don't believe I can break it into those percentages. In a specific organization in which a good job of operating has been done for a long time, it is perfectly obvious that much of the groundwork is already laid and that a level of confidence exists. But if management has constantly betrayed itself, and has not kept its word with people, as for example where industrial engineering has consistently chiseled on rates, then I submit to you that the percentages you suggest are not going to get acceptance. You are working against the mirror of the past.

Question: Mr. Hamstra, why are not these matters given to the industrial engineer in his education? He is so behind times that it appears that his instruction is short. Answer: Many of the things I have discussed today are matters of common sense. However, essentially what I have been talking about stems from basic experimental work which didn't start until about 1937 and which for a number of years was not recognized. Probably it is only since the end of World War II that it has come out of the experimental phase. In other words, it is comparatively new, so for the majority of people in this room there was no opportunity for it to be included in their educational background. It is an essential part of the training for young engineers, and I am under the impression that the University of California has been moving very strongly in that direction. A number of men on the staff are very well qualified in these facets of engineering instruction.

Question: What you say about the characteristics of the engineer as an authoritative personality seems to me to apply to any line of work. Can you suggest any lines of work where you don't have this authoritarian pattern? Answer: I wasn't trying to point an accusing finger at the engineer alone. It is true that his basic personality structure lends itself to the authoritarian approach. It is also true that in his dealings with other engineers, this approach often works effectively. He expects it of his superiors and his subordinates expect it of him. But when the engineer starts dealing with non-engineers who understand less of the authoritarian, manipulative, mechanistic approach, trouble is the inevitable result. But certainly there is no reason why we should believe that engineers are any more authoritarian than accountants or others. Authoritarianism is found everywhere, but because engineers often spend a great amount of their time working only with other engineers they may be less aware of it, and have experienced less actual difficulty with it in the past.

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RESULTS OF INTEREST QUESTIONNAIRE

Distributed at Fourth Annual Industrial Engineering Institute

Berkeley, February 1, 2, 1952

Number in Attendance: 375 Number of Questionnaires returned: 252

1. Attendance at Previous Institutes

Institutes	No.	General Interest: Better	Same	Worse	No Answer
1949 1950 1951	21	13	6	2	
1950 1951	9	4	5		
1949 1951	1		1		
1949 1950	8	5	3		
1951	40	14	19	6	1
1950	12	9	2	1	
1949	6				
No other Institute	155	5		1	
	252	52	36	10	1

2. Session Preference (Weighted by preference number)

Friday morning: 478 Saturday morning: 419
Friday afternoon: 550 Saturday afternoon: 441

3. How often would you attend institutes on industrial engineering?

Annually: 138 Semi-Annually: 85 Quarter-Annually: 14

4. Should institutes be held on Friday-Saturday as at present: 164
or on Thursday-Friday: 81

	Yes	No.
5. Did your company allow you time off to attend?	229	10
If on Thursday-Friday:	144	18
6. Did your company pay for your registration fee:	197	35

7. Should content of meeting be more general: 76 more technical: 83 same: 6
8. What topics would you prefer at next institute (Weighted by preference number)

	Pref.	Checked Only
Human Problems	232	44
Production Engineering	180	32
Cost Controls Systems	161	25
Work Simplification	148	27
Organization Problems	131	30
Engineering Economy	123	27
Plant Layout	115	32
Office Work Simplifi.	93	20
Job Evaluation	78	19
Quality Control	78	21

	Pref.	Checked Only
Training Problems in I. E.	74	20
Wage Incentives	69	17
Time Study Rating	68	14
Standard Data Systems	64	19
Safety Engineering	25	11
Motion Study	24	15
Detailed I. E. Research	19	5
Production Control	4	-
Supervisory Incentives	4	-

9. How did you hear of this program? Direct Mail from University: 51%
Newspaper Story: 6. 4% Company: 28% Friend: 12. 1%
Trade Magazine and Other: 2. 1%