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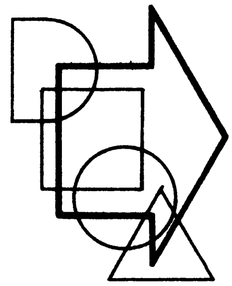

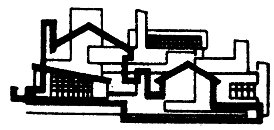

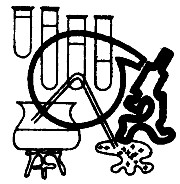

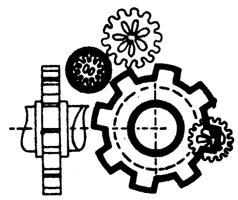

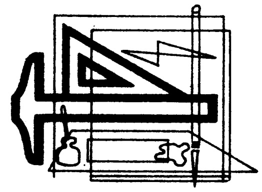

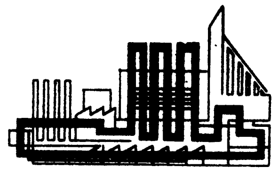

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UNIVERSITY OF CALIFORNIA

BERKELEY February 3 and 4, 1956 LOS ANGELES

PROCEEDINGS

EIGHTH ANNUAL

INDUSTRIAL ENGINEERING INSTITUTE

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THE COLLEGES OF ENGINEERING

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THE INSTITUTES OF INDUSTRIAL RELATIONS (Berkeley & Los Angeles)

UNIVERSITY EXTENSION

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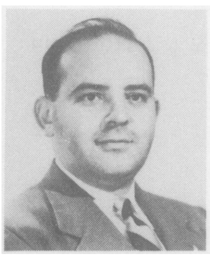

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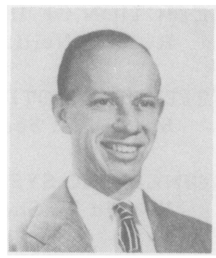

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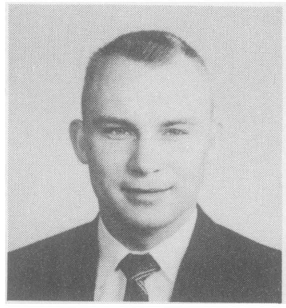

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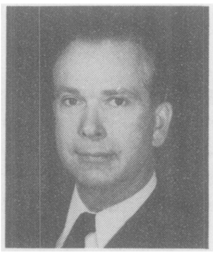

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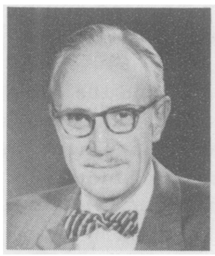

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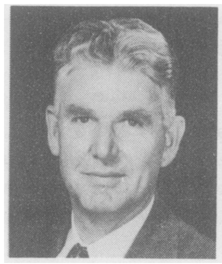

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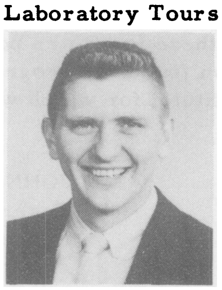

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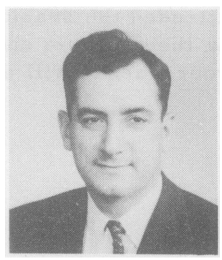

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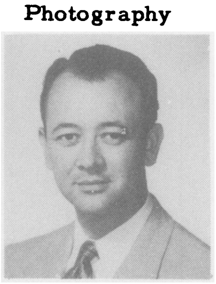

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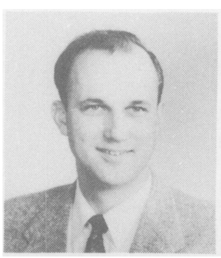

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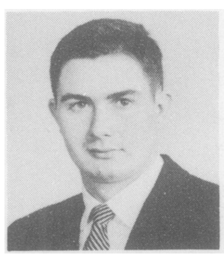

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FOREWORD

The Industrial Engineering Institute presented each year on the Berkeley and Los Angeles Campuses of the University of California is one of the key West Coast conferences devoted to industrial engineering and managment. Each year more and more people attend the Institute sessions. This year the eight hundred who were present forced us to move the Los Angeles Sessions to a larger auditorium and to plan for a similar change in Berkeley next year. Such interest encourages and gratifies everyone connected with the Institute.

An Industrial Engineering Institute represents the efforts of many people, Program planning starts ten months before the Institute is held; preliminary programs developed then are based largely on the interests of the participants as determined from the questionaires completed by those attending the previous Institute. The Planning Committee, which consists of faculty and administrative personnel from both compuses, develops the final program with the assistance of other University personnel and the representatives of the sponsoring societies. A joint budget is prepared for the Los Angeles and Berkeley sessions. Then, and only then, are individuals invited to present papers to the Institute sessions.

The large number of people who attend the Annual Industrial Engineering Institute permits us to invite outstanding speakers from all over the nation. These men are selected because they are developing and applying the new techniques of industrial engineering and management, because they are applying recognized techniques in new areas, or because they are applying recognized techniques in traditional areas with outstanding success. Each year the old and the new are combined into a program that, we hope, offers new ideas and inspiration to everyone in attendance.

The speakers whose papers appear in these Proceedings are men of outstanding ability and accomplishment. Their ideas and suggestions are stimulating and practical. Each man has taken time from a busy schedule to share his ideas and experiences with those who participated in the Institute. All of us on the Institute staff appreciate each speaker's contributions; they should promote a better understanding of the best practices in industrial engineering and management.

In closing, I want to thank the speakers, all the University staff members, and the cooperating societies for helping to make this Eighth Annual Industrial Engineering Institute the success it was. My thanks also to you who attended the sessions. Your interest, support and attendance make these Institutes possible; they provide everyone on the program and the staff with much satisfaction. We all hope you found the program worthwhile and that you and your friends will attend the Ninth Annual Industrial Engineering Institute, for which we already have many ideas.

JOHN R. HUFFMAN
General Chairman and
Proceedings Editor

WELCOMING REMARKS

LOS ANGELES

David F. Jackey
Dean, College of Applied Arts
University of California
Los Angeles, California

Personally welcoming a group who have been given an enthusiastic welcome by invitation is a formal, considerate, delightful, and expected custom of institutes and conferences. It is considerate in that its purpose is to direct the attention of the participants to the purpose at hand. It is expected because it provides someone from the administrative staff an opportunity to give a personal human feeling to the otherwise cold, brick and mortar structure, which is too frequently envisioned when we think of an institution such as a university. It is a delightful experience to me, for in this way I can say good morning to all of you, and tell you that we are proud and honored that you have chosen the University of California as the place in which to hold your discussions.

The administration from President Sproul and Chancellor Allen to the individual members of our faculty like to have you here--to have you become acquainted with us and we with you and your interests and problems. Progress and development is basically a matter of knowledge and understanding brought about through cooperation between our great institutions of learning and the agricultural, industrial, and social economies of our country.

In preparing for this morning a few thoughts came to my mind from recent experiences which directed themselves to your program for today and tomorrow. The first is maintenance. A sea of overwhelming activities requiring maintenance comes to mind, a list so long that it is impossible to give even a summary of the largest of these. Some of these maintenance activities are simple ones as found on the average farm and in the home; others assume hugh proportions, such as provided by the telephone companies or aircraft industries.

Recently I read of the new service base to be established by the Lockheed Aircraft Corporation at Ontario, California. Two questions came to my mind. The first, why such emphasis on maintenance? I concluded that these must be some of the reasons:

1. To keep the production machinery at the maximum efficiency for which it was designed.
2. To keep the human element at the maximum efficiency while enjoying the maximum safety and job satisfaction.
3. To provide a maximum consumer satisfaction.
4. To provide the employer-producer and employees with a continuous maximum employment.
5. To keep automation functioning requiring hordes of technical maintenance workers.

The second question, what are the ingredients that are essential to adequate maintenance? I am sure you have in mind -

1. Training of effective maintenance crews. Training consisting in complete familiarization with the product, the machine, its operation, and its proper performance.
2. Clear precise communications. The "why" is just as important as the "how".
3. Establishment of public confidence through good personnel and human relations practices essential in adequate maintenance.
4. Competence in maintenance (not easily attained). Nevertheless, this one ingredient is one to which I am sure all of you direct your energies and thinking as you discuss your problems. "There is no right way to do a wrong thing."

As one example of the importance of quick competent maintenance, I point to one major trans-Atlantic airline which discloses that with a 60% load factor on a tourist flight, at a utilization of ten hours per day, it nets $3.60 per mile. Since it averages 72,000 miles per month, it is most important that maintenance be effectively and competently performed, or tremendous losses are incurred.

These are just a few of the important topics your program presents for discussion. I am sure all of you will be interested in suggestions for cost reduction in construction. Why does it take one and one-half to two times as long as it did before World War II to build an individually-planned family home?

Your discussions of inspection, administrative controls, attitudes, motivations, designs, cost controls, and supervisor selection are all related. Building, producing, and maintenance is possible only by teamwork - teamwork by individuals, by institutions.

The university takes pride in offering its facilities for your use in discussing your problems, and wishes you well in at least finding a part of the answers to your problems - in fact <u>our</u> problems.

WELCOMING REMARKS

BERKELEY

Morrough P. O'Brien
Dean, College of Engineering
University of California
Berkeley, California

On behalf of the Colleges of Engineering and of the administration of the University, I am most happy to welcome you to the Berkeley campus for this Eighth Annual Institute of Industrial Engineers.

Your work, and that of all others everywhere, is most important at this juncture in the history of Western civilization. We are engaged in two conflicts -- one military and the other economic -- and we do not choose which one will be active at any given time. There are indications that our adversaries will give increasing attention to the economic side -- competing through Aswan dams rather than bombers. Whichever phase is dominant, engineers will be essential -- and because we must both prepare for war and avoid overstraining our economy -- engineers must obtain maximum results from their use of men, money, and materials.

I should like to take a few moments to review some statistics which, taken in conjunction, have considerable import. Productivity and the standard of living in the United States have increased steadily during the past century, and this change has coincided with the emergence of engineering as a major profession; pertinent figures are as follows:

year	Workers in construction and similar industries per professional engineer	Wages per hour in 1950 dollars
1850	---	0.34
1900	255	0.75
1950	62	1.94

This downward trend in the ratio of workers to engineers will continue as machines and energy are further substituted for human labor.

Following the last war, Great Britain, through numerous boards and commissions, studied the reasons for a greater rate of increase in productivity in the United States than at home. Sir Winston Churchill has expressed the conclusions reached in this statement:

> "We have suffered in Great Britain by the lack of colleges of university rank in which engineering and allied subjects are taught. Industrial production depends upon technology and it is because the Americans like the pre-war Germans, realized this and created institutions for the advanced training of large numbers of high-grade engineers to translate the advances of pure science into industrial techniques -- it is for this reason that their output per head and consequent standard of life are so high."

One of their studies, made by the Technical Director of Imperial Chemical Industries, Ltd., found that the annual increase in productivity was 3% in the United States as compared with 1.5% in Great Britain. In the United States we confer approximately 6 times as many technical and scientific degrees per year as they do in Great Britain.

A recent report, entitled "Soviet Professional Manpower," states that in 1954, the USSR graduated 53,000 professional engineers from their $5\frac{1}{2}$ year engineering program and 60,000 technicians from their two-year programs. In the same year, 24,000 students completed the four-year engineering curriculum in the United States and a smaller number completed two-year technical institute programs. Quality is difficult to appraise. It is, I believe, significant on this score that the 10-year Russian primary and secondary school sequence includes algebra, trigonometry, and geometry, 5 years of physics, 4 years of chemistry, 5 years of biology, and one year of astronomy for all students entering either the engineering or technician programs. Other evidence regarding quality is given by their design and production of bombers, jet engines, radar, and other military equipment. General White of the Air Force stated recently that the Russians have "halved our lead time on heavy bombers." He also stated: "Here is the area of deep concern -- the Soviets are beating us at our own game -- production."

These remarks are not made as a prophecy of doom -- but only to stress the fact that, despite all the official attention and private discussion about a "cold war," the average American is living and thinking as though there were no conflict. We will win -- I have no doubt -- but to do so will require considerable "belt-tightening"; our school system must be made more effective, particularly in the preparation of students for the study of science and engineering, and past achievements in cost reduction and labor saving must be substantially surpassed -- and in the effort industrial engineers will play an increasingly important role.

MANUFACTURING COST CONTROL - OPERATION LEVEL

H. C. Andersen
Division Industrial Engineer - Rates of Pay
Columbia-Geneva Steel Division
United States Steel Corporation
San Francisco, California

The importance of adequate cost control at the plant level has greatly increased in the last few years. Employment and associated costs have gone up steadily with only partial compensation through price increases. Combating this ever-narrowing squeeze on profits calls for real ingenuity and is perhaps the greatest challenge facing management today. United States Steel does not claim to have licked this problem yet - far from it. However, progress is being made through a systematic and progressive cost reduction program and we would like to tell you a little about it today. The terms cost control and cost reduction are used interchangeably because cost control and cost reduction are regarded as synonomous terms. Cost control is static and lifeless if it doesn't yield systematic and progressive reduction in operating costs.

Experience indicates that there are four (4) basic requirements to a good cost control or cost reduction program. Here is a listing of these four requirements and they will be expanded on later. They are:

1. A costing system which yields a true measure of managerial performance.
2. Full knowledge and understanding of the cost system by all supervisors.
3. Clear-cut objectives for cost reduction.
4. Supplementary procedures and techniques to help supervisors attain the objectives.

Prior to 16 years ago U.S. Steel operated under a so-called "actual" cost system. While the system furnished cost statements that were satisfactory from a financial report viewpoint, the statements were woefully inadequate for proper cost control. Why? Well, while it was known each month how much it cost to make a ton of steel, there was no way of determining whether performance was good or poor. True, it could be related to past performance but such a comparison is meaningless insofar as adequately appraising a true cost performance level is concerned. Good and poor performances in the various manufacturing operations were lumped together. The true effect of volume and product mix on plant costs was unknown, and variation in unit prices for materials and services went unrecognized. There must have been a good deal of head-scratching in those days trying to locate home plate. It was finally concluded that a standard cost system was absolutely necessary in order to have effective control over costs. Sixteen years' experience with standard costs has furnished convincing proof that it is one of the most useful tools available to management today for control of business.

DEVELOPING A COST SYSTEM THAT MEASURES MANAGERIAL PERFORMANCE

Since costing methods vary somewhat from one corporation or company to another, a brief description of the basic fundamentals of a standard cost system is perhaps in order. This can probably best be done by describing how such a cost system is typically developed.

Cost Centers - The first step is to locate areas of responsibility within the organization for which isolated costs can be obtained. These areas of responsibility are called cost centers.

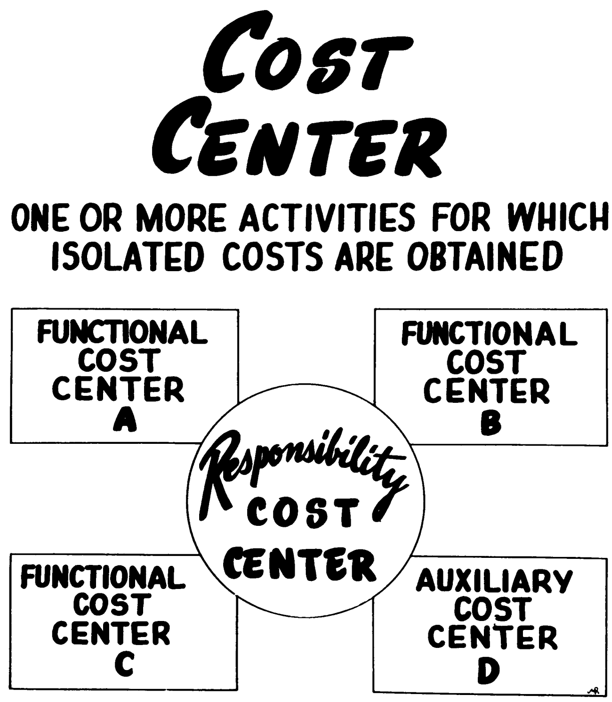


Figure 1

A "responsibility cost" center consists of one or more operations or activities for which one head only is responsible. Several functional cost centers may be included within one responsibility cost center. Responsibility cost structures generally follow organizational lines to enable control by the next higher level of management.

Normal Volume - In the second step a normal volume of production is assigned to each plant and to each cost center within the plant. Normal volume is the amount of goods and services forecasted to be produced by the various operating and staff units of an organization under normal business conditions, providing for an integrated and balanced production activity with the available and planned facilities.

Standard Operating Practice - The next step is to establish the Standard Operating Practices necessary to manufacture the products. This involves consideration of the following factors:

1. The product specifications - type, chemistry, physical characteristics, etc.

2. The materials needed to make the product including fuels, utilities, services, etc.

3. The process requirements as to operating speeds, chemical or physical treatments, etc.

4. The best sequence of operations.

5. The specific equipment needed to perform the best sequence operations.

6. Number of men required.

7. The methods for use of the equipment and materials by the required crews.

Basic Standards - With completion of the first three steps basic standards can then be developed for each expense item of each cost center. Basic standards are the physical amount of equipment, time, materials, or manhours required to produce a unit of product under the specified operating conditions. Basic standards are the very heart of a cost system and must be completely objective and factual. Basic standards are developed by the industrial engineer for approval of top operating management. The working of basic standards into dollar budgets, the actuation of budgets, maintenance of the system for price changes and the preparation of the many statistics that are required for good cost control is a function of the Accounting Department.

Variance Statements - With the budgets established and dollarized it is then possible to measure performance by comparing actual expenditures (at standard prices) to amounts earned by the various cost centers. If the actual amount at standard cost varies from the budget, the difference is called a variance. Such variances are displayed on a cost center statement similar to Figure 2.

A statement like this is prepared for each cost center, recognizing detailed items of expense for each operating unit as well as organizational responsibility at the first level for such unit operation. These statements combine all the operations under the responsibility of individual general foremen and are then further consolidated into a statement portraying the monthly cost performance of an entire operating department or division and an all-inclusive consolidated cost center statement for the entire plant each month. The preparation of cost center statements in this manner provides an overall view of the cost performance at each level of supervision and authority,

VARIANCE STATEMENT

Dept. ROLLING Works PLANT A Date JAN. 1955

Account	Variance
1. MATERIAL PRACTICE	$ (980)
2. WAGES AND SALARIES	(3040)
3. OVERTIME PREMIUM	(1100)
4. OTHER LABOR PREMIUM	(240)
5. REPAIR AND MAINTENANCE	4380
6. FUELS	400
7. UTILITIES	(380)
8. TOOLS AND OPERATING SUPPLIES	2230
9. SERVICES	400
10. GENERAL PLANT EXPENSE	(2450)
TOTAL PERFORMANCE VARIANCE	(780)

Figure 2

which is essential for properly measuring and controlling costs.

As a corollary to this concept of cost by responsibility the standard cost system also provides cost detail by operation for each element of operation expense and by product. A standard cost system is a flexible instrument which facilitates detailed analysis of cost performance.

Advantages of Standard Cost System - Some of the major advantages that accrue from application of a standard cost system are:

1. Responsibility for costs is fixed. The performance of each cost center is not influenced by performance in other cost centers.

2. Consistent, impartial standards of measurement are provided. Soundly engineered standards eliminate guess-work.

3. Performance can be measured for each level of operating activity.

4. Highlights variances, indicating where effort should be directed.

5. Gives a comparison of performance from month to month.

6. Performance of like units can be compared.

7. Provides a uniform foundation on which to base prices of products.

8. Enables better advance plans for operations, for new facilities, and for financial control. This last point is particularly significant. Forecasting or anticipating costs before they occur is a very important aspect of cost control which has had too little application in the past.

Since the success of a Standard Cost system rests largely with the entire plant management organization, it is important that everyone understand the need for and the benefits that can be derived from cost reduction. Foremen and supervisors hold the key to cost reduction. Each foreman or supervisor incurs costs in his unit and these costs must be controlled at their source. The decisions they make and the actions they take determine how well cost control is accomplished.

STANDARD COST SUPERVISORY TRAINING

You will recall that the second basic requirement involved full knowledge and understanding of the cost system by all supervisors. To meet this second basic requirement, extensive training programs must be conducted for supervisors on every level so that they can become familiar with the cost system and make it operate effectively. Such a basic training program can be divided into several steps as follows:

1. An initial session to show the need for supervisory understanding and active participation in the Standard Cost System. The cost system can be compared with a typical family budget thereby providing understanding of the terms.
2. A sample problem will illustrate the development and operation of the Standard Cost System.
3. General background covering the installation and operation of the particular Standard Cost System in effect for the Company.
4. Actual cost statements for the units in the plants that are represented by conference participants should be reviewed. Specific problems should be considered and discussed with questions encouraged to develop understanding.

Lavish use of illustrative material is recommended to sustain interest in the program. It may be helpful to take just a moment to look at a few sample illustrations which might serve the purpose of maintaining interest and developing understanding.

Let's Face The Facts -

1. The customer is boss. He will decide which products will be made, the prices charged and the quantities produced.
2. There are strong competitors within an industry and from other industries producing substitute materials.
3. The low cost producer of quality products will make the sale.
4. Sales make jobs.

Controlling Costs -

1. Costs come from each unit, however large or small.
2. Costs add up. The costs of each of these units add up to a staggering total.

Figure 3

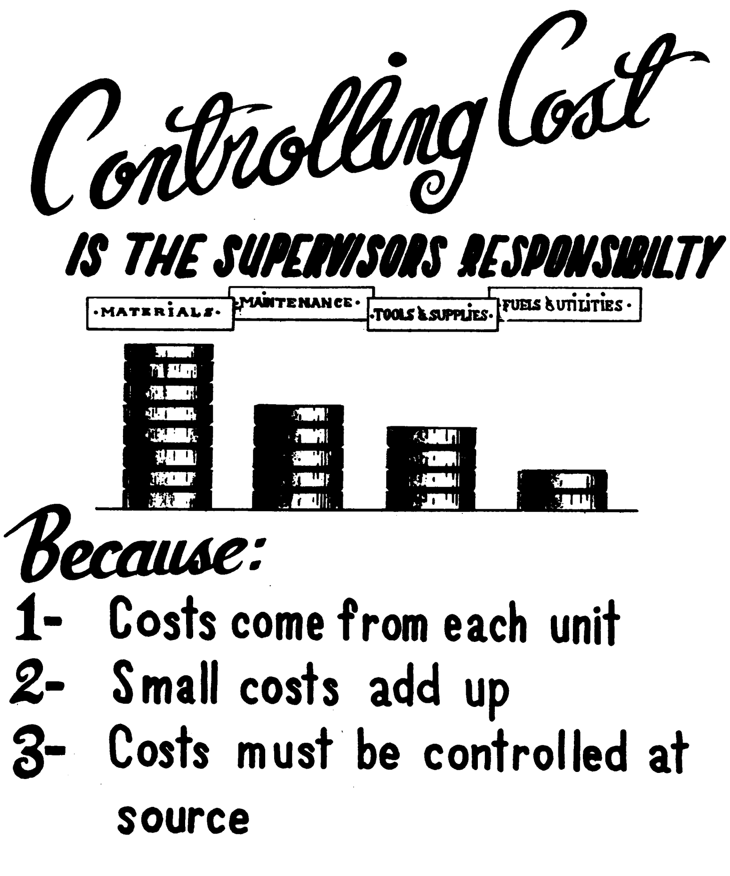


Figure 4

3. The decisions made and the actions taken determine costs. Costs must be controlled at their source.

Effective Operating Controls - It is clear that with effective control at each supervisory level, it is possible to:

1. Establish sound practices and procedures.
2. Plan production.
3. Effectively coordinate activities.
4. Insure low product cost.

Successful completion of these actions will facilitate accomplishment of the company's objective.

In discussing and explaining standard cost terminology, illustrations like these may be used.

Standard Practice Budget: Actual Volume of Production - The actual volume of production in a given month will seldom be identical to the established normal volume; therefore, a standard practice budget reflecting the actual level of activity must be developed.

1. The amount of the standard practice budget is determined by the actual volume of production of a cost center. This production may be in net tons, manhours or service hours depending on what the cost center produces.

Standard Practice Budget: Measuring Performance - The standard practice budget provides a way of measuring performance. Performance is measured by:

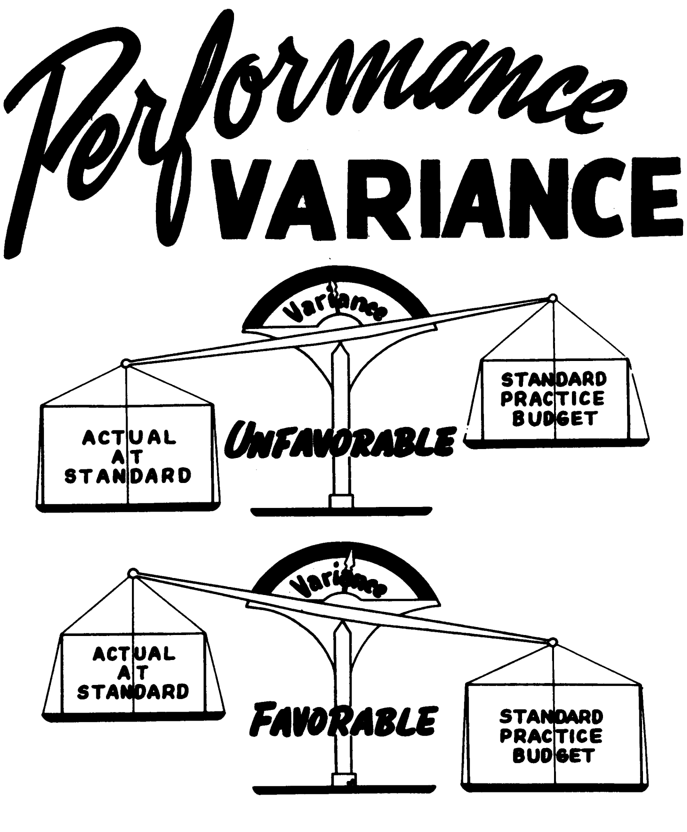


Figure 5

1. Comparing a total of the actual quantities of materials used at standard prices, actual units of service charged at standard rates and actual manhours of labor used at actual rates paid, with the standard practice budget.
2. If the actual quantities used at standard rates are greater or less than the budgeted amounts, these differences are called performance variance for which the operator is responsible.
3. Most materials and services are received at standard prices. Therefore, the supervisor is not penalized for performances in operations outside of his own cost center.

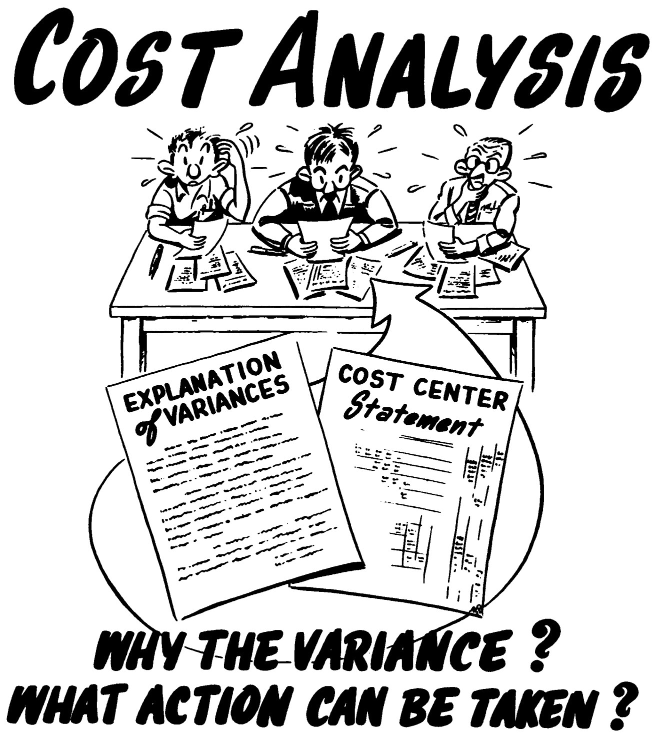


Figure 6

Cost Analysis - Unfavorable performance variances must be studied by the operator in order that appropriate remedial action may be taken.

The time and effort required to train supervisors in the use of a standard cost system will return dividends a hundred-fold. Favorable cost trends are indicative of an alert management organization that is cognizant of its cost problems and is taking specific action wherever necessary.

CLEAR-CUT OBJECTIVES FOR COST REDUCTION

It was previously indicated that the third basic requirement for Cost Control involved the establishment of clear cut objectives for cost improvement. These objectives may be established in terms of long term and short term goals.

An objective related to a desired profit return that will be adequate to satisfy the diverse interests of the stockholders, government and others, would probably be considered a continuing or long term generalized objective.

Short term objectives relate directly to particular and specified items of cost incurrence which unfavorably affect the over-all level of plant cost performance. The purpose here would be to identify specific areas and elements of current cost performance which should and can be improved in order to achieve a desired level of over-all plant performance.

The short term objective might logically be initiated annually by the General Superintendent specifying on a broad basis the over-all target of plant performance to be attained. Each Department Superintendent could then select, for a number of specific operations and elements of expense incurrence, objectives of improvement which in total would meet the over-all objective expected. These items of improvement should be defined individually as projects with the specific objectives clearly stated and evaluated.

The successful realization of the individual projects and total objective will be greatly enhanced, and perhaps only attained, by use of a formalized program of follow-up reporting. Such reporting, in addition to indicating the status of accomplishment, keeps the objectives clearly before the supervisors, thereby maintaining interest in realizing the objectives.

These objectives and projects resolve into two main categories. First, there are the pre-defined projects of improvement just described. In addition, it is logical to expect that a formalized and actively promoted training and follow-up program on Methods Improvement will produce a number of new ideas and projects throughout the year.

1. Specific Cost Reduction Projects - Here certain phases of operations are selected and specific goals established for the coming year. This would include such items as:
    1. Improved product yields
    2. Better labor utilization
    3. Lower repair and maintenance costs
2. "Spontaneous" Methods Improvement Ideas - The number of ideas which the average supervisor will submit each year may be estimated, and the financial benefits that might be realized can be calculated.

The sum savings of these two categories would then constitute the overall objective for the respective departments and plant.

Typical Cost Reduction Project - The possibility of substituting cheaper materials which will perform as satisfactorily as higher cost materials presents many opportunities for substantial cost reduction. A typical cost reduction project in this area was initiated by an Open Hearth Department where it was believed that double-burned dolomite might successfully be substituted for both magnesite and basifrit in a number of the product specifications produced. This practice was tested extensively over a wide range of operating conditions and proved to be satisfactory in every respect. Substitution of the cheaper material has resulted in a savings that may appear relatively small on a per ton basis. The furnace crews have been instructed as to the revised practices to be followed and standard practice records have been adjusted accordingly. However, this small unit savings on a large operation such as this represents very substantial benefits per year.

Methods Improvement Program - One of the significant ways to improve operating costs is to direct the extensive knowledge and experience of the management group towards better ways of using existing facilities.

Objectives can well be established for so-called "Spontaneous Methods Improvement" ideas from supervisors. A good methods improvement program can be measured in terms of how much the costs are being improved, how much the profits are increasing, what is the average value of each idea, how many ideas are being installed; but most important, how many people are getting ideas. The ultimate success of the program lies in active participation by the entire management team. A number of companies have been remarkably successful in this regard, receiving on an average as many as 8 or 10 ideas a year from each supervisor. Through an extensive training program you can make the management team methods men. Train them to look for and recognize processes or practices that can be improved. How can you do this? By formal lecture or classroom training in using a systematic approach to improve methods. This training might utilize typical plant case examples with "Before" and "After" illustration of methods improvement already installed. By providing staff service to give technical advice, to help write up and engineer the basic ideas that come from foremen. A methods program is effective only to the degree that the operating management team - from the top man to the first-line foreman - is enthusiastic about it, and that they are shown the results. Displays and charts showing the number of suggestions received per supervisor, the average dollar value of each idea, the effect on the cost of the responsibility center, and on product cost, as well as on the total plant cost, are very effective ways of demonstrating the results or effectiveness of the Methods Program. There is just time to show you one typical methods idea that well illustrates the type of creative thinking that can be manifested by an alert management organization.

A Typical Methods Improvement: Iron Depressions In Slag Runners - Originally, when casting the blast furnaces the iron would flow from the tap hole, down the trough and underneath the skimmer. The skimmer is designed to skim the slag from the top of the iron. From the skimmer, the iron would flow down the iron runners and the slag would back up into the bathtub and from there down the slag runners. As the trough became full of iron a portion of the iron would overflow into the bathtub and from there down the slag runners into the slag ladles. This resulted in a loss of metallics along with decreased slag ladle life due to hot metal striking against the cast iron or steel ladle sides.

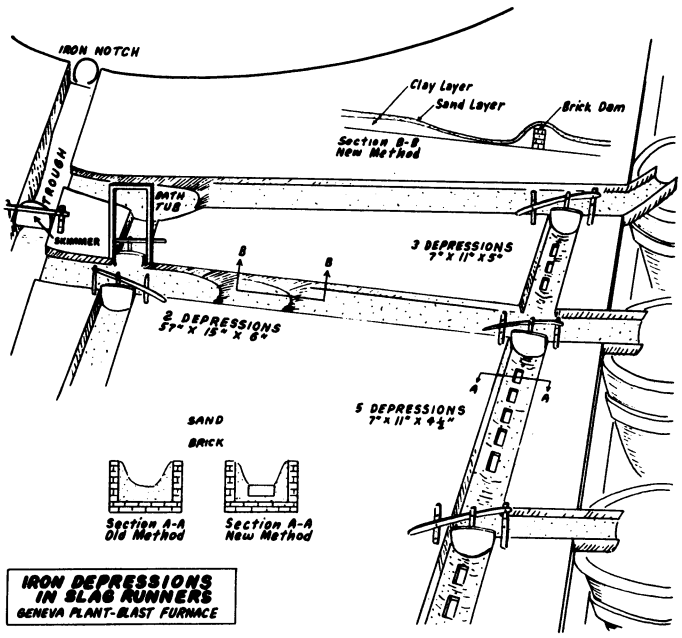


Figure 7

A methods improvement was submitted to prevent the loss of metallics in the slag and to increase the slag ladle life. This improvement consisted of putting small depressions in the slag runners. The iron which backs up into the bathtub and flows down the slag runners, has a higher specific gravity than the slag and settles in the depressions. After the case is completed this iron solidifies and can be salvaged.

A typical Blast Furnace operation will yield 4,000 tons or more of additional iron scrap a year under this practice having a substantial value.

Up to this point we have reviewed the first three requirements for adequate cost control. Just to refresh our memories once again, look at Figure 8.

BASIC REQUIREMENTS FOR ADEQUATE COST CONTROL

1. **A Costing System which yields a true measure of managerial performance.**
2. **Full knowledge and understanding of the cost system by all supervisors.**
3. **Clear-cut objectives for Cost Reduction.**
4. **Supplementary procedures and techniques to help supervisors attain the objectives.**

Figure 8

SUPPLEMENTARY PROCEDURES AND TECHNIQUES TO HELP ATTAIN OBJECTIVES

It is recognized that most Accounting data provided for analysis purposes is available after the fact of actual performance. It is obvious that in critical cost situations forehanded knowledge with respect to budgets would assist greatly in controlling actual expenditures. Accordingly, it would seem that the degree to which advance knowledge of budgets is available will be directly reflected in the success with which costs are satisfactorily controlled in critical situations.

On this line of thinking it would seem logical that efforts be made to augment specific cost reduction projects with over-all "blanket" controls functioning on before-the-fact knowledge of the budgets likely to prevail.

To illustrate the fourth point regarding procedures and techniques to help supervisors attain these objectives it may be helpful to describe a typical example of the kind of cost reduction program undertaken at our plants.

Let us assume a situation where the cost reduction goal for the ensuing year is 101% performance or a favorable performance variance. Further assume that the current cost performance reflects an incurred monthly unfavorable variance and that the bulk of this unfavorable variance is confined to three accounts:

1. Labor
2. Repair & Maintenance
3. Tools & Operating Supplies

In this cost problem illustration labor cost was identified as a significant item. Generally, there exist adequate controls on the direct labor force wherever there are extensive incentive applications since use of non-standard forces would make the incentive plan inapplicable and hence unfavorably influence earnings. Indirect labor forces represent a somewhat different problem. The indirect labor force often tends to vary somewhat haphazardly with changes in mill operating schedules or backlog of work on hand or expected to occur. Accordingly, a great deal may ordinarily be left to the unguided judgment of the foreman in scheduling such forces with variations in operating activity rates or unusual work requirements. This type of scheduling may be characterized as a non-controlled use of labor forces.

The problem of controlling indirect labor forces is obviously simplified if as mentioned above, knowledge is available as to the budget amount of forces that should prevail for the planned production schedule. By augmenting the specific cost reduction projects with the beforehanded type of control previously referred to, it is clear that the foreman's job is simplified in the scheduling of indirect labor forces. There then exist controlled use of such forces on the basis of before-the-fact budget information.

Perhaps this may seem to be a ridiculously simple concept but its execution in any complex manufacturing operation is not an easy one. In fact, all too often it is not practical to provide before-the-fact budget information to supervisors. An added complexity to such an approach lies in the fact that production schedules should be stiffened to minimize in-process changes, and at the same time there is a continuing need to maintain or improve customer order promise performance. A method also has to be found to normalize or average the many determinants in the cost system to provide before-the-fact budgets with a minimum of administrative expense and the required degree of accuracy. Time does not permit describing the degree of analysis and detail which must be considered in developing before-the-fact controls and budgets, and in any event each situation would prove to have different complexities requiring specific analysis and testing.

Returning again to the example case, let us consider how such controls might apply to the problems of maintenance expense.

Repair and Maintenance Expense - A typical maintenance organization might consist of centralized maintenance shop crews and crews which work in small decentralized groups regularly assigned to a specific group of facilities. Work done by the highly specialized shop screws is generally initiated on shop orders entered by the operating responsibilities requiring the maintenance work. Thus, there is a dual cost control problem involved - the maintenance shop supervisor must concern himself with keeping his forces in line with the amount of work at hand to minimize idle time - and the ordering responsibility supervisor must keep the issuance of such orders within the budget for this type of expense. With forecasted budgets the shop supervisor can determine the working force required as reflected by the hours of service to be furnished other responsibilities. The operating responsibility supervisor ordering shop services will know the amount of maintenance services his budget will allow and can control his expenditures accordingly in the current period.

As previously mentioned, the assigned maintenance forces will provide for on-the-spot inspection and maintenance of the operating facilities for repair services not requiring central maintenance shop facilities. Typically the assigned crew size is established at a level large enough to take care of all the routine, in-department work, recognizing that they must be supplemented at times by the central shop maintenance workers if a particular task is too large for the normal assigned crew.

To take a hypothetical case, a total crew of seven maintenance workers might be determined as the standard force requirement for a group of facilities comprising a temper mill, two shear lines and two side trimmer - recoilers. Under conditions considered normal at the time of the establishment of this standard, the flow of material - in this case cold reduced steel strip for tin plate - would be through the temper mill, then partly to the shear and partly to the side trimmers, in proportions which would utilize all four units to capacity. Product mix changes subsequent to the installation, however, might call for an increase in output of side-trimmed coils, with a corresponding decrease in the output of sheared plate. This means that to hold total production constant until additional side-trimming facilities can be installed, the existing units are required to work beyond the normal working schedule. On the other hand, the number of turns required per week of the shear is halved, resulting in operation of the mill, one shear line, and both side trimmers for the normal period of operation for the department, plus the several extra turns for the side trimmers alone on weekends.

If there is a backlog of deferred maintenance work to be done, the foreman in charge of this crew may continue to schedule the full seven-man maintenance crew for the normal operating period. For the operation of the side trimmers only, two maintenance men might be scheduled. This operation then will result in a chronic unfavorable variance for assigned maintenance crews.

With the introduction of forecasted budgets the foreman, in this instance, like the rest of the plant supervisors, can forecast his manhour usage for the coming period. If this forecasted usage is more than that provided in the budget, he could be required to submit his reasons thereto in writing for consolidation into a department report. This report might be reviewed regularly by the General Superintendent and cases of excess labor usage carefully followed up. In the case under discussion the foreman would probably agree to adhere to the standard crew schedule except in cases of emergency, making up such deficit as might occur in maintenance work by use of central shop labor. As soon as this principle of scheduling becomes established, any tendency, on the part of the maintenance workers to "stretch out" the work is relatively pointless, since their working schedule is determined by the schedule of the operating units rather than the amount of maintenance work which might be admissable to undertake on a given day.

Experience has proven that marked improvement in cost performance can be expected when operating expenditures are controlled in accordance with forecasted budgets.

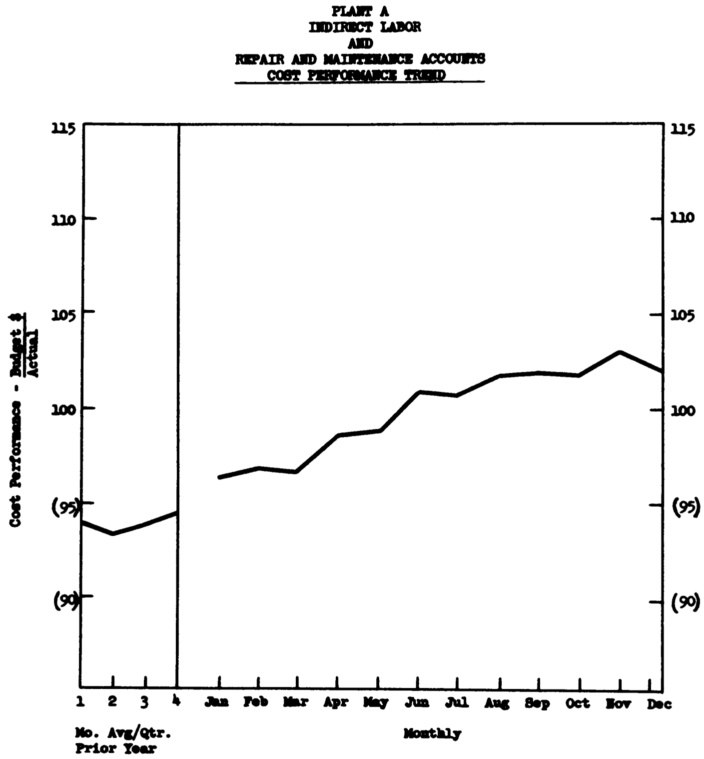


Figure 9

Figure 9 is representative of the improvement results that have typically occurred when the type of supplementary controls described have been applied to situations outlined in the cost problem illustration. This illustration depicts only the typical improvement trend in indirect labor and Repair and Maintenance expense. Similar benefits are attainable on other elements of expense such as Tools and Operating Supplies.

The question naturally arises whether such a significant improvement is achieved at the expense of deferred maintenance. This is an important point and it would therefore be well to parallel this program with suitable and adequate checks of the actual maintenance results to avoid any possibility of shortsighted actions for temporary cost improvement. Actual results have demonstrated that properly planned maintenance expenditures in light of the real maintenance needs will result in adequate maintenance and protection of the facilities concurrent with cost reductions arising out of preplanned and controlled expenditures.

Generally, there are two major factors which will contribute to a significant improvement as indicated in Figure 9:

1. The supervisor has a definite guide to follow in scheduling work forces and ordering material and is in a position to take corrective action on a current basis.

2. Knowledge by the supervisor that his performance is being followed with keen interest by top plant management.

In conclusion, let's summarize what we consider the critical points required for good cost control:

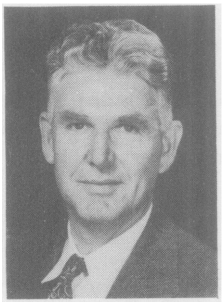
1. Standard Cost System
   Remember that a costing system is only as good as its basic standards. These standards must be authentic and maintained up-to-date if we expect to achieve good results.

2. Supervisory Knowledge and Understanding of Standard Cost
   Costs are controlled at their source and our front-line foremen must act as though they were in business for themselves. They are entitled to know what their profits and losses are, where and why they occurred. A continued assurance that top management considers them the people who can improve costs will do a great deal to instill a "way of thinking" or cost awareness in their consciousness.

3. Clear-Cut Objectives for Cost Reduction
   We have to establish specific targets for cost improvement that may be difficult to attain but are basically realistic and fair.

4. Supplementary Procedures and Techniques to Help Attain the Objectives
   We have to furnish our supervisors with an adequate set of tools in good repair. These include provision of as much before-hand information as practicable with regard to standard forces and budget earnings for various commodities. Also consistent encouragement to be alert at all times to possible improvements in operating methods and practices and providing of qualified assistance as necessary to carry their ideas through to a successful conclusion.

That pretty much sums up our philosophy towards cost control. No doubt some of what has been said is already familiar to you. If there are any points that have not been made clear, perhaps they can be clarified in the question and answer period.



Ralph M. Barnes

WORK SAMPLING

by

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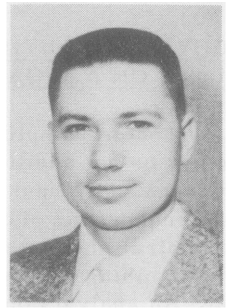

Robert B. Andrews

Random sampling for measuring activities and delays of men and machines has been used in industry for over twenty years[42]. However, its use for establishing time standards for manual tasks is a more recent development.

Work sampling employs the random sampling theory similar to that used in quality control. The method consists of selecting samples at random from a large group and when a sufficient number of samples has been selected, a prediction is made for the whole group.

The determination of the percentage of the day that the operator or machine is working or idle is based upon the theory that the percentage number of observations recording the man or machine as idle is a reliable measure of the percentage time that the operation is in the delay state, if sufficient observations are taken.

Briefly the work sampling procedure in its simplest form consists of making observations at random intervals of a department or a group of workers or machines and noting whether they are working or idle. If the operator is working, he is given a tally mark under "working"; if he is idle he is given a tally mark under "idle". The percentage of the day that the worker is idle is the ratio of the number of idle tally marks to the total number of "idle and working" tally marks. For example, if there were 36 "working" observations and four "idle" observations or a total of 40 observations, then the percentage of idle time would be 10% (4/40 x 100 = 10%) and the working time would be 90%. If the study is properly made, the reliability of the results will depend upon the number of observations made.

We have just completed a new color sound motion picture entitled "Introduction to Work Sampling" which we want to show to you at this time. (The 15 minute film was shown).

WORK SAMPLING--PERFORMANCE SAMPLING--RATIO-DELAY

We are using work sampling as the broad term which includes results obtained from performance sampling and also from the application of the ratio-delay method. Performance sampling is the name we have given to the sampling procedure for obtaining the average performance index of the operator's productive activities during the working day. Whereas ratio-delay is the name of the sampling method used to determine the part of the work day (number of minutes or hours) during which the operator is working productively and the part of the day during which he is not working. Ratio-delay studies also make it possible to obtain a breakdown of the reasons for the delays or idle time.

WHAT WORK SAMPLING CAN DO

1. Where there is a clear distinction between working time and idle time, work sampling will give time standards for repetitive manual tasks which are substantially the same as standards obtained by time study.
2. For an activity where a production count is not easy to obtain, such as indirect labor operations, it is possible to obtain a performance index of the operator studied during the period studied using performance sampling.
3. The measurements mentioned above can be made with a pre-assigned degree of reliability.
4. Work can be measured by sampling in many instances in less time and at less cost than is required by time study.
5. With work sampling the analyst makes an instantaneous observation of the operator at random intervals during the working day, thus making prolonged time studies unnecessary.
6. No stop watch or other timing device is needed for work sampling.
7. Work sampling studies may be made over a period of days or weeks, thus decreasing the chance of day-to-day or week-to-week variations affecting the results.
8. This type of study may be interrupted at any time without affecting the results.
9. Even in a plant where methods are not standardized and job descriptions are nonexistant, a performance index by operator or by department can be obtained. Also, the work sampling data could show the percentage of idle time and delays, and a breakdown of the various reasons for the non-productive time.

SOME EXAMPLES OF WORK SAMPLING APPLICATIONS

We believe you will be interested in some examples of actual applications of work sampling together with the results of each.

[42] See Bibliography at end of paper.

STUDY OF THE UTILIZATION OF SEMI-TRACTOR TRUCKS ON A SUGAR CANE PLANTATION

A random sampling study was made to determine whether or not additional semi-tractor trucks should be purchased to haul sugar cane seed to the fields on a large sugar-cane plantation. These trucks were kept in a central shed when not in use. The study consisted of determining at random how many trucks were in the shed. An analysis of 900 random observations showed that the trucks were working 63 percent of the time and were in the shed and available for use 37 percent of the time, and therefore, that it was unnecessary to purchase additional trucks.[7]

STUDY OF CAUSES OF DOWNTIME ON A PACKAGE ASSEMBLY LINE

The ratio-delay method was used to determine the ratio of downtime to running time on a straight line package assembly activity. There were 40 individual pieces of equipment on the line and the study covered a two-week period. Sixteen causes of delays were identified. Approximately 20 man hours were used to make the ratio-delay study. All-day time studies would have required several times the number of man hours.[17]

METHODS STUDY OF POLISHING CHROMIUM CHAIR PARTS

This operation consisted of polishing steel tubing parts for chromium kitchen chairs using a sisal buffer. Operators worked on this job during the three shifts of the twenty-four hour day. As a result of a careful study the very best method of polishing each of the parts of the chair was developed and the operators were taught to use this method. Even though the operators were experienced on this work, it was apparent that there was variation in the method. The main difference in the method was a difference in the number of strokes or passes against the polishing wheel per piece. Random sampling was used to measure the variation from the standard method which had been developed for the job. This enabled the industrial engineer to arrive at a new "standard method" for performing the polishing operation and this was used as a basis for establishing time standards on this operation.[7]

SAMPLING TECHNIQUE FOR DETERMINING THE PERCENTAGE OF A SUGAR-CANE FIELD TO BE REPLANTED

Random sampling in its simplest form was applied to the problem of determining the percentage of a given acreage of sugar cane to be replanted. There are two main reasons why sugar cane must be replanted. In harvesting sugar cane the stocks are cut off close to the ground and some of the cane stumps or roots may be damaged or torn out by the tractors and other heavy equipment and, consequently, must be replanted. Also, in newly planted fields some of the seed cane may not grow and so must be replanted. Since the men who replant the field are paid on an incentive basis, it is necessary to know the number of lineal feet of furrow per acre or per field that requires replanting. Random sampling was used to determine this and thus formed the basis for a more equitable wage incentive application. This method was far superior to the methods that were formerly used.[7]

WORK MEASUREMENT OF A WAREHOUSE HANDLING GROUP

The object of this study was to measure the work and install a wage incentive plan for thirty people employed in a film warehouse. The time standards were established by work sampling. The men were engaged in receiving materials, storing and stacking, filling orders, packing, shipping, reoperating (opening and repacking for tests, etc.), and record keeping. Mark-sensing IBM card were used to aid in collecting and analyzing the data. The work measurement and wage incentive installation resulted in an annual saving to the company of $45,000.00 per year. Considerably less time was required in making this installation through the use of work sampling than would have been the case had a continuous time study been used.[22]

OPERATIONS IN FRUIT PACKING HOUSES

The work sampling method was used in studies of work in deciduous fruit packing houses in California. These studies included operations in 22 plants in which the number of job classifications varied from 12 to 45 and the total number of workers per plant ranged from 25 to 180. The studies were made to obtain three types of data: (1) The proportion of the nonproductive time to the total working time, (2) Time requirements per work unit for specific jobs, (3) The flow pattern in materials handling. It is estimated that the field time required 80 percent less time than would have been necessary to obtain a one-day production study of each job.[37]

MEASUREMENT OF OFFICE WORK

The initial study using work sampling was made of four girls typing customer invoices in the Central Typing Section of an oil refinery. The results of this study were so promising that this company has used the work sampling technique for establishing performance standards for planning and scheduling purposes, for non-financial measurement purposes, and for individual wage incentive applications.[3]

PERFORMANCE SAMPLING

Introduction

In 1934 L. H. C. Tippett described a statistical method which he had developed in the English textile industry to measure operator and machine delays.[42] R. L. Morrow was one of the first people in this country to use Tippett's methods and this technique has come to be known as the Ratio-Delay method.

In 1940 we started our statistical studies of work measurement, and a summary of some of our findings was published in 1950. That report [18] presented evidence as to the reliability, validity, and practicability of the ratio-delay method as applied to manufacturing operations in this country. Over the years the ratio-delay method has found increasing use, and numerous articles have been published describing applications of this technique.

From the outset we believed that sampling could be used to measure work and a few people have used sampling for this purpose. However, no one has studied the type of statistical distribution which is representative of performance levels of manually paced operations, nor has a specific statistical technique been developed based upon the appropriate distribution and which is applicable to work measurement. This report contains the results of several studies of our pertaining to performance sampling in work measurement, including a comparison of performance sampling and time study as means of measuring industrial operations.

General Conclusions

Our main conclusion is that where there is a clear distinction between working time and idle time, work sampling will give time standards for repetitive manual tasks which are substantially the same as standards obtained by time study. Moreover, sampling measurements can be made with a pre-assigned reliability. Even in a plant where methods are not standardized and where job descriptions are nonexistant a performance index by operator or by department can be obtained by work sampling. Also, the work sampling data could show the percentage of idle time and delays, and a breakdown of the various reasons for the nonproductive time.

We believe that work sampling provides a valuble tool for measuring work, and that this simple inexpensive method will find wide use in many areas where manual work is performed.

Acknowledgements

The authors want to express their sincere appreciation to all those who participated in this study. Special thanks are due E. S. Buffa, Donald C. Demangate, J. A. Gary, Professor E. P. Coleman and Professor Paul G. Hoel who assisted with various phases of this investigation. We are also greatly indebted to the organizations that so generously participated in the validation study and whose identity we agreed not to reveal.

PERFORMANCE SAMPLING PROJECT

Objective:

This project was undertaken to develop a sampling technique which would provide an accurate and economical method of determining, with a pre-assigned reliability, the performance level of labor activities. The technique was to be applicable to any well defined physical activity which could be affected by the worker's skill and effort.

Scope of the Investigation:

The study of the applicability of statistical sampling methods to work measurement was divided into three main phases:

I. The investigation of the type of statistical distribution which is representative of performance levels of manually paced operations.

II. The development of a specific statistical technique based upon the appropriate distribution and applicable to work measurement.

III. The testing of the validity of the proposed statistical method by studies actually carried on in industrial organizations.

Phases I and II:

Detailed descriptions and the results of phases I and II have been published.[8] The investigation of the nature of the distribution which is representative of performance indices resulted in a strong rejection of the hypothesis that such indices are normally distributed.[11] Because of this result, non-parametric methods were used to derive the relationships applicable to performance sampling. The basic equation governing performance sampling of work was determined to be $n_m = \frac{\sigma^2}{d^2 a}$, where the quantities are as defined in Appendix I.[10]

Phase III - Test of the Validity of Work Measurement by Performance Sampling

PROCEDURE

To validate performance sampling as a method of measuring work, it would be desirable to compare its results with other accepted methods of measuring work. Since time study is the most widely used method, performance sampling was tested against time study. The procedure for evaluating the proposed technique was a comparison of the normal time established by performance sampling, for each selected operation studied, with its corresponding normal time obtained by time study.

The necessary data were obtained under actual factory conditions through the cooperation of several industrial organizations. The actual studies were made by experienced industrial engineers of the cooperating firms. The studies which the participating companies were asked to make consisted of four main parts:

1. The selection of the operation to be studied.

2. The definition of the elements of the selected operation which were to be measured and the establishment of a normal time for the defined operation.

3. The taking of a random sample of:
   a. The productive effort applied to the measured work elements.
   b. The machine-controlled portion of the operation.
   c. The unmeasured work.
   d. The delays, personal, unavoidable, and avoidable.

4. The compilation of additional necessary information, including:
   a. The actual total time spent by each operator in the experimental group during the period of the study.
   b. The total number of units of work produced by each operator in the experimental group during the period of the study.

The selection of the operation to be studies was based upon certain definite requirements:

1. It must have had a standardized method.

2. The operators must have been experienced in the particular operation and have been following the prescribed method.

3. An additional restriction was placed upon operations which were partially machine controlled. The machine-controlled portion must have constituted from 15 to 85% of the total normal cycle time. To attain the desired accuracy with the desired statistical confidence, machine-controlled portions outside these limits would have required a prohibitively large sample size.

Once the operation to be studied had been selected, it was necessary to clearly define the elements to be included in the measured work category. In general, the criterion used for making this decision was the frequency of occurrence of each element. Those elements which occurred at least once each cycle were measured. Less frequent elements such as inspection, recording production counts, lining trays, etc., were classified as unmeasured work. The elimination of these infrequent elements tended to increase the reliability of time study. The variation in the time duration of such elements is usually greater than in cyclical elements. This is particularly significant because the number of occurrences of such elements which are timed during a time study is typically small.

Since only experienced industrial engineers were utilized, the exact method of conducting the time study was left to the individual preference of the engineer. It was suggested that it be conducted according to the procedure regularly employed in the particular plant. It was considered essential that the same engineer make both the time study and the performance sampling study. This precaution eliminated one source of possible error--differences between raters in their concept of normal performance.

Another possible source of error was eliminated by restricting the validation procedure to only the measured portion of the total actual working time. Thus the comparison was made between the normal times established by performance sampling and by time study. Allowances were not included in the time study and, except for their use in ratio-delay analysis, personal, unavoidable and avoidable delays were excluded from performance sampling. This made it necessary to insure that a sufficient number of observations were taken to permit ratio-delay analyses to be made with the desired confidence. The number of observations necessary to determine the percent of the total actual time spent on measured work, within the desired accuracy, exceeded that required for performance sampling. Hence, the ratio-delay requirement was the determining factor in choosing the required sample size. A sample size of 600 observations was decided upon as a compromise between sample reliability and minimizing the demands upon the company. This sample size, with 95% confidence, resulted in absolute errors of ±2.4% and ±3.2% in the percent of actual time spent on measured work when the delays and unmeasured work totalled 10% and 20% respectively of the actual time.

The number of operators, individually measured and simultaneously performing the selected operation, determined the number of sampling trips required to give a total of 600 observations. For example, if there were five operators, 120 (5 x 120 = 600) sampling trips would be required. Once the number of trips had been established, the trip times themselves could be determined. The method used to select the sampling times was exceedingly important. Estimations of sampling errors are dependent upon a knowledge of the probability with which individual observations would be included in a sample. By simple random sampling, all possible combinations of observations, comprising a sample of a given size, will have equal probabilities of being selected. Trip times were randomized to maintain statistical validity.

The procedure used in making the actual performance sampling was as follows:

1. Observations were made of each operator in the experimental group at the selected times.

2. At the instance that the observer viewed each operator, the state of the operation was noted.
   a. If the element observed was classified as measured work, the operator was rated and his performance level was recorded. Appendix III contains a brief description of an exploratory study into the effect of the length of observation time on performance ratings.
   b. If the operation was in a delay or unmeasured work state it so was recorded.

The engineer making the study was supplied with written procedural instructions which included a table of random sampling times. Performance sampling data sheets were also provided.

RESULTS

The results of the studies made are summarized in Table I. The following guide to the chart explains each column. The illustrative figures are those actually used in computing the various quantities for the Company A study, line 1 of the Table. (See pages 14, 15 and 16).

As an illustration of the results which would have been obtained if smaller size samples had been taken, Table I includes the results of 50% and 25% subsamples of each full study. These sub-samples were obtained by systematic sampling of the original observations of each study. The systematic sampling plan for taking the 50% sub-sample consisted of selecting at random either 1 or 2 as the starting point and taking every second observation thereafter in the chronological order in which observations were originally taken. Similarly for the 25% sub-sample, every fourth observation, after a random starting point, was included in the sample.

Figure 2 shows the percent difference between normal time obtained by performance sampling and normal time obtained from time study for each of the fourteen different industrial operations studied. The average difference is 2.5% with maximum variations of +15.5% for Study No. F-2 and -6.2% for Study C-4.

Figure 3 shows similar information for a sample size of 50% of that shown in Figure 2. In this case the average difference is 6.6% with a high of +14.6% and a low of -9.2%. Likewise, Figure 4 shows the results when the sample size equals to 25% of the original. In this case the average difference is 17.6% with a range of +15.0% and -9.6%.

We have observed in actual practice that some people appear to get satisfactory results by using a considerably smaller sample size than that recommended. Therefore, we have included a 50% and a 25% sample in order to compare results. (See top of next column).

CONCLUSIONS

The conclusions of our study are presented at the beginning of this paper under the title, "What Work Sampling Can Do".

APPENDIX I

DEFINITION OF SYMBOLS

a = level of significance

$1-a$ = conficence level

β = relative kurtosis of the distribution

d = variation between the population mean and the sample mean

e = absolute sampling error in p_m, the percent of actual time spent on measured work

i = length of the class intervals of the grouped frequency distribution

n = total number of observations

n_m = number of measured work observations

n_o = number of measured work observations which are operator controlled

p_m = percent of actual time spent on measured work

p_o = percent of measured work time which is operator controlled

s = sample standard deviation of performance indices

σ = population standard deviation of performance indices

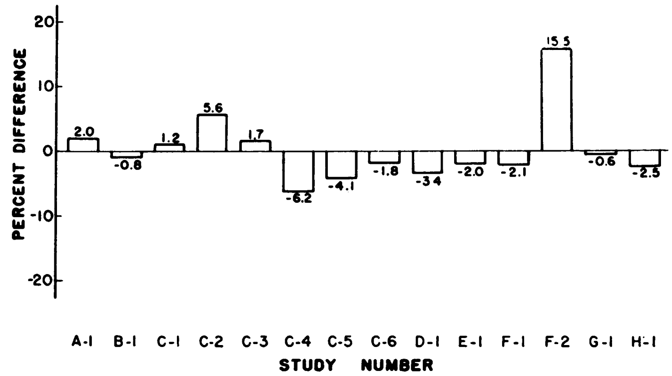

FIG. 2. Results of Full Studies
Percent difference between normal time—performance sampling and normal time—time study.

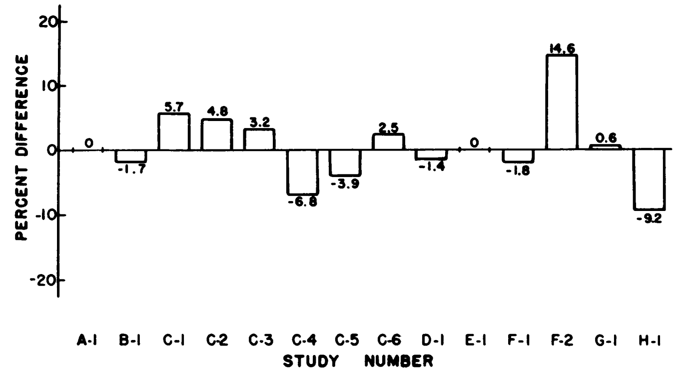

FIG. 3. Results of 50 Percent Sub-Samples
Percent difference between normal time—performance sampling and normal time—time study.

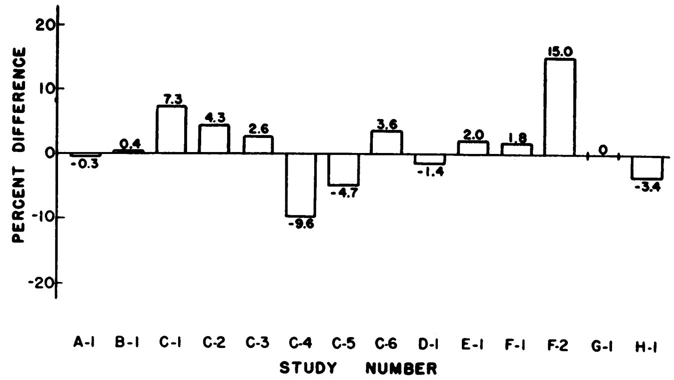

FIG. 4. Results of 25 Percent Sub-Samples
Percent difference between normal time—performance sampling and normal time—time study.

σ_s = standard deviation of the distribution of sample standard deviations

$\sigma_{\bar{x}}$ = standard deviation of the distribution of sample means

v_j = j^{th} moment about the assumed calculation mean, j = 1,2,3 and 4

π_2 = second moment about the actual sample mean

π_4 = fourth moment about the actual sample mean

$\bar{x}$ = sample mean of performance indices

μ = population mean of performance indices

Experimental Group (1) Company	Experimental Group (2) Study Number	Experimental Group (3) Number of operators simultaneously performing the operation	(4) Operation Description	(5) Total Actual Time: Minutes	Ratio-Delay Analysis, Full study (6) Total Number of observations (n)	Full study (7) Percent of total actual time spent on measured work (p_m)	Full study (8) Absolute sampling error in p_m at 95% confidence level (e)	Full study (9) Percent of measured work time operator controlled (p_o)	50% Sub-sampling (10) Total number of observations (n)	50% Sub-sampling (11) Percent of total actual time spent on measured work (p_m)	50% Sub-sampling (12) Absolute sampling error in p_m at 95% confidence level (e)	50% Sub-sampling (13) Percent of measured work time operator controlled (p_o)	25% Sub-sampling (14) Total number of observations (n)	25% Sub-sampling (15) Percent of total actual time spent on measured work (p_m)	25% Sub-sampling (16) Absolute Sampling error in p_m at 95% confidence level (e)	25% Sub-sampling (17) Percent of measured work time operator controlled (p_o)	Time Study (18) Total units produced	Time Study (19) Normal time from time study in minutes per unit	Time Study (20) Performance Index from time standard
						%	%	%		%	%			%	%				
A	1	10	Mechanical Subassembly	13,650	720	98.7	±0.8	100	360	98.3	±1.3	100	179	97.8	±2.2	100	16,314	1.00[1]	121.6
B	1	3	Electrical Subassembly	1,380	596	89.9	±2.5	100	300	89.3	±3.5	100	150	90.7	±5.0	100	6,468	0.241	125.6
C	1	1	Cutting	460	766	74.5	±3.2	100	394	77.9	±4.1	100	197	79.2	±5.7	100	7,290	0.0424[1]	90.2
	2	1	Notching	460	766	80.0	±2.9	100	383	79.4	±4.1	100	191	79.1	±5.8	100	6,800	0.0627[1]	115.9
	3	1	Cutting	460	766	83.2	±2.7	100	382	84.3	±3.7	100	193	83.9	±5.2	100	8,061	0.0346[1]	72.9
	4	1	Cutting-Bandsaw	460	766	75.6	±3.1	100	387	74.7	±4.3	100	193	72.5	±6.3	100	6,544	0.0498[1]	93.7
	5	1	Hand Nailing	460	766	90.9	±1.0	100	384	90.6	±2.9	100	192	90.1	±4.2	100	345	0.741[1]	61.1
	6	1	Machine Nailing	460	766	75.8	±3.1	100	383	76.8	±4.2	100	191	77.5	±5.9	100	1,068	0.277[1]	84.8
D	1	4	Typing Invoices	5,580	458[2]	73.6	±4.0	100	226	75.2	±5.6	100	114	74.6	±7.8	100	2,790	1.47	99.9
E	1	7	Packaging	9,660	598	80.7	±3.2	100	298	82.2	±4.3	100	147	83.7	±6.0	100	93,732	0.103	123.3
F	1	8	Assembly	15,372	649	83.7	±2.8	100	326	83.7	±4.0	100	162	86.4	±5.3	100	201	60.7	94.9
	2		Drill Sheet Metal	2,646	540	93.0	±2.2	33.1	269	92.6	±3.1	34.5	134	93.3	±4.2	34.4	900	2.33	85.1
G	1	1	Drill, Bore & Ream Casting on Turret Lathe	4,600	300[2]	95.0	±2.5	75.8	151	96.0	±3.1	73.1	75	96.0	±4.4	69.4	2,790	1.72	109.8
H	1	4	Grinding	1,840	396[2]	68.9	±4.6	46.5	198	64.1	±6.6	48.0	99	67.7	±9.2	44.8	10,900	0.119	102.3

[1] This symbol denotes that the normal time was obtained from an established time standard rather than a concurrent time study.
[2] These companies were unable to obtain the desired 600 observations.

Explanatory Guide to Table 1

Column 1—Company Code

Companies are identified by code letter to maintain their anonymity.

Column 2—Study Number

Studies are numbered beginning with No. 1 for each company.

Column 3—Number of Operators Simultaneously Performing the Operation

In certain instances more than one operator was engaged in performing the same operation. In such cases all operators were included in the experimental group. The production of each operator was individually tabulated. In each case the operation was a one-operator task—not group work.

Example: For Company A, there were 10 employees, individually measured, performing the operation selected for study.

Column 4—Operation Description

A brief indication as to the type of operation studied is presented.

Example: Mechanical Sub-assembly

Column 5—Total Actual Time

This is the total cumulative clock time spent on the selected operation by the experimental group during the period covered by the study.

Example: 13,650 minutes were spent on the operation by the 10 employees of Company A while the study was being made.

Column 6—Total Number of Observations

The total number of observations taken in the course of the study. This includes measured work (i.e., elements of the operation which are included in the normal time), unmeasured work (i.e., productive work which was not included in the normal time), unavoidable delays and avoidable delays.

Example: 720 observations were taken during the study.

Column 7—Percent of Total Actual Time Spent on Measured Work

This represents the ratio of the measured work time (i.e., time during which elements of the operation which are included in normal time are being performed) to the actual time. The quantity is determined in accordance with conventional ratio-delay practice. Thus, the percent of actual time spent on measured work is determined by dividing the number of measured work observations (Column 21) by the total number of observations (Column 6).

Example:

$$p_m = \frac{n_m}{n} = \frac{\text{Column 21}}{\text{Column 6}}$$

$$p_m = \frac{711}{720} = 0.987 = 98.7\%$$

Where:

p_m = percent of actual time spent on measured work

n_m = number of measured work observations

n = total number of observations

Performance Sampling Study

Full study						50% Sub-sampling						25% Sub-sampling					
(21) Number of measured work observations n_m	(22) Performance index from performance sampling	(23) Absolute sampling error in performance index from performance sampling at 95% confidence level	(24) Normal time from performance sampling in minutes per unit	(25) Absolute difference between normal time—performance sampling and normal time—time study Col (24)—Col (19)	(26) Percent difference between normal time—performance sampling and normal time—time study Col (25)/Col (19)	(27) Number of measured work observations n_m	(28) Performance index from performance sampling	(29) Absolute sampling error in performance index from performance sampling at 95% confidence level	(30) Normal time from performance sampling in minutes per unit	(31) Absolute difference between normal time—performance sampling and normal time—time study Col (30)—Col (19)	(32) Percent difference between normal time—performance sampling and normal time—time study Col (31)/Col (19)	(33) Number of measured work observations n_m	(34) Performance index from performance sampling	(35) Absolute sampling error in performance index—from performance sampling at 95% confidence level	(36) Normal time from performance sampling in minutes per unit	(37) Absolute difference between normal time—performance sampling and normal time—time study Col (36)—Col (19)	(38) Percent difference between normal time—performance sampling and normal time—time study Col (37)/Col (19)
					%						%						%
711	123.6	±2.1	1.02	0.02	2.0	354	122.0	±2.2	1.00	0	0	175	121.8	±3.0	0.997	−0.003	−0.3
536	124.7	±2.1	0.239	−0.002	−0.8	268	124.6	±3.1	0.237	−0.004	−1.7	136	125.1	±4.2	0.242	0.001	0.4
571	91.2	±2.1	0.0429	0.0005	1.2	307	91.2	±2.7	0.0448	0.0024	5.7	156	91.1	±3.7	0.0455	0.0031	7.3
613	122.4	±1.2	0.0662	0.0035	5.6	304	122.4	±1.5	0.0657	0.0030	4.8	151	122.3	±2.1	0.0654	0.0027	4.3
637	74.2	±1.6	0.0352	0.0006	1.7	322	74.3	±2.3	0.0357	0.0011	3.2	162	74.2	±3.3	0.0355	0.0009	2.6
579	87.9	±2.3	0.0467	−0.0031	−6.2	289	88.2	±3.2	0.0464	−0.0034	−6.8	140	88.3	±4.8	0.0450	−0.0048	−9.6
696	58.7	±1.4	0.711	−0.030	−4.1	348	58.9	±2.11	0.712	−0.029	−3.9	173	58.8	±3.4	0.706	−0.035	−4.7
581	83.3	±2.8	0.272	−0.005	−1.8	294	85.8	±4.1	0.284	0.007	2.5	148	86.1	±5.7	0.287	0.010	3.6
337	96.4	±2.1	1.42	−0.05	−3.4	170	96.2	±2.8	1.45	−0.02	−1.4	85	96.9	±4.1	1.45	−0.02	−1.4
483	121.9	±3.2	0.101	−0.002	−2.0	245	121.1	±4.5	0.103	0	0	123	122.0	±6.1	0.105	0.002	2.0
543	92.8	±1.0	59.4	−1.3	−2.1	273	93.1	±1.4	59.6	−1.1	−1.8	140	93.5	±2.1	61.8	1.1	1.8
502	98.2	±0.9	2.69	0.36	15.5	249	98.1	±1.2	2.67	0.34	14.6	125	97.9	±1.8	2.68	0.35	15.0
285	109.2	±3.8	1.71	−0.01	−0.6	145	109.0	±4.2	1.73	0.01	0.6	72	108.9	±6.0	1.72	0	0
273	100.1	±1.3	0.116	−0.003	−2.5	127	99.4	±2.0	0.108	−0.011	−9.2	67	100.2	±1.8	0.115	−0.004	−3.4

Column 8—Absolute sampling error in p_m at 95% confidence level

The absolute sampling error is ±1.96 times the standard deviation of the sample percentage. This represents the range about the observed percentage within which the population percentage can be expected to lie 95 out of 100 times. 1.96 and −1.96 are the 0.975 and 0.025 fractile values of the cumulative frequency distribution of the standardized normal variable.

Example:

$$e = \pm 1.96\, s_{p_m}$$

$$s_{p_m} = \sqrt{\frac{p_m(1-p_m)}{n}}$$

$$e = \pm 1.96\sqrt{\frac{p_m(1-p_m)}{n}}$$

$$e = \pm 1.96\sqrt{\frac{0.987(1-0.987)}{720}} = \pm 0.008 = \pm 0.8\%$$

Where:

s_{p_m} = standard deviation of the sample percentage

p_m = percent of actual time spent on measured work

e = absolute sampling error in p_m

n = total number of observations

Column 9—Percent of Measured Work Time Which is Operator Controlled

This is the ratio of "measured work time—operator controlled" to the measured work time. This quantity is similarly determined by ratio-delay analysis. Accordingly, the percent of measured work time which is operator controlled is estimated by dividing the number of measured work-operator controlled observations by the number of measured work observations (Column 21). "Measured work time-operator controlled" is that time during which those elements which are included in the normal time, and operator controlled, are being performed. Operator controlled elements are considered to be that portion of the total operation which can be influenced by the employee's skill and effort.

Example:

$$p_o = \frac{n_o}{n_m}$$

$$p_o = \frac{711}{711} = 1.00 = 100\%$$

Where:

p_o = percent of measured work time which is operator controlled

n_o = number of measured work—operator controlled observations

n_m = number of measured work observations

Columns 10 through 13

These columns are computed in the same manner as Columns 6 through 9. The only difference is that the data used are based upon a 50% systematic sub-sampling of the original complete study.

Columns 14 through 17

These columns are computed in the same manner as Columns 6 through 9. The only difference is that the figures used are based upon a 25% systematic sub-sampling of the original complete study

Column 18—Total Units Produced

The actual total number of units produced by the participating operator or group of operators during the period covered by the study.

Example: The 10 operators of Company A produced 16,314 units (sub-assemblies) during the test period.

Column 19—Normal Time—Time Study

The time required under standard conditions to perform the measured work at a normal pace but excluding any allowances. This normal time in minutes per unit was established by time study. In some instances the normal time was determined by time studies made by the same engineer who made the performance sampling studies and in other cases the normal time was obtained from data already available.

Example: 1.00 minutes per unit is the normal time for the operation studied at Company A.

Column 20—Performance Index—Time Study

The performance index from time study is determined by dividing the earned normal minutes by the measured work time in minutes and expressing the result as a percentage. The earned normal minutes are the product of the total units produced (Column 18) and the normal time from time study (Column 19). Measured work time is the percent of actual time spent on measured work (Column 7) multiplied by the total actual time (Column 5).

Example:

$$\text{Performance Index} = \frac{(\text{Column 18})(\text{Column 19})}{(\text{Column 7})(\text{Column 5})} \times 100$$

$$\text{Performance Index} = \frac{(16314)(1.00)}{(0.987)(13650)} \times 100 = 121.6$$

Column 21—Number of Measured Work Observations

This represents the total number of observations in which the observed state of the operation was an element included in the normal time.

Example: 711 of the 720 observations made during the Company A study were of measured work.

Column 22—Performance Index—Performance Sampling

This quantity is the arithmetic mean of the performance ratings made whenever the observed state of the operation was measured work. Although separately recorded on the data sheet, "measured work-machine controlled" observations were added to the operator performance ratings as 100% performance observations. Measured work-machine controlled is the portion of the operation, included in the normal time, which is mechanically paced so that it cannot be affected by the operator's skill and effort.

Example:

$$\text{Performance Index} = \frac{\text{sum of the individual performance ratings}^{2}}{\text{Column 21}}$$

$$\text{Performance Index} = \frac{87901}{711} = 123.6$$

Column 23—Absolute Sampling Error in Performance Index from Performance Sampling at 95% Confidence Level

This quantity represents the range about the sample mean performance index which will include the population mean performance index 95 out of 100 times in the long run. The equation for computing this quantity is given by:

Example:

$$d = \pm\frac{s}{\sqrt{n_m \alpha}}$$

$$d = \pm\frac{12.3}{\sqrt{(711)(0.05)}} = \pm 2.1$$

Where:

d = absolute sampling error in performance index

s = sample standard deviation of performance ratings

n_m = number of measured work observations

α = level of statistical significance ($1 - \alpha$ is the confidence level)

Column 24—Normal Time—Performance Sampling

This normal time is the product of the average performance index (performance index, Column 22) multiplied by the selected time. The selected time is determined by dividing the measured work time (i.e., percent of actual time spent on measured work, Column 7, multiplied by the total actual time, Column 5) by the total units produced (Column 18).

Example:

$$\text{normal time} = \frac{(\text{Column 7})(\text{Column 5})}{(\text{Column 18})} \times \frac{\text{Column 22}}{100}$$

$$\text{normal time} = \frac{(0.987)(13650)}{16314} \times \frac{123.6}{100}$$

normal time = 1.02 minutes per unit

Column 25—Absolute Difference Between Normal Time—Performance Sampling and Normal Time—Time Study.

As the name implies this quantity is the algebraic difference between Columns 24 and 19.

Example: Column 24 − Column 19 = 1.02 − 1.00 = 0.02 minutes per unit

Column 26—Percent Difference Between Normal Time—Performance Sampling and Normal Time—Time Study

This quantity is the algebraic difference between Columns 24 and 19, as given by Column 25, divided by Column 19 and expressed as a percentage.

Example: $\frac{\text{Column 25}}{\text{Column 19}} = \frac{0.02}{1.00} \times 100 = 2.0\%$

Columns 27 through 32

These columns are computed in the same manner as Columns 21 through 26. The only difference is that the data used are based upon a 50% systematic sub-sampling of the original complete study.

Columns 33 through 38

These columns are computed in the same manner as Columns 21 through 26. The only difference is that the data used are based upon a 25% systematic sub-sampling of the original complete study.

[2] Sum of individual performance ratings are obtained from the original data sheets.

APPENDIX II

DEFINITION OF TERMS

TOTAL ACTUAL TIME: Total work period in minutes covered by the study minus scheduled rest periods and lunch periods.

MEASURED WORK: Elements of the Operation which are included in the normal time.

MEASURED WORK - OPERATOR CONTROLLED: That portion of the total measured work which can be affected by the employee's skill and effort.

MEASURED WORK - MACHINE CONTROLLED: That portion of the measured work which is mechanically paced (such as power feed and speed) so that it cannot be influenced by the operator's skill and effort.

NORMAL TIME: The time required under standard conditions to perform the measured work at a normal pace excluding any allowances.

PERFORMANCE INDEX: For the purposes of this study, the quotient found by dividing the earned normal minutes (normal time per piece multiplied by the total number of pieces produced) by the measured work time in minutes. The measured work time is determined by multiplying the total actual clock time by the percent of the total actual time spent on measured work.

UNMEASURED WORK: Productive work which is not included in the normal time. In most studies only the repetitive elements occurring at least once a cycle were included in the normal time. For example, such elements as inspect work, line trays, record production, which occur only infrequently were omitted from the normal time. These exclusions were made to simplify the study and to increase the probable accuracy.

APPENDIX III

STUDY OF THE EFFECT OF LENGTH OF OBSERVATION TIME ON PERFORMANCE RATING RESULTS

The performance sampling technique of work measurement, which requires the observer to make ratings of operator performance based on short duration observations, raises the question of what effect the shortening of observation time has on the ability of the observer to rate performance. A limited study of this problem was undertaken.

Experimental Procedure

The method chosen for this study was to have experienced time study engineers rate a film showing several different lengths of viewing time for each of a group of different performance levels of the same operation. This provided a series of performance ratings which reflected the effect, if any, of varying the length of observation time. The film used for this purpose was a composite of the Work Measurement Film, "Dealing Cards". It consisted of three different viewing times of 5, 10, 15 seconds for each of eight different performance levels ranging from 55 to 187 percent of normal performance, based upon the national average. The sequence of scenes was randomnized, with respect to both viewing time and performance level, by the use of a random number table.

As an introduction, a scene showing an entire deck of 52 cards being dealt preceded the actual rating scenes. It served to familiarize the raters with the format of the scenes that they would be asked to rate and to provide a reference from which each observer could crystalize his own personal concept of normal performance of the card dealing operation before the rating test was begun.

The film was shown, the participating engineers were thoroughly briefed as to the purpose of the study, what they would see in the film, and what was requested of them. It was made clear that the introductory scene did not necessarily represent normal performance and that they were free to establish their own personal concepts of normal pace. Since it was the comparison between ratings and not their absolute value which was important, it was only necessary that raters have a consistent concept of normal performance.

Analysis of Data

The film was shown to fifteen experienced time study engineers at three different Los Angeles companies. The hypothesis that ratings were not affected by the length of the observation times was tested by means of analysis of variance. The results showed that the effect of differences in length of observation time was insignificant at the 95% level when compared to the inter-action between the length of observation time and the performance level being rated. This is to say that the two variables, observation time and performance level being viewed, combine to produce variations in the performance ratings which are greater than the sum of their separately produced effects.

Conclusions

No definite conclusions are to be drawn from this study and such was not its purpose. It was designed to be exploratory--to provide insight into the effect of length of observation time on performance ratings. It was undertaken on a limited scale and for only one type of operation--card dealing. It would be exceedingly dangerous to attempt to generalize the results beyond the boundaries of the study. The results indicate, however, that there is at least some basis for believing that variations in the length of observation time, within practical limits, does not have a very great effect on performance ratings.

References

1. Abruzzi, Adam, "Applying the Control Chart Method to Worker Evaluation and Incentive Plans," Personnel, Vol. 25, No. 3, p. 204, November 1948.

2. Abruzzi, Adam, "Determining Reliable Delay Allowances," The Management Review, Vol. 37, No. 4, pp. 198-201, April 1948

3. Addoms, Jeremy and Frederick A. Long, "Work Sampling in the Office," Office Management Series No. 140, American Management Association, pp. 21-39, 1955.

4. Allderige, John M., "Statistical Sampling, a Sharp Tool for Industrial Engineers," Advanced Management, Vol. 16, No. 9, p. 12-15, September 1951.

5. Allderige, John M., "Work Sampling Without Formulas," Factory Management and Maintenance, Vol. 112, No. 3, pp. 136-138, March 1954.

6. Barnes, Ralph M., Motion and Time Study, 3rd ed., John Wiley and Sons, Inc., New York.

7. Barnes, Ralph M., Work Sampling, Wm. C. Brown Company, Dubuque, Iowa, 1956, 270 pages.

8. Barnes, Ralph M. and Robert B. Andrews, "Performance Sampling in Work Measurement," The Journal of Industrial Engineering, Vol. VI, No. 6, November-December, 1955.

9. Barnes, Ralph M. and R. B. Andrews, "Work Sampling," Proceedings Eighth Annual Industrial Engineering Institute, University of California, Los Angeles, 1956.

10. Barnes, Ralph M., E. S. Buffa, D. C. Demangate, and R. B. Andrews, "Performance Sampling in Work Measurement," Proceedings Sixth Annual Industrial Engineering Institute, University of California, Los Angeles, pp. 85-89, February 1954.

11. Barnes, Ralph M., E. S. Buffa, and J. A. Gary, "A Statistical Study of Performance Sampling in Work Measurement," Bulletin Number 510, University of California, Los Angeles, June 1953. (Out of print)

12. Bogenrief, C. A., "Measuring Indirect Work for Cost Control," Factory Management and Maintenance, Vol. 110, No. 12, pp. 113-114, December 1952.

13. Brisley, C. L., "The How and Why of Ratio-Delay Study," Proceedings Fifteenth Annual National Time and Motion Study and Management Clinic, Industrial Management Society, Chicago, 1951.

14. Brisley, C. L., "How You Can Put Work Sampling to Work," Factory Management and Maintenance, Vol. 110, No. 7, pp. 84-89, July 1952.

15. Brisley, C. L., "Ratio-Delay Developments," Proceedings Seventh Annual Time Study and Methods Conference, Society for Advancement of Management, New York, 1951.

16. Brisley, C. L., "Work Sampling--A Cost Cutting Technique," Proceedings of the American Institute of Industrial Engineers, pp. 168-179, May 1955.

17. Cogan, A. J., and G. N. Stilian, "A Quick New Way to Get Downtime Data," Factory Management and Maintenance, Vol. 110, No. 3, pp. 136-137, March 1952.

18. Correll, D. S. and Ralph M. Barnes, "Industrial Application of the Ratio-Delay Method," Advanced Management, in two parts, Vol. 15, No. 8 and No. 9, August and September 1950.

19. Davidson, H. O., "Activity Sampling and Analysis - Present State of the Theory and Practice," ASME Paper No. 53-F-24, 1953.

20. Gaylord, L. E., "Indirect Labor Standards Without Time Study," Proceedings of the Fourth Annual Industrial Engineering Conference, Technical Bulletin No. 37, West Virginia University, pp. 73-79, 1953.

21. Gaylord, L. E. and C. R. Gillespie, "How to Establish Material Handling Incentive Standards Without Time Studies," Flow, Vol. 9, No. 5, pp. 78-81, Feb. 1954.

22. Gustat, George H., "Incentives for Indirect Labor," Proceedings of the Fifth Annual Industrial Engineering Institute, pp. 80-86, 1953.

23. Jaske, W. M., "Work Measurement by Work Sampling," Factory Management and Maintenance, Vol. 113, No. 1, pp. 102-106, January 1955.

24. MacNiece, E. H., "How Work Sampling Can Help You Rate Your Key People," Factory Management and Maintenance, Vol. 110, No. 10, pp. 98-100, October 1952.

25. MacNiece, E. H., "Newest Way to Check Maintenance Efficiency," Factory Management and Maintenance, Vol. 111, No. 7, pp. 110-112, July 1953.

26. Mahaffey, Daniel E., "Work Sampling--To Set Standards on Indirect Labor?" Factory Management and Maintenance, Vol. 112, No. 11, p. 142-144, November 1954.

27. Malcolm, D. G., and L. L. Sammet, "Work Sampling Applications," The Journal of Industrial Engineering, Vol. 5, No. 3, pp. 3-6, May 1954.

28. McAllister, G. E., "Random Ratio-Delay," The Journal of Industrial Engineering, Vol. IV, No. 3, 1953.

29. Morrow, R. L., Time Study and Motion Economy, p. 175, Ronald Press, New York, 1946.

30. Mundel, M. E., Motion and Time Study, 2nd ed., Prentice-Hall, Inc., New York, 1955.

31. Nadler, Gerald, Motion and Time Study, McGraw-Hill Book Company, New York, 1955.

32. Nadler, G. and D. H. Denholm, "P Charts Improve Methods for Downtime," The Iron Age, Vol. 170, No. 22, pp. 110-113, November 27, 1952.

33. Owens, Berl W., "Sequential Work Sampling," The Trend in Engineering, Vol. 6, No. 1, January 1954, University of Washington, pp. 23-27.

34. Petro, J. S., "Using Ratio-Delay Studies," Factory Management and Maintenance, Vol. 106, No. 10, p. 92, October 1948.

35. Rowe, A. J., "The Work-Sampling Technique," Transactions of the ASME, pp. 331-334, Feb. 1954.

36. Sammet, L. L., "The Ratio-Delay Study," Proceedings of the Third Annual Industrial Engineering Institute, University of California, pp. 54-58, 1951.

37. Sammet, L. L., and J. B. Hassler, "Use of the Ratio-Delay Method in Processing Plant Operations," Agricultural Economics Research, Vol. 3, No. 4, pp. 124-134, October, 1951.

38. Sammet, L. L., and D. G. Malcolm, "Work Sampling Studies: Guide to Analysis and Accurate Criteria," The Journal of Industrial Engineering, Vol. 5, No. 4, pp. 9-12, July 1954.

39. Schaeffer, E. H., "Observation Ratios - A-Short Cut to Time and Cost Analyses," Factory Management and Maintenance, Vol. 99, No. 7, p. 58-59, 158, July 1941.

40. Smith, Wayland P., "Work Sampling: Fast Way to Get Facts on Handling," Factory Management and Maintenance, Vol. 111, No. 5, pp. 70-71, May 1953.

41. Tippett, L. H. C., "The Ratio-Delay Technique," Time and Motion Study, Vol. 2, No. 5, pp. 10-19, May, 1953.

42. Tippett, L. H. C., "Statistical Methods in Textile Research. Uses of the Binomial and Poisson Distribution. A Snap-Reading Method of Making Time Studies of Machines and Operatives in Factory Surveys," Shirley Institute Memoirs, No. IV, Vol. 13, pp. 35-93, November 1934. Also, Journal of the Textile Institute Transactions, Vol. 26, pp. 51-55, 75, February, 1935.

"A COST REDUCTION PROGRAM FOR CONSTRUCTION"

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Engineering Division
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I am very glad to have an opportunity to talk to you this morning on the subject of a cost reduction program for construction - a development which has been entered into jointly by the Procter & Gamble Company and a number of its contractors. Before we explore this interesting subject, we ought to tell you that Procter & Gamble is a manufacturer of soap, food and drug products and a processor of chemicals and oils. It performs one or more of these functions in some 40 odd factories and oil mills located in this country and abroad. Design and fundamental engineering required to service and expand these facilities are carried out by the central Engineering Division.

As some of you may know, the Procter and Gamble Company has had a plan for controlling factory costs in effect for over 25 years. The costs controlled include such expenses as wages, steam, power, repairs, losses and depreciations. The return from this program was so attractive that our management, several years ago, raised the question of whether or not a cost control program could be developed to cover our construction activities which might also help to further reduce costs.

The control of costs in construction presented a somewhat different problem than that of controlling production and maintenance costs within the factories where all the personnel involved were members of our own Procter and Gamble organization. Factory expansions have been subject to more cyclic variations than production or maintenance, which has caused us to farm out the greater part of our new plant and construction work to outside contractors. The subject was further complicated by some lack of continuity of contractor's supervision on our own jobs. Durations of projects were short - from 8 to 18 months - so that techniques had to be capable of being understood quickly and applied in time to return us money. Our problem would have been simpler, too, if it had been feasible to work with only one contractor; but it has not been practical to do this across the country.

At about the same time, one of our contractors also evidenced interest in developing better means to reduce the controllable costs on construction jobs. At this time we were erecting a number of synthetic detergent spray drying towers in this country and agreed with the contractor to place one or two Methods Engineers on each of these projects. These men worked as Staff Engineers to concentrate on construction methods and techniques. They worked out better ways to perform individual pieces of work. For example, they developed short cuts to building forms for concrete and developed better procedures for erecting various pieces of equipment. It was soon clear that extra Staff Engineers would more than pay for themselves by evolving better techniques. In 1952, this same contractor erected a new soap plant for us here in California and employed nine Methods and Planning Engineers to improve the planning of more routine work as well as to evolve newer and better methods. It developed that more detailed planning of all work, whether or not a new method for doing the work involved, also reduced delays and saved us money. This movement grew and today our contractors employ some 25 Planning Engineers on four separate projects.

A brief review of how design and constructions are carried out in our particular case might be in order at this point. Basic engineering design, performed by the Engineering Division of Procter and Gamble is turned over to an engineering contractor whose duty it is to make the drawings, purchase materials and provide all the information needed by the field forces to erect new plant. The construction contractor, who may also be the engineering contractor, is then responsible for erecting the new plant in the field. Wherever possible, engineering for erection is completed in time to let subcontracts on a lump sum basis for erection. However, in too many cases, time will not permit the seeking of firm bids and construction must be let on a cost plus basis.

In the past, when the drawings and other instructions reached the field, it was customary for superintendents and other line supervision on the job to examine them and work out material deliveries, methods, plans and schedules for the most part with a minimum of field staff help. When supervision took the time to plan adequately less time was left to supervise in the field. When field problems demanded attention, too little time was left to work out planning details. I believe most of you who have had experience with field construction will agree that you could have used more time to insure that the right tools, materials and men would be brought to the right place at the right time for the most effective execution of work.

It has been our experience that the use of staff engineers to perform extra methods studies and planning for the line organization has helped immensely to solve this problem. Planning, or Methods Engineers, as they are sometimes called, are hired by the contractor to perform this work. Planning Engineers are for the most part young college graduates between 25 and 30 years old, who have majored in mechanical, electrical, civil, or industrial engineering, who have had some construction experience. Hopefully, they are men whom the contractor is training to specialize in this work or is training for promotion into the line organization. They will report in the field to a Chief Planning Engineer, whose duty it is to supervise their technical activities. The planners are loaned out to and work for various area and craft superintendents.

EXAMPLE OF FIELD ORGANIZATION

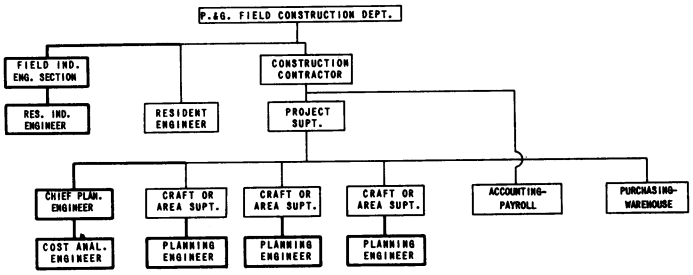


Figure 1

A glance at a chart (Figure 1) of a typical field organization shows the positions of the various planning people. Planning Engineers are assigned to craft superintendents but at the same time report for technical industrial engineering assistance to a Chief Planning Engineer. A Cost Analysis Engineer is assigned to compile reports, assist the accounting people and develop preplans and unit cost comparisons. Most important of all, a Chief Planning Engineer is appointed to head up the cost control efforts. He is responsible to the Project Superintendent for cost control procedures, for training and supervising Planning Engineers and for developing techniques to plan, analyze and evaluate work better. Contractor's line supervision has about the same responsibilities and about the same type of organization it would normally have. Over on the left hand side of the chart, we note that Procter and Gamble is represented on each job by a Resident Engineer and a Resident Industrial Engineer from our home office Construction Department.

P. & G. ENGINEERING DIVISION - CONSTRUCTION CONTRACTOR RELATIONSHIP

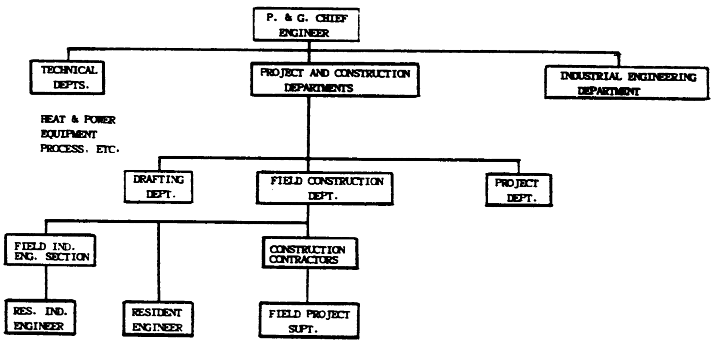


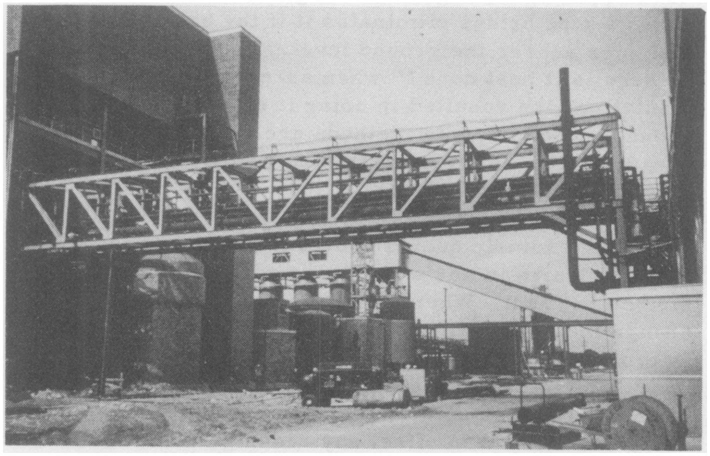
Figure 2

Figure 2 might help to show the relationship between ourselves and the contractor throughout a construction project. The contractor functions for the field Construction Department of our Engineering Division, as do our own two representatives on each project as shown here in the lower left hand corner. The technical, drafting and project departments indicated here operate during fundamental engineering to develop the basic design. The Industrial Engineering Department, shown at the upper right, works with the contractor to translate our experience in Industrial Engineering to him.

The cost reduction program as currently practiced by our contractors can be thought of as following a seven step sequence:

1. Break up the job into logical blocks of work by crafts and location.
2. Study overall methods and design alternates to perform these blocks.
3. Break down blocks of work into elements which can then be studied and combined into a preplan.
4. Show on the preplan how long each element and each preplan should take to perform.
5. Schedule and assign a full day's work from the preplans.
6. Analyze and evaluate work in progress and after completion.
7. Review results of analysis with line supervision for corrective action.

A glance at a few examples of methods studies, design alternates and preplans will help us to understand the terms used. We use the term "Method Study" to mean an overall examination of a block of work to determine the cheapest method of erecting it. Normal or conventional methods of erection are costed and compared with new approaches. An example will illustrate.



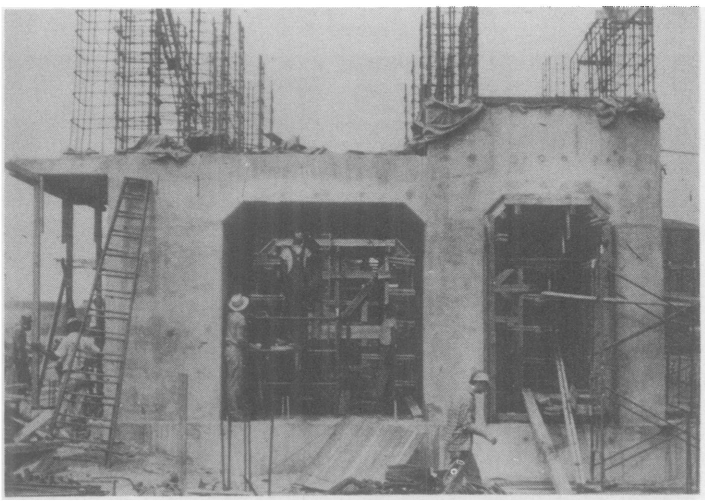
Pipe Bridge - Outside View
Figure 3

Pipe Bridge - Inside View
Figure 4

Figure 3 shows a pipe bridge in a recently constructed pulp plant at Foley, Florida. As you can see, it is a fairly typical pipe bridge which was fabricated in a steel fabricating shop and shipped to the site in one piece. Figure 4 shows the inside of the bridge and indicates the quantity of pipe that was placed in it. This bridge was studied with a view to finding alternate ways to erect it for a minimum cost. The normal procedure for erecting a bridge of this sort would involve picking it up with a crane, fastening it in place and afterwards loading it with pipe and conduit. The method study indicated that a cheaper alternative was available. It showed that if the pipe inside the bridge was installed while the bridge was still on the ground, a savings could be realized. Further, if the insulation and painting were done before lifting and if the bridge was raised on to cribbing about seven feet high and the conduit under the bridge installed while in this position, still further savings could be realized. After all the work in and under the bridge was completed, the loaded bridge could be raised with the same cranes that would have been required to lift the empty one. The loaded bridge was erected in this manner with an ultimate saving of $2,800 over the more normal method.

The method study is made by listing the detailed steps for accomplishing any particular task in each of several ways. The "way" questioning is employed throughout. The question, "Why is it done at all?" when applied to using scaffolding to install conduit under a pipe bridge eliminates it if the bridge is loaded with pipe nearer the ground level. The question, "Where is it best done?" when asked in connection with insulating pipe resulted in doing it more cheaply on the ground. The alternate methods are costed and the cheapest plan commensurate with good quality and safety is selected.

In the example quoted above, it was not necessary to alter design in any way to take advantage of a cheaper method to erect. Where methods studies reveal that a change in design will yield sufficient savings, a channel is provided to request such a change from the design group which make the original drawings. Such changes, however, must be clearly justified and must be great enough to more than offset any redesign costs.



Turbine Foundation
Figure 5

The design alternate written in connection with the turbine foundation shown in Figure 5 will serve as an example. Instructions called for a single pour of a very complex piece of concrete. Some of the upper layers were over four feet thick. Arches existed at two levels and numerous projecting ledges were provided in the design. It was very evident in the field that money could be saved through simplifying the form work if the foundation could be poured in two or more pours instead of one. A carefully worked out construction joint was accepted as a result of a design alternate worked out in the field and approved by the home design office. As a result, two pours, instead of one, were made and the cost reduced. This slide shows one of these foundations at the end of the first pour. In all fairness to the designers, it should be pointed out that the design group was fully within their rights in first designing a monolithic pour, for the Westinghouse Turbine Manual had recommended it. But the difficulties presented by this design were more evident in the field. Quite often the designer is unable to foresee all the field conditions and the people in the field can suggest less expensive alternates - given the time and the staff to develop them.

Methods studies and design alternates are not new in construction. Our contractors are merely concentrating more line and staff attention on them in a more formalized manner.

Today, the work involved in making the overall methods studies and design alternates referred to above comprises perhaps 20 per cent of the work of Planning Engineers in the field. By far the most important part of the Planning Engineer's work is the more detailed preplanning and follow up of each controllable block of work on the job - once the overall method has been established. Each logical block of work, for example, the erection of a tank, is studied and written up on Preplan Forms. These blocks may contain from 50 to 1,000 manhours of work - preferably under the control of one foreman. Each block may take from two days to six weeks to perform. The information shown on and attached to these forms and accompanying drawings will include all the information a foreman will need to carry out his work. The front

2397-1a-700-11-55 **THE FERRO CONCRETE CONSTRUCTION CO.**

M A & R EXPANSION - 1960

PREPLAN AND ESTIMATE **SUMMARY SHEET**

JOB NO. 2397 - Procter & Gamble Co.

PREPLAN NO. 2553 - LE - 1 **CODE** 300 - 40% 400 - 60%

DESCRIPTION OF WORK

Remove old loading dock S. side of Building 116, and replace with concrete dock and steel roof over.

OUTLINE OF CONDITIONS

Transformer work must be complete. Deliveries must be made to MA&R court. Clearance @ Sodium buildings on Sk. S-1. Access way around dock area not established. Caustic tap and safety shower to be moved. Unusual footing conditions may require additional consideration.

ENGINEERING STATUS

Dwgs.	Specs.	El's
1998-1-510	None	2
S-1		
S-2		

MANPOWER REQUIREMENT SUMMARY

Craft	M-HR	Craft	M-HR	Craft	M-HR
Carp	224				
Lab.	343				
I.W.	92				
R.W.	33				
C.F.	55 1/2				
O.E.	4				
Plumb	23				
Elect	38				

DATE OF PREPLAN 9/1/55 & 9/30/55

DATE START WORK 9/26/55

DATE WORK COMPLETE 10/15/55

PLANNED AND ESTIMATED BY:

L.Z.S. G.F.

Preplan - Summary Sheet
Figure 6

page (Figure 6) will contain a statement of the job, sketch and material references, and a manhour summary for scheduling purposes.

The second sheet (Figure 7) will list tools and materials . . . . .

2307-1b-700-11-55 THE FERRO CONCRETE CONSTRUCTION CO. Sheet No.______

BILL OF MATERIAL PREPLAN NO. 2553-S-1

DESCRIPTION OF ITEM	STORAGE LOCATION &/or SHIPPING DATA	STEP NO.	HANDLING DATA
Acetylene cutting outfit	Order from warehouse. Store on job site well away from sodium storage shed.	1,15,22, 29,30,38	
Hand tools, shovels, picks, bars, etc.	Order from warehouse - lock in box overnight	Various	
CO_2 Fire extinguisher	Mounted on Sodium shorage shed and on extreme west wall of 11b Building	Various	
Vitrified tile 6"	Plumber will order	7.9	
1 pc. 24" x 50" lg concrete pipe	Requisition from purchasing		
2500 psi concrete approximately 36 yds.	Order from Richter when required		Chute all concrete to place
Reinforcing rod 36 cwt.	Stored on jobsite east of new dock		Stored at jobsite when received
C. I. Grating	Requisition from purchasing	10	
Compressor, Rock drill	Order from warehouse	11	
Portland cement - 3 sacks	" " "	14	Store at jobsite
2004 1" T & G Sheeting	Requisition from purchasing department	14,28	
Wall ties and accessories	Order from warehouse	14	
7 sacks Maximent	Requisition from purchasing department	33	Store in dry at jobsite
165# Durafax	" " " "	33	" " " " "
1 Hair broom	Order from warehouse	33	
Carborundum rubbing stones	" " "	34	
1 8" Electric Saw	" " "	Various	
1 ½" Electric drill	" " "	Various	

Preplan - Bill of Material
Figure 7

. . . . .The remaining sheets (Figure 8) provide a chronoligical list of work elements, along with the

2307-1c-1050-11-55 THE FERRO CONCRETE CONSTRUCTION CO. Sheet no.______

WORK SHEET PREPLAN NO. 2553-S-1

STEP NO.	SEQUENCE, DESCRIPTION AND REMARKS	CRAFT	EST. MANHOURS	EST. QUANTITIES
1	Block off driveway and tear out old loading dock, burn off bumper posts and rail bard. Set iron aside and take remainder to dump. (Note: Locate fire alarms before burning.)	Lab. Carp. I.W.	16 2 2	Welding Permit Truck time Cutting Outfit Wrecking tools CO_2 Fire Ext.
2.	Switch door and window of Sodium storage shed, end for end. This is a sectional shed and may be merely unbolted to re-arrange. Perform work on dry day - Mr. Sharpe: Room 116-3-1, Phone 1131 has key to the house	I.W.	18	Crescent wrench
3.	Remove caustic tap and safety shower head	P & G		
4.	Dig to locate combined sewer along a line three feet west of west dock footer. Note the location of the 8" fire main, if found.	Lab.	10	Pick and shovel 2 lbs. excavation
5.	Layout to line and grade and excavate by hand for wall footings. See sketch S-2 for detail of detour around Sodium storage shed. Remove fill below old dock.	Lab. Carp.	60 8	Pick and shovel Truck time 14 1/2 yds. exc.
6.	Dig for catch basin and tap to 12" sewer Note: On all excavation, haul all paving and unsatisfactory backfill to dump. Stock pile backfill inside area of dock, or to west of dock.	Lab.	6	Pick and shovel 2 yds. exc.

Preplan - Work Sheet
Figure 8

man-hours and crafts required for each element. Attached, too, are any required sketches and drawings. Written preplanning or its equivalent originated on critical work where extra planning and scheduling was required to complete a piece of work in a very definite period - for example, to meet a specific start-up date. Our experience with it on other work as well indicates that it is very worth-while on a large percentage of our construction work.

We believe the written preplan reduces costs in several ways:

1. Permits supervision to make well considered decisions on the best method, best tools, etc., in advance.

2. It minimizes delays brought about by improper utilization of manpower, machinery and tools.

3. It serves as a base for scheduling and assigning work.

4. Improves safety and quality through providing more advance knowledge of the job.

On these forms we try to provide thought-out answers to the basic industrial engineering questions:

a. What? Scope of the work.

b. Where? Location of optimum place for performing the work.

c. When? Time and sequence.

d. Who? Designation of crafts required.

e. How? Description of the method selected.

f. Time: From sharpened bogies.

One of the key items shown on preplans is the estimated manhours for each element of work shown in the second column from the right of Figure 8. They represent units which, if met or improved upon, will make us money. They are not as sharp as ideal, time study or real work units but are realistic units which can only be met if extra planning efforts are made. They are figures which, if equalled, will give us a net saving over performance in the past after taking into account the additional cost of Staff Engineers. The responsibility for the estimate of manhours should be with the Planning Engineer. Supervision often reviews them but should not have to approve them.

In carrying out such a preplan program, we have merely followed the advice of the father of Industrial Engineering, Frederick Tayler, when he stated back in 1885, "The greatest production results when each worker is given a definite task to perform in a definite time and in a definite manner."

Line and staff working together should develop the preplan at least seven days in advance of the actual start of work. Detailed step by step preplanning is not employed on emergency work or where adequate time is not available for planning.

Not all preplans will be to the same degree of detail. Planning of more straight forward work such as fabricating the normal types of piping bends in pipe fabrication shops is not written up in detail. A more streamlined form of preplan is then used and indicates only the total time the whole block of work should take to perform.

The next step in the field is work scheduling - which is done from the man-hours shown on the preplans. It is also based on certain key construction dates shown on an overall engineering-construction schedule which is made up early in the job to schedule engineering, purchasing of equipment and finish dates. The work schedule (Figure 9) is made up each week and covers the preplanned work which will be performed in the

ONE WEEK & FOUR WEEK WORK SCHEDULE

WEEK END 1/6/55
SHEET 1 OF 2
JOB NO. 2396

PLAN NO.	DESCRIPTION OF WORK	MON	TUE	WED	THR	FR	TOTAL THIS WEEK	TOTAL WK END	TOTAL WK. END	TOTAL WK END	CRAFT
BL-1	CHEMSTONE SERVICE STRIPS						0	160	160	80	CARP.
							0	40	40	20	LABOR
BL-3	LAB. SERVICES	81	81	81	81	81	405	300	300	300	P.F.
BL-6	LAB SHELVES & CABINETS	16	16	16	32	32	112	20	20	0	CARP.
BL-7	ANIMAL LAB BENCHES & TOPS	16	16	16			48	120	120	160	CARP.
		8	4	4			16	32	32	40	LABOR
BP-5	PREFABRICATE PROCESS PIPE	18	18	18	18	18	90	90	90	90	P.F.

Work Schedule
Figure 9

following week and to a less accurate degree, the known work for the following three weeks. The left hand columns of the schedule show the preplan numbers and a brief description of the work. The remaining columns state the hours of planned work by days for the coming week and by weeks for three weeks in advance, with the crafts involved stated in the right hand column.

We might point out that the schedule is only a guide to work assignment. Daily adherence to the schedule is not achieved at the cost of improved work reassignment if studies made daily show that improvements can be made to the published schedule. It aids in hiring and planning for the weeks ahead but it must be used in conjunction with daily and even hourly follow up.

The preplan performs two important functions in addition to providing on-the-job supervision with a good basis for work assignment. It provides the basis for comparing actual performed hours against a good target and secondly, it provides the frame work for accounting and cost prediction.

Actual costs to perform the work are accumulated against the preplan number. Once each week the pertinent information from all active preplans is summarized on a Weekly Preplan Status Report - (Figure 10). This form shows the manhours estimated to date (Column 7) for each preplan. The right hand column, titled "Effective Ratio", is the ratio of the estimated time to the actual time for each preplan. If used correctly, this ratio gives an indication of how effectively each preplan is being carried out each week.

As mentioned a moment ago, the preplan is also the basis of cost accounting on all our construction work. The actual costs of our work are accumulated on blocks of work, against the preplan, and not necessarily against types of work such as making forms or placing reinforcing rod. On projects such as ours where building work is not the major portion of it and where non-building items such as piping and setting up of equipment does form a major part of it, this basis of cost accounting appears to us to have advantages. We realize that building contractors are more used to keeping and

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THE FERRO CONCRETE CONSTRUCTION CO.
M A & R EXPANSION - 1960
WEEKLY PREPLAN STATUS REPORT

JOB No. 2397 - Procter & Gamble Co.

Sheet 1 of 4

WEEK ENDING 1/5/56

PREPLAN NUMBER	DESCRIPTION OF PREPLAN	DATE WORK BEGAN	EST. PERCENT PROGRESS	MANHOURS: PREPLAN ESTIMATE	MANHOURS: ALLOWED TO DATE	MANHOURS: EXPENDED TO DATE	MANHOURS: EXPENDED THIS WEEK	ESTIMATED EFFECTIVE RATIO: TO DATE	ESTIMATED EFFECTIVE RATIO: THIS WEEK
	FINISHING								
	COMPLETED PREPLANS				1421	1144			1.30
FB-5	INSTALL MOP SINKS	11-10	100	585	584	655	8		.89
FM-5	FAB. & ERECT STEAM COIL FOR REMELT TK.	10-29	100	310	310	214	174		1.45
FP-1	SHOP FABRICATION	11-15			243	272	20		.89
FP-2	PIPE ERECTION - BLDG.	11-18			600	663			.90
FP-3	REMOVALS IN TEMPERING ROOM	12-3		2087	376	299	140		1.26
FE-1	POWER WIRING	10-6	55	2100	1155	641	188		1.80
	TOTAL ACTIVE PREPLANS				3445	2909			1.18
	TOTAL TO 12/22/55				4128	3446			1.20
	TOTAL TO DATE				4866	4053			1.20
	ACTIVITY THIS WEEK				808	607			1.22

Preplan Status Report
Figure 10

predicting costs on a unit basis by types of work, such as form work, brick work, etc., and that we do ask them to perform their accounting on a basis less well known to them. While this has its disadvantages, we believe that cost predictions which can be made from accounting by preplans is far superior to predictions based on unit costs and that the advantages outweigh the disadvantages.

The weakness of any cost report, as we all know, is that it is too late when it is published. The costs have already been incurred and unless management is unusually effective in correcting items which have contributed to poor costs on the week before, little corrective action can be taken. If, for any reason, the estimated target times posted on our preplans are too generous, or if the nature of the work is not too well understood at the outset, it is realized all too well that the Effective Ratio may not enable us to gauge job effectiveness as quickly or as well as we would like. If we are to correct weaknesses of poor planning and work assignment in time to affect costs adequately we must look more critically at work in the field as it is being performed.

If preplans are to save us money, work must be assigned from them as a base and the work followed in the field by the staff engineers to insure that the crews and materials are the best ones for the job. If the scope of the work changes appreciably before or during the work, he may need to write an addendum or revise the preplan. Non-repetitive work in particular will need to be studied and reexamined to improve work assignments during progress of work. It is necessary to look daily or oftener at most going jobs to keep assigning only necessary work - and to do that by the best method.

Field follow-up of preplanning, therefore, comprises the next logical step in our program to cut costs. This employs staff engineers to assist line to analyze and evaluate work while it is progressing in the field. The staff engineer helps check that: (a) the best method continues to be used; (b) the plan for work is modified where necessary; (c) points out the need for work reassignment to reduce delays; (d) accumulates data for future planning. As soon as sufficient preplans have been written in advance to get a job under way, he may spend as much as 60 percent of his time following up work assignments - always acting in the capacity of assisting the responsible superintendents or other supervision. In following up work he will take time to make flow charts or planning studies to separate out the job elements to tell him how delays can be further reduced.

Good work assignment is the key to reducing idle time and making savings. If the work assignment from the preplans was not the best, follow-up using good tools will help to show this in time for correction.

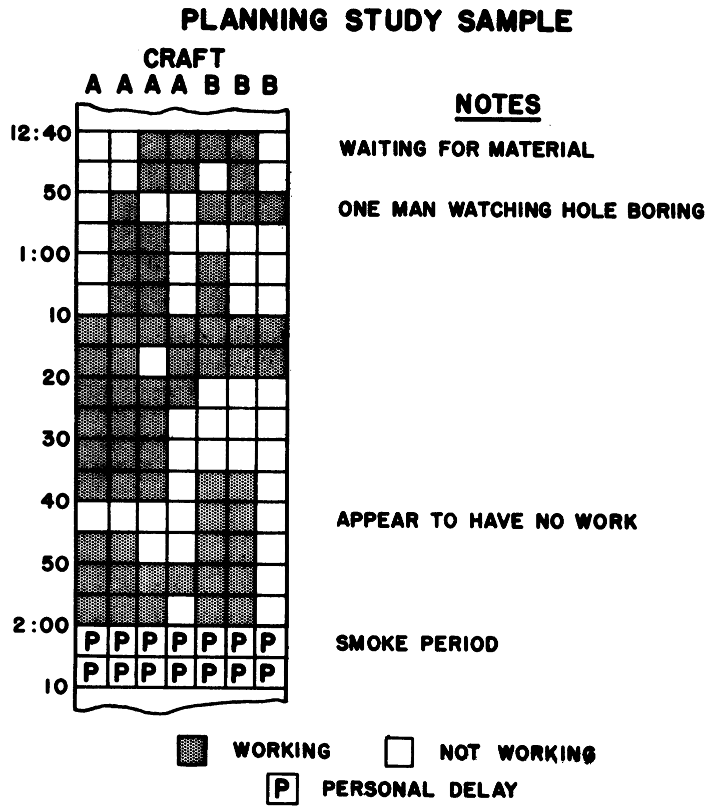
An example of how staff follow-up has pointed the way to better work assignment might be helpful at this point. On a recent laboratory expansion a number of crews were assigned to installing asbestos insulation on air conditioning ductwork. Each crew consisted of a cutter, as shown in Figure 11, and an applicator,

Insulation Cutter
Figure 11

Insulation Installer
Figure 12

shown in Figure 12. At the time the preplan was made, it was thought that two-man crews of this type would perform most effectively. A general foreman asked for a study to be made of a typical crew at work. This study was made by a staff man who stayed close to the crew for an hour or two, noting the activity of the crew by five-minute periods. He noted whether each man was working or was delayed - and why. He made notes to help him evaluate the work assignment. When he completed his study he found that A, the applicator, was busy only 48 per cent of the time, while B, the cutter, was working 94 per cent of the time trying to keep up. His superintendent added an additional cutter and a new study of the three-man crew showed that A was now working at 95 per cent while B and C were busy about 72 per cent of the time. A comparison of total crew activity before and after crew rearrangement indicated an increase from 71 per cent for the two-man crew to 80 per cent for the three-man crew - a worthwhile savings in work and cost.

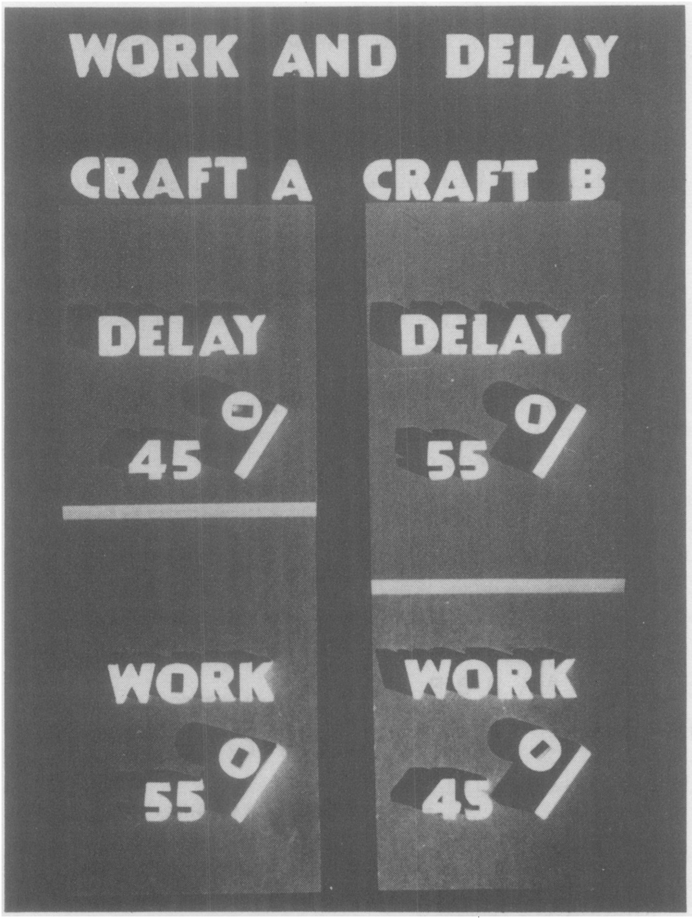
Another example of a Planning Study, this time of a seven-man crew, taken from another job, is shown in Figure 13. The black areas denote work and the



Planning Study Sample - Seven Man Crew
Figure 13

white areas denote delay. It can be readily seen from this chart that the third Craft B man was not needed. Observation brought out that he was not idle becuase he chose not to work, he was idle because little or no work was assigned to him as an individual. The studies are not made to criticize individual workers in any way, but are made to show how work assignment can be broken down and improved by assigning work in more detail from more carefully drawn preplans and schedules.

Figure 14 (top of page 26) shows the breakdown between work and delay recorded in Figure 13. It is fairly typical in that roughly 50 per cent of the time on



Analysis of Delay - Seven Man Crew
Figure 14

the job is represented by work and 50 per cent by delay. These planning studies have been found to be very valuable in first showing that a problem exists and secondly, pointing the way to reassigning people to reduce delay.

We have used ratio-delay counts and other forms of work sampling in the past with some degree of success. Head counts taken by areas or by crafts daily or twice daily have been used to give us indications of areas or crafts where greater than average delay has been encountered. We know that one chemical manufacturer, for example, who has done considerably more work in the field of work sampling than we have, has found it a very useful tool in his construction work. We have not found that the field count has been of the same advantage to us as the more detailed planning study.

We believe that the time honored way in which work has been assigned in the past has been the main cause for most of the delay which we have all encountered on construction work. If supervision can be made to see the delays encountered and if staff help can be made available to help plan and follow up preplanning in the field, crew sizes will be reduced or additional work added to a given crew.

Reviewing the program as outlined we have aimed to:

1. Reduce current costs of construction, and at the same time
2. Improve cost predicting, and
3. Record data and experience for future jobs.

In order to accomplish these aims, we have recognized that work will be performed:

1. By a number of contractors
2. In various localities
3. By union labor
4. Over short periods - say 6 to 18 months
5. By semi-permanent supervision

These aims can best be accomplished, we believe by:

1. Emphasizing strong management
2. Using added staff to help
3. Searching for the better way
4. Assigning only the necessary people to perform only the necessary work to as great a degree as possible.

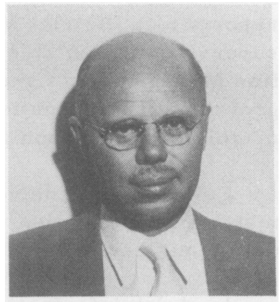
The key to successful field cost control is management. Each contractor is selected with great care to insure that he is interested in such a program and secondly, has alert, open-minded supervision to put on our jobs. His top field personnel are then given several weeks with us to learn our experiences. Conferences are held on subjects which will range all the way from fundamental principles of good foremanship to cost analysis. The contractor then weaves the best of his own and our experience into a program he believes will fit his job best and trains his own personnel in the techniques for carrying it out.

It has not been found that supervision has been replaced with staff or that the number of supervisory people needed has been reduced by the addition of planning staff. The addition of staff has freed superintendents to spend more time supervising in the field and the ratio of supervision to direct labor has not been reduced. Supervisors who see the existence of delays and understand how they can be reduced utilize this extra time in the field to advantage.

While the nature and type of contract negotiated with our contractors affects the set up of the cost reduction program, added planning staff can be utilized on both cost - plus and lump-sum work to reduce costs. While most of our experience to date has been with cost-plus contracts we are gaining experience with it on lump-sum contracts which also looks promising. In the cases of a number of subcontractors, planning engineers have been added to assist the subcontractor to carry out his own cost control program.

We would like to repeat that our experience with a cost control program of this sort for construction is still relatively new to us. Our contractors have been very alert to modify and improve their approaches as they gather experience with it and will welcome the experiences and suggestions of others in this work to continually improve it.

You might well ask what savings we have obtained from the application of this approach. The gross return is currently about 15 per cent of controllable labor. For each dollar spent on it we receive a gross return of about $2\frac{1}{2}$ to 1. Our goal is to boost this to over 4 to 1 and we believe it can be done.



THE PROBLEM OF SELECTING SUPERVISORS

by
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One of the most critical problems that confronts modern management is the successful selection of supervisory personnel. With increasing emphasis on production efficiency and the rapid development of the complexity of the technological product, the need for successfully controlling and guiding the human variable becomes evermore apparent. No amount of motion or time study or increased effectiveness in the development of systems can offset human failure at the supervisory level. During the period marked by the end of the Second World War, the most relied upon procedure for the selection of supervisory personnel was the time tried process of extended observation of the individual over a period of time prior to selection.[2] The upsurge in testing, following the Second World War, resulted in tests coming into the picture and continuing to gain in strength until criticism has been voiced against the apparently excessive faith that has been placed in tests as a means of selection of the supervisor.[10] These criticisms have been aimed at the rapidly growing practice of the establishment of selection cut-off scores for tests when these cut-off scores have not been validated or when the validity has been based upon relatively poor criteria.

The purpose of this paper is to call to the attention of the industrial engineer and others who are involved in the problem of selection the results that are being achieved by one of the largest chain store organizations in the United States and Canada. These results are helping to attain the goal of better selection of supervisors, and are based upon the development of a sound philosophy of selection and the careful validation of the tests.

The program, which took a number of years to prepare and place into effect, was the outgrowth of the conviction of management that selection procedures could be developed that would be better than the old practice of promoting an individual on the basis of supervisory opinion obtained at the time the vacancy became available. While Safeway Stores believed that the immediate supervisor of the individual would probably know his work and behavior better than any other person, however, it was deemed both necessary and desirable to furnish the supervisor with selection aids that would help him offset "spur of the moment" judgments and reduce the factor of personal bias to a minimum. At the same time, it was believed that the basic principle of holding the administrator responsible for making the final decision was a sound one and should be retained.

The problem then became one of determining what aids could be devised that would enable the administrator to make a better decision in his selection of supervisors without introducing factors that would pre-determine this decision. An investigation of the literature revealed that two principal devices[2,7,8] had become useful to some extent in employee promotions. One was the use of a rating procedure that could be administered systematically over a period of time and would lead to the accumulation of data on all employees.[2] The second assist that could be given the administrator appeared to be through the use of a battery of tests designed to reveal information about the individual. Numerous tests have been used in the attempt to isolate the successful supervisor from the unsuccessful one. Those which appeared to have met with some measure of success may be grouped according to the purpose of the test.

1. Tests for job knowledge
2. Tests of general capacity or brightness
3. Tests related to the area of decision making
4. Tests measuring the individual's interest pattern
5. Tests in the field of personality

To meet the need for a continuous record of the individual's performance, an evaluation procedure was devised that allowed for checking factors relating to his performance in one of four categories: Outstanding, Good, Fair, or Poor. No provision was made for translating these determinations into a numerical score. The form was designed so that the individual was given an over-all summary evaluation according to one of the four categories. Provision was made on the back of the form for writing in comments pertaining to his present work and future potential in terms of training needs, etc. An over-all rating was given the individual on his advancement potential in terms of his being "ready for advancement," "ready for further training," and "limited."

Simultaneously, with the development and the introduction of the rating procedure throughout the company, work was conducted on numerous tests to determine those which offered the greatest promise for the particular type of supervisory selection. In a company such as Safeway, the greatest need for adequate supervisory selection was at the Location Manager level, for here the responsibility for the supervision of others was great. The Location Manager is in charge of a complete market and responsible for the varied personnel working in the meat, groceries and produce section. He

*The work reported here was done under the direction of the author in his capacity of Industrial Psychology Consultant to the Central Employee Relations Department, Safeway Stores, Inc.

reports to a District Manager. Not only must he be a supervisor but an able merchant as well. In the Location Manager rests great responsibilities--the sales, growth, and continuation of the company; hence the premium placed upon good selection is enormous.

Following extensive experimentation with many tests, the battery that was decided upon for final validation and use in the selection program consisted of:

1. A job information test. This test was constructed by the Central Employee Relations Department of the company and was designed especially to measure the extent of the individual's knowledge of the operation of a Safeway Store. It is a paper and pencil achievement test of operating information.
2. SRA Verbal,[9] the paper and pencil test of general capacity distributed by Science Research Associates.
3. Test of Practical Judgment,[1] also distributed by Science Research Associates.
4. Kuder Preference Record - Personal,[5] an interest test that measures interests in five areas: a. preference for being active in groups; b. preference for familiar and stable situations; c. Preference for working with ideas; d. preference for avoiding conflict; and e. preference for directing others.
5. The Guilford-Zimmerman Temperament Survey,[3] a factor analyzed personality test of the paper and pencil type that gives a number of personality traits.

Management conferences were held to decide upon the ways in which the information to be accumulated through the rating forms and the test battery could best be utilized. As a result of these conferences, it was decided that the error many companies (who were utilizing tests in their post-war selection activities) were making could be avoided if validity data for the tests could be accumulated and norms established based upon the company's entire population of Location Managers. The key to avoiding the error into which many companies had fallen lay in making the test information available to the responsible executive as a check against his own judgment. To do this he would utilize the results as a form of additional information along with the employee's history as supplemented by the systematic rating procedure. Thus an executive selecting an individual to take over the functions of a store could compare his candidates against the norms made by the entire group of store managers. He could then consider all of the factors that were available and pertained to the position in arriving at his decision.

After agreement had been reached as to the ultimate use and aims of the program, ways and means of getting it under way had to be considered. In order to gather validating data and assure the computation of evaluation data, it was necessary that all Location Managers be evaluated at approximately the same time throughout the entire organization. Therefore, a day was fixed by which all Location Managers should have been rated by their immediate supervisor. Simultaneously, teams from the Central Employee Relations Department went to all of the company zones and proceeded to train each Zone Employee Relations Manager in the use of the tests. This entailed the preparation of test manuals and the careful coordination of the administration of the tests throughout the United States and Canada. Instructions as to how to score the tests and record the test scores were given and forms in triplicate for each Location Manager showing the test results were sent to the Central Employee Relations Department from the zones. The plan entailed the return of one of these forms to the zone with the results (after the norms had been established) recorded on it for each of the test scores.

When the record of test scores was received at the Central Employee Relations Department, an IBM card was punched for each Location Manager. The data recorded on the IBM card was as follows: manager number, zone, sales, volume, district, type of location, time in present location, time as a Location Manager, total time with company, birthdate, highest educational level, raw test scores for all tests, over-all rating of the Location Manager, rating of his operating results, and his advancement potential.

The next major problem was the validation of the tests. The importance of the selection of suitable and the best criteria cannot be overemphasized. After careful study of the available data, it was decided that the use of composite criteria would give the truest picture of the most successful as against the least successful Location Managers in the company operations. Location Managers who had been in their present store for less than a year were not used as it was not possible to determine whether the success or failure of the prior Location Manager in that store was affecting the picture. It was decided to take all of the individuals who fell in the upper and lower twenty-five percent of sales by dollar volume for each type of location. This would equate for the various types of locations. (Type of location refers to the store layout, date of construction, size of store, type of equipment, etc.). Secondly, in order to get rid of the chance of the location either being physically in an area where it produced a high volume or practically no volume by factors due to others than the successful or unsuccessful supervision on the part of the manager, only those individuals in the upper 25% of sales volume who scored (1) Outstanding in their over-all rating, (2) Outstanding on operating results, and (3) Ready for Advancement, would be used as the sample of the most successful managers against which to check the test results. Similarly, only those individuals falling in the lowest categories for over-all rating, operating results, and advancement potential, and who were at the same time in the lower twenty-five percent of sales volume for each type of store would be used as the sample of the least successful managers.

The means for each of the tests for these two groups were then computed and since the means for the most successful group differed from the means for the least successful group, the means were then tested for the significance of the difference. The SRA Verbal[9] was found to be significant at the 5% level. The Job Information Test was significant at the 1% level, and the Test of Practical Judgment[1] was found to be significant at the 5% level. Neither the Kuder Preference Record - Personal[5] nor the Guilford Zimmerman Temperament Survey[3] showed significant differences between the means for the two groups. However, this was not deemed as an indication that these tests were not useful in the battery since the range of scores for the entire group of Location Managers differed markedly from the norms published by Kuder.[5] For example, the median score for Location Managers on one of the scales was equivalent to the 79th percentile for the normal population. Similarly, in the Guilford-Zimmerman Temperament Survey[3] when new "C" scores were computed for the Safeway group and these compared with the norms established by Guilford, for both supervisory and non-supervisory personnel, differences were found that indicated that the test could serve a useful function. The group as a whole showed somewhat different characteristics from the normal population[4] and also from the supervisory group reported by Guilford.

Norms were established for the entire group using the system that gave the best differentiation between the most successful and least successful groups. A four category breakdown (Outstanding, Good, Fair, or Poor) was used for reporting the results (to the supervisors of the Location Managers) for the tests of Practical Judgment,[1] Job Information, and the SRA Verbal.[9] The Kuder Preference Record - Personal[5] was reported using the terms of High Preference, Moderate Preference, and Low Preference. The Guilford-Zimmerman Temperament Survey[3] was reported in terms of Extreme, Borderline, and Typical, and a profile chart was prepared showing the Location Manager "C" score values graphically for each individual.

In the handling of the results of the testing program, great caution was taken to make certain that adequate explanation accompanied the presentation of the results to all executives who would have access to or use the material. Care was taken to have a group meeting of these executives at which time the results were returned and the group was shown in the subsequent discussion how these results could be useful in helping them check their jedgment and opinion to aid them in the selection of new Location Managers.

Probably the single most important factor resulting from the carefully planned and controlled research program was the evolved concept that points the way to a greater and sounder use of tests in major industries in the selection of supervisory personnel. Simply stated, it is that in making a promotional judgment, one assembles all of the available information and data on the individual being considered, including his performance record, his assets and liabilities as measured by test scores, and the opinions of his supervisors. After the analysis of all this information, the administrator then makes a decision as to the individual's chances of success in a particular position. In the final analysis, this decision is a subjective one on the part of the administrator, and cannot be made completely objective by the use of any selection devices. Management can do no more than provide for the administrator's consideration of all possible information on the individual being considered. This concept eliminates the dangers of using a cut-off score, and utilizes tests as a counseling aid to the supervisor. It involves a principle that is relatively new to large business but that has been utilized for many years by colleges and universities in their counseling and guidance centers.

REFERENCES

1. Cardall, A. J.; Test of Practical Judgment, Science Research Associates, 1950.
2. Ghiselli, E. E., and Brown, C. W.; Personnel and Industrial Psychology, McGraw-Hill, 1955.
3. Guilford, J. P. and Zimmerman, W. S.; The Guilford-Zimmerman Temperament Survey, Sheridan Supply Company, 1949.
4. Guilford, Joan S.; Temperament traits of executives and supervisors measured by the Guilford Personality Inventories, Journal of Applied Psychology, 1952, 36, pp. 228-233.
5. Kuder, G. F.; Kuder Preference Record - Personal, Science Research Associates, 1949.
6. McNemar, Quinn; Psychological Statistics, John Wiley & Sons, New York, 1949, p. 65.
7. Ryan, T. A., and Smith, P. C.; Principles of Industrial Psychology, Ronald Press, 1954.
8. Smith, H. C.; Psychology of Industrial Behavior, McGraw-Hill, 1955.
9. Thurstone, T. G., and Thurstone, L. L.; SRA Verbal Form, Science Research Associates, 1947.
10. Whyte, Wm. H., Jr.; The Fallacies of "Personality" Testing, Fortune, Sept., 1954, pp. 117-119.

ADMINISTRATIVE CONTROLS FOR THE INDUSTRIAL ENGINEERING DEPARTMENT

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Your presence here at this Institute indicates that you either have a Science background or have an active interest in the field of applied Science. Since I consider myself one of you, I feel free to point out that we are the group that is inclined to be a little smug when we gaze around us and see the results of our efforts: a standard of living far above the dreams of the most imaginative of our ancestors. These things, we hasten to point out to anyone who will listen, are realities because as practical men we are realists. We have been weaned on mathematics and matured on the study and application of physical laws. We have little tolerance as a group for the abstract. To discuss philosophy before such a group might at first thought appear to be heretical. However, I am fairly convinced that most of you have already discovered for yourselves what I am now in the process of learning: there is much to be learned from the not-so-lowly liberal arts. Furthermore, considerable discussion still goes on as to whether Management is a Science or an Art.

From your reading you might recall the words of Thomas Carlyle, "What you are speaks so loudly I can't hear a word you are saying." In these words - concisely and specifically - is spelled out the theme that forms the basis for my discussion on Administrative Controls. Let's take an example that might illustrate what I mean. I visited a fairly large company in the Midwest a few years ago whose Administrators did not exactly practice what they preached. (Some of you may be familiar with departments that are guilty of the same practice). I saw prominently displayed organization charts - files bulging with policy manuals - procedures (past, present and future) - and up-to-date training manuals occupying a position of respect on the desks of the Supervision; yet the actual day to day operation of that department is one that could best be described as rolling merrily along in blissful ignorance of these controls. So, at this point we draw upon our first lesson from literature: what some men try to tell us they are, organizationally speaking, and what the organization really is might not necessarily be one and the same thing.

Our discussion now appears to be taking a philosophical turn. However, we don't have to be philosophers in order to examine some of the thinking underlying our pattern of administrative behavior. Our own personal philosophies describe the way each of us lives as an individual. An operating philosophy of a staff department should logically describe the behavior of that department and of that particular department alone. If a philosophy can be described as a way of thinking and behaving, then this discussion can be justly accused as being philosophical in nature. What we are saying is that there must be certain fundamental or basic tenets that mold and fashion the behavior of each department. These basic conditions are described as principles of organization and administration. I suggest that we review some of the factors that influence your own organizational or administrative behavior. Approaching our discussion in this manner will permit the inclusion of departments of all sizes and with varied functional responsibilities. Furthermore, any controls that develop as a result of fulfilling the basic conditions that govern your own operating philosophy should be necessary ones and not merely red tape. These controls - the form they take, and the degree of formality - should fit like the proverbial glove.

You may recall from your reading or from courses you may have taken in business management that sound practice dictates that you must view your operation as a whole if you wish to determine the necessary functions and organization in detail. This orientation is a necessary step and generally conceded to be an important one if not the most important. One way to get an overall view of where you fit in is to make certain of your responsibilities, so, let's begin with a review of your responsibilities as the head of a department doing industrial engineering work. Whether you are about to take over such a responsibility or whether you now have it should not materially affect our discussion. You should be able to list the responsibilities that you have as a department head both up the organizational ladder as well as down. We did just this in our own department a few years ago and we learned quite a bit about our own administrative controls. Such a list might break down into six major headings as follows; your responsibilities to:

1. Management
2. Production supervision
3. Your own supervision
4. Your industrial engineers
5. Other staff and service departments
6. The industrial engineering profession

Under each of these you should be able to list all of the things that are expected of you and why. Of course, some of your responsibilities are literally handed to you on a platter in the form of directives from your own Management. Others are crystallized only by your interpretation of the many comments, suggestions, or questions that you receive in your daily discussions and conferences. The latter, of course, are the kind that require careful analysis. It is not enough just to listen - even though this is important - but questions must be asked to make certain there is mutual understanding; your own comments must be so directed and so stated that differences will not arise just because of the semantics that may be involved.

Nor is it enough just to list under each of the above six headings your responsibilities as you see them. The existence of each responsibility and why it even exists should be definable and clear to everyone directly concerned. Furthermore, you should be able to realistically and specifically outline the manner of accomplishing or carrying out each responsibility. In brief, you should ask yourself if this is a responsibility, why does it exist and how do you try to meet it. This step is a difficult one to take because responsibilities are constantly changing up and down the organizational ladder. This in itself, of course, can be good. In fact, intelligence is often defined as ability to adapt to change. We won't take the time to develop this particular step any further for two reasons: First, we are interested in determining what the fundamental conditions are that influence our administrative behavior and even though your responsibilities are the major conditioning influences there are, in addition, other related factors we should discuss. Second, all the responsibilities under each of the main headings that we have discussed could and should vary from plant to plant. We are not interested in determining just how many such responsibilities exist but as individuals we should be deeply interested in knowing those that affect us alone. So this is a step we can undertake in the privacy of our office.

Knowing exactly what your responsibilities are within the company does not necessarily solve your organizational problems. That an inter-relationship exists is almost axiomatic. As most of you know, it is not unusual in industry to have two organizations in existence within any given department: one is the theoretical or ideal organization to meet your responsibilities and the other is the one that really exists for one reason or another. Dr. E. K. Carver, Technical Assistant to the General Manager at Kodak Park, pointed out one of these reasons in an address before the 6th Annual Conference on Industrial Research in 1955. "Unusual men are best for creative thinking and unusual men do not always fit in the organization chart. The best answer is to make the organization fit the man. Make sure the man is grouped to do his proper work then make the chart so it corresponds to the grouping. It is well to keep two organization charts: First an ideal chart to best fit the work if the men were available to fit it; Second another that is made especially to fit the man. As opportunities arise the actual chart can be brought closer to the ideal chart."

Organization in itself is not always a cause of success or failure. However, an organization that best fits your responsibilities and the men working with you is the most conducive to a high degree of success. Failure or success of a department are indications of personal managerial ability - a well managed department is a reflection of a person with an intelligent grasp of his department's responsibilities - a person who identifies himself with these responsibilities in such a manner that a oneness is achieved. History points out to us that men like to be organized. The Romans, the Church, in Europe the Military, and the development of the large industries in the United States gives sustenance to this statement. We are told that one of the reasons for this is that man is a social creature and wants to be part of a group. It then appears that organization is a natural function and you as a department head should make your responsibilities the responsibilities of the group. This step then makes it natural for certain people to report to certain places within your department and though your organization may be all wrong for someone else's department it should be just the right one for you. You should test each arrangement of your organization to see whether or not it helps fulfill your responsibilities. If it does fine, then use it; if it doesn't, then you should reject it. Organization, then, is means of co-ordinating the manpower within your department in such a manner as to produce a harmonious relationship with your responsibilities.

After examining our responsibilities and the organization needed to fit our job we should review the functions necessary for us to fulfill some of the responsibilities. This step incidentally should also help us in modifying or shaping our organization. The functions that you perform in order to meet your responsibilities reflect the thinking of your management, your production supervision, the engineer's minds in your own department, and the influence of professional literature. What other industrial engineers do should be of interest and might even be of value in serving as a guide in shaping your own thinking. This is one reason why attendance at institutes such as this is of value to administrators.

However, if we want to remain true to the operating philosophy which has been generated by our own responsibilities and organizational structure, we should view with reluctance the adoption of someone else's practices except where they conform in part or in whole with our pattern of behavior. The failure of some techniques in an organization can probably be traced to the blind acceptance of the tool on the strength of the fanfare and hoop-la generated by its enthusiasts. How else can we explain to ourselves the frequently radically opposed points of view after the trial of a given organizational control or functional technique between two otherwise competent administrators. The environment must be right for one and wrong for the other. For instance, in a recent Seminar held in New York City on Industrial Engineering Administration, I found an almost even split of acceptance on the value of progress reports written by industrial engineers. At similar seminars attended by our supervision in the past ten years we have found a very wide variation in the functions performed by industrial engineers throughout the country. Some indications of this spread in functions may be found in Occupational Brief #19 prepared by the National Roster of Scientific and Specialized Personnel of the War Manpower Commission for use in the education programs of the Armed Services, in which is described what an industrial engineer does. One other source of information, and there are many, indicating this wide spread in functions is a survey reported in the Industrial Engineering News, published by Michigan State College in 1950. We have recorded just such differences during these past two weeks at the U. C. L. A. Engineering and Management Course. This is as it should be. What other industrial engineers do should serve as a guide only to those who might wonder what functions they should perform in their own department. It is not for an outsider to decide. It must stem from your own operating philosophy.

Consider the matter of how and where you get your industrial engineering jobs. The logical extension of our reasoning indicates that the recognition of your responsibilities along with the capabilities of your own supervision and that of your engineers together closely govern the type of job and the number of jobs that you are asked to study. This may mean that the bulk of your studies will come in the form of a request for an investigation from your production supervision; your own engineers and supervision may be directly responsible for initiating interest in a large number of other projects; perhaps top management may even request assistance in gathering data on some major problem. This is pretty well the pattern of operation at Kodak Park. However, the details of the assignment procedure should be unique to your own conditions.

Take a closer look at the controls in which we as administrators are interested. It doesn't matter too much at this point which ones you look at first. From the moment you interview, screen, and select your engineers you begin to demonstrate what your operating philosophies really are. The choosing of the individual, his orientation to the company, his indoctrination into the department, his training, the records that you keep of his professional development, his experience, in fact the scheduling of all of the activities involving the engineer as an individual speaks more loudly than words, what your interests and purposes really are. The personnel files and records that result from this phase of your activities are the expression of what you want - what you are trying to accomplish - in the development of your personnel. These particular records fit your operations - what others do and what records they keep in the training of their men might be of interest but you surely would not adopt them solely on the strength of their popularity rating.

Let's examine another phase of your administrative responsibility: the procedures involved in assigning work to your men. The assignment or project must be described in some manner - perhaps for the sake of uniformity or simplicity you might find it desirable to use some kind of form. You or your supervisors will probably review or screen these potential jobs as they come in; files will probably have to be established to accumulate studies as a reference for future projects and progress on the studies must be reported or evaluated in some manner. In one way or another all of these things are usually done in most departments. The form that they take, the degree of control over the procedure, the files or records kept, should all reflect your own particular set of operating conditions. You may require detailed supervisory controls such as individual analyses of workload by engineer - especially where the engineers do the bulk of their own planning. Where a number of groups or units of engineers are involved you may need workload analysis or project Status Reports by groups. This information may then be summarized in terms of the load of your whole department for planning and scheduling purposes. This is the kind of information you may need to effectively carry out your responsibilities. Whether you have no controls, adequate controls, or superfluous controls is directly proportional to your understanding of your responsibilities. This, in effect, also means that your adoption of a particular administrative tool because you have heard a lecture or read an article describing it might possibly result in your getting a fit just like you get when you borrow someone else's clothes. It certainly is no more intelligent than taking a cathartic for a stomach ache just because a cathartic eased someone else's stomach ache - no telling what caused your stomach ache and your supposed cure could have disastrous results.

There is certainly a discernible pattern of reasoning here and as we continue to examine other administrative controls we can see this basic pattern repeating. You may or may not have accomplishment reports. If you do have them perhaps you need them weekly, or monthly or yearly. These written reports are quite formal in some companies and in others, such as our own department, quite informal. They might even take the form of verbal summaries as in the case of six out of fifteen companies represented at a recent Seminar in Engineering Administration in New York City mentioned earlier. What is best for you can only be answered by asking in turn, "What are you trying to accomplish? Which of your responsibilities does this control help to fulfill?"

If you must work under a budget (and most of us do) certain budgetary records must be made available: you will need to know your past experience in your engineering and clerical labor cost, variances in your expense items such as in office supplies, equipment, or business trips. You will need to keep records of rate and classification changes and of the men hired and transferred. You will keep this information for a particular purpose to fulfill a particular responsibility. If budgeting is to be used as a tool for planning for the future - you will need records to examine the past.

The methods you employ for insuring the professional development of your personnel springs directly from your interpretation of the significance attached to this responsibility by those above and below you. Providing a course in some technique is a hollow achievement, if it is not part of a plan to make the men and the department more effective. One of the plants I visited last year was quite proud of a course in human relations given to all the supervision. One of the foreman in an aside to me caustically commented that they (plant management) should 'try putting into practice some of the things that they teach.' This one man may have been a chronic griper - but again he may not.

On the other hand, knowing your goals in the development of your personnel will help you in deciding whether you should have periodic interviews, whether you should keep experience records not only in techniques but in company processes, the frequency and kind of performance or progress reviews, and the need or value of special assignments to test the growth and capabilities of your personnel. These adminstrative tools and records become part and parcel of your department's philosophy - the physical expression of the manner in which you are trying to fulfill your responsibility - not just so much red tape.

Some of your responsibilites, once clarified and defined, may literally solve your communication problems. What one manager likes to see in the form of a report may be inadequate for another. I know one superintendent of a very large plant who practically refuses to read past page one of a report and will only do reluctantly. He skips the printed material and devours the charts and graphs. Another superintendent in the same organization insists on quite detailed reports and reads every word contained therein. I know of a large organization on the East Coast that insists on 45 copies of all Industrial Engineering Activity Reports so that everyone in the organization is kept posted on activities within the department. On the other hand, another industrial engineering department in a still larger organization circulates just one copy of a very informal two page summary of the industrial engineering activities as a means of informing the top management of the more important studies underway. Although these extremes may be perfectly suited to the companies concerned, there is no pat answer for what best suits you. Each of the above extremes fulfills a responsibility vested in the industrial engineering supervision and this is really all that is important - that the responsibility is fulfilled.

Increasing importance is being attached to the valuable part that industrial engineers can play in civic and community affairs. In one department with which I am familiar, one of the engineers is a member of the Town Water Commission. Two others are members of local school boards and a very large number in the same department are active leaders in Scout activites. Two were officers of Y.M.C.A. activities; in fact almost every man present is actively engaged in one outside activity or another. It is interesting to note that the head of this particular department is himself a member of the School Board, active in adult education programs and an elder of the church. Perhaps the setting of a good example might be one of the reasons for this interest in civic and community affairs.

It would appear that if we were to summarize our thoughts at this point we would acknowledge two things: One - the administrative controls or records of any given department should reflect the basic operating philosophies of that department. Two - as a correlary those records or controls should logically be "tailor-made." Of course, none of us would ever believe that records or controls will ever take the place of a good administrator. Our thesis has been that if you approach your administrative problems by an examination of your responsibilities the resulting form or degree of control will best fit your own particular operating requirements. Then you can rest assured that what you say you are, you really are.

RESEARCH IN PRODUCTION SCHEDULING

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Suppose we wish to choose among several standard operating procedures, to select the procedure which will lead to the best results in practice, considering that the application of any standard method will require exceptions when extraordinary circumstances arise. It is very reasonable to compare the procedures _as if_ they were to be used rigidly, with no exceptions, and to make our choice on this basis.

The reasonableness of such "as-if" comparisons underlies the research to be described below, in which rigidly applied rules for making detailed scheduling decisions are compared. It is not suggested that such rules should ever be rigidly used in practice.

We shall consider a specific "made up" scheduling problem, which is very simple compared with most practical problems. The simplification results from including a number of restrictions on the scheduling decisions to be made -- for instance, overtime work is not permitted. These restrictions can be considered as statements that certain types of decisions are to be considered as "exceptions." It is not suggested that a blanket prohibition of overtime should be made in the operation of a plant. Our research plans include studies of problems like those described in this paper, but with fewer limitations -- for instance, problems in which overtime is permitted, and scheduling rules which include criteria for working overtime.

THE PROBLEM

A machine shop with certain facilities is required to produce a certain bill of goods. Each item on the bill of goods is a job-lot, requiring certain operations in a specified order, and with a given due date. The machine type required for each operation is specified. Transportation of a job-lot from one machine to another can be performed in a given minimum time interval. Further, the following restrictions are made:

1. Lot-splitting is not allowed. That is, once an operation on a given job-lot is started, that operation must be carried out on the entire lot.
2. Lap-phasing is not allowed. That is, one operation must be completed on an entire job-lot before the transportation of the lot to the next machine can be started.
3. A machine cannot be left idle when there is work available for it.
4. Overtime is not permitted.
5. Work cannot be sent out.

Under these limitations, it is not hard to see that the schedule will "work itself out" if a rule is given for deciding which of several available job-lots should next be processed by a machine, when it finishes an operation. For instance, we could always assign the job-lot with the earliest due date, among those available. Such a rule can be more than a simple priority system, since it can take into account the time at which the decision is made, conditions in other parts of the shop, etc. In the research reported here, we have considered rules involving due dates, required times for future operations, and number of future operations. Future research will extend analysis to other types of rules.

It is impractical to experiment with the actual shop. Because of the high cost of errors, real experiments would have to be extremely conservative -- we could only try "sure things." Further, the effective comparison of two methods can only be carried out under the same conditions, and actual circumstances in a shop do not repeat themselves. However, there is an experimental method which can be used to study the above problem.

THE SIMULATION TECHNIQUE

For simplicity, we shall assume at first that the exact amount of time, including setup, which will be required by each operation is known in advance (this very unrealistic assumption will be dropped later).

We shall represent the machines in the shop by pigeonholes, and the job-lots by cards carrying the data relevant to them (sequence of operations, required machine types, required times, and such other information as will be needed to apply the decision rules under consideration). The schedule resulting from a given decision rule can be worked out by simulating the behavior of the shop with the cards and pigeonholes. Specifically, job-lots waiting for a machine type are represented by cards lined up beside the corresponding pigeonholes, and a job-lot being worked on by a machine is represented by its card in the pigeonhole representing

1. This paper was prepared while the author was under contract to the Office of Naval Research, and working on the Management Sciences Research Project, University of California, Los Angeles. Reproduction in while or in part is permitted for any purpose of the United States Government. The writer is indebted to R. T. Nelson and to W. H. Marlow for the part they have taken in the research reported by this paper.

that machine. A card is kept in a pigeonhole for an interval equal to the time required for the operation concerned, then removed, and -- after a delay corresponding to time required for transportation[2] -- placed in the waiting line for the machine type required for the next operation on the job-lot. When a card is removed from a pigeonhole, it is replaced by one of the cards representing job-lots waiting for the corresponding machine type, chosen according to the decision rule being used. The schedule thus can be allowed to "work itself out." Such information as completion times, in-process inventory, etc., can be recorded as desired, so that the rules under consideration can be compared by whatever criterion is believed to be appropriate.

In practice, only estimates are available of the amounts of time required by the various operations, and actual times will vary statistically from these estimates. Historical data will indicate the nature of this statistical variation, and the above-outlined simulation process can be carried through with the "actual" times required by operations as statistical variables, whose particular values are determined by flipping coins or by reference to a table of random numbers. Similar procedures can be used to introduce into the simulation of the shop such statistical effects as machine breakdown and worker absenteeism. It is then desirable to try each decision rule several times, in order to see how well it works out under various statistically possible circumstances.

The above card-pigeonhole procedure can easily be transferred to an electronic computer, with the various elements required represented by the contents of memory cells, and the process of moving cards around and recording data carried out by a computing program. Space does not permit us to go into the details of the appropriate computer programs here.

PRELIMINARY RESULTS[3]

Card-pigeonhole experiments were carried out in 1954 and 1955 by R. T. Nelson and by the present writer, with miniature "made up" problems involving about 6 machines and 30 job-lots, the job-lots requiring about 4 operations each on the average. The scheduling objective in most of these experiments was to meet due dates. Among the decision rules which turned out to be of particular interest were those of the form: "Assign the job-lot for which the quantity is least," where

π = (Time until due) - (k) x (Expected time required for remaining operations), (k is of the order of magnitude of 1.5). The use of rules of this type generally led to schedules which persons familiar with the practical aspects of production scheduling were unable to improve, at least without getting into exceptions based upon unusual characteristics of individual problems.

These card-pigeonhole experiments were thought of mainly as preliminary work intended to give direction to electronic computer experiments. A first set of simulations was recently completed by W. H. Marlow, of the Logistics Research Project, George Washington University, using the Logistics Computer. The problem studies was again much smaller then most practical job shop problems, 8 machines, 70 job-lots, and about 4 operations per job-lot on the average. The "actual times" required for operations were statistical variables, and a statistical sample of 9 was taken for each of 7 decision rules, closely related to the rule stated above. The due dates in these experiments were slightly too tight for all production to be completed on time, and the various runs have been compared on the basis of the sum of the tardinesses of the job-lots completed after due dates. The decision rule which gave the best results in most cases was: "Assign the job-lot for which the quantity π is least," where

π = (Time until due) - (Expected time required for remaining operations and transportation, excluding the time for the operation now being assigned)

If the time required for the operation currently being assigned were not excluded from the second parenthesis, then this quantity would be the amount of time that the job-lot could stand in waiting lines and still be expected to be completed by its due date. The exclusion of the current operation's time can be rationalized on the ground that is less committing to assign a job which will not tie up the machine concerned for a long interval.

Another result was that the goodness of the schedules (within the limits of the experimentation) depended much more strongly upon chance occurences than upon decision rules. Statistical tests showed that the variation among decision rules was significant at the one per cent level, but it is clear from the data that the variation among random choices of "actual" required times for operations was a much more important variable. Specifically, the most important factor seemed to be the total "actual" processing time required by the three most heavily loaded machines. This result indicates that larger gains are to be made from decreasing operation times than from improving scheduling decision rules. This conclusion is hardly startling. It does indicate that the simulation technique described above is sufficiently true-to-life to verify the obvious, and thus gives credence to the applicability of this research methodology.

2. In actual computation, it is not necessary for operations and transportations to take place in "real time," but only that they keep in step with the artificial time of the computing process.

3. The contents of this section will be enlarged upon in a forthcoming Management Sciences Research Project Research Report.

REFERENCES

C. R. DeCarlo, "Application of Data Processors in Industry," Proceedings of the Western Joint Computer Conference, Los Angeles, March 1955.

W. R. Fair, "Analogue Computations of Business Decisions," Journal of the Operations Research Society of America, vol. 1 (1953), pp 208-219.

C. C. Hurd, "Simulation by Computation as an Operations Research Tool" (letter), Journal of the Operations Research Society of America, vol. 2 (1954), pp 205-207.

A. J. Rowe and J. R. Jackson, "Research Problems in Production Routing and Scheduling," Management Sciences Research Project, Research Report 46, 1955, 14 pp.

SOME PHYSICAL VARIABLES IN THE DESIGN OF PROTECTIVE HANDCOVERINGS

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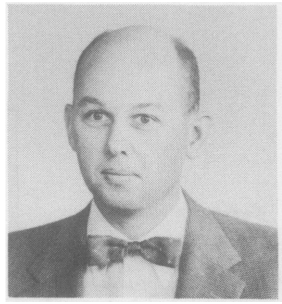

This report is a summary of some work in the area of hand protection which has taken place in the Biotechnology Laboratory in the Department of Engineering over approximately the past two years. This work has been sponsored by the United States Army Quartermaster Corps, and I wish to express my appreciation for this support as well as my indebtedness to Mr. Thomas Sheridan who carried out a large portion of the experimental work on which this talk is based as a part of his studies for the M.S. in Engineering.

Protection of the hands from environmental agents by means of handcoverings is a standard technique for many industrial operations. Such protection presents the industrial engineer and industrial designer with the class of problems for which solutions are not always clear-cut and for which additional design information may be welcome. Special technical needs for handcovering design such as the requirement of insulation for protection from heat or cold increases the complexity of these problems immensely. Very little appears to be known about the basic design variables of importance for retaining manipulative function in the case of thermal protection, and the thought of hand-protection problems in such a radical innovation as a space suit chills the enthusiasm of the best intentioned designer. As the trend continues for man to place himself in increasingly severe environments, it appears clear that detailed knowledge of hand protection variables will be of crucial importance.

When viewed with respect to what handcoverings do to manipulative ability, the requirements for design have a common basis somewhat independent from the environmental agent for which protection is sought. Both common observation and systematically obtained experimental data verify the fact that manipulative performance is impaired when the hand is gloved.[1] Some results in our laboratory have clearly shown this to be the case even with thin surgeon's gloves. The extent to which impairment occurs depends on many factors, of course, such as the degree of fine manipulative skill required, the fit of the glove, the kind and severity of the environmental agent, the training of the glove wearer in the use of the gloves for the particular task on which he is working, etc.

Figure 1 (see page 38) shows a block diagram of the system with which one must deal once the handcovering is on the man. In this system, the external object is in contact with the glove. Information from the external object goes through the visual and auditory senses as it does also from the surface of the glove to the brain and is acted on in terms of the task which the person must perform. It is fed out to the muscles of the hand which in turn act through the handcovering back to the external object. Feedback to the muscles occurs, and we have a completed circuit. This is the information flow, and there is, of course, corresponding to this control function, a power flow function which is from the muscles of the hand to the external object. Methodological problems beset the experimenter when he wishes to establish the design specifications in such a system quantitatively. Since many of the variables of importance to design are not themselves known and manual activity is so varied, it appears important that a very elementary approach must precede a more sophisticated presentation of design requirements. I will describe three experiments which were done at this elementary level with the purpose of establishing the relative importance of certain design variables and then will touch briefly on a new measurement method which we have evolved that shows promise for measuring certain effects of design variables on any arbitrarily selected task.

Our first problem was to determine where, if at all, the site of interference by a handcovering on manipulative performance was located. There are many ideas about this, including the idea that restriction of movement is a principal source of trouble. We suspected that maybe the big problem was in the sensation at the tip of the fingers, so we took a leather army glove with a knitted liner in it as the intact glove assembly, clipped the fingers off at the tips, attached those tips including the liner to a light cotton glove and this was the basis for the first experiment. To investigate the problem of restriction in an idealized case, the device shown in the lower right hand corner of Figure 2 (see page 38) was constructed. It consisted of steel springs and a strap to hold it to the hand. In Figure 3 (see page 38) one of the three tests that were used is shown. The Minnesota Rate of Manipulation Turning Test is familiar to many of you as a selection device in which the blocks are picked up and turned over. The subject is wearing the tips attached to the light cotton covering. Figure 4 (see page 38) shows the bare-handed performance for a plug insertion task in which the problem was to remove the plug, place it, then pick it up and insert it in the hole at the top. The disk could be rotated so that the plug was always at the top. A preliminary investigation showed that the only thing that seemed to count was the first two fingers for the light tasks that were used in these experiments, so an effort was made to keep the other three fingers out of the way by taping them back during the bare-handed performance. A third task, the Craik Screw Test, is shown in Figure 5 (see page 38). The problem was to insert a screw in a hole in which there is a lower level that is tapped and which must be located before the screw can be tightened. The hole in the top plate is a loose fit on the screw.

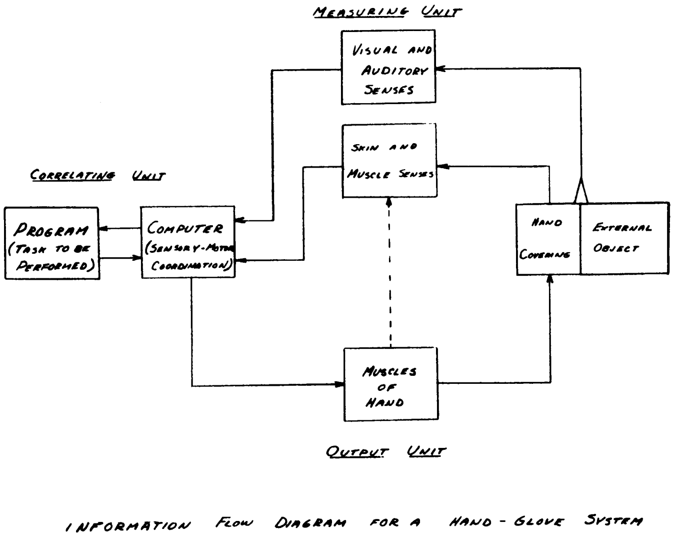

Figure 1

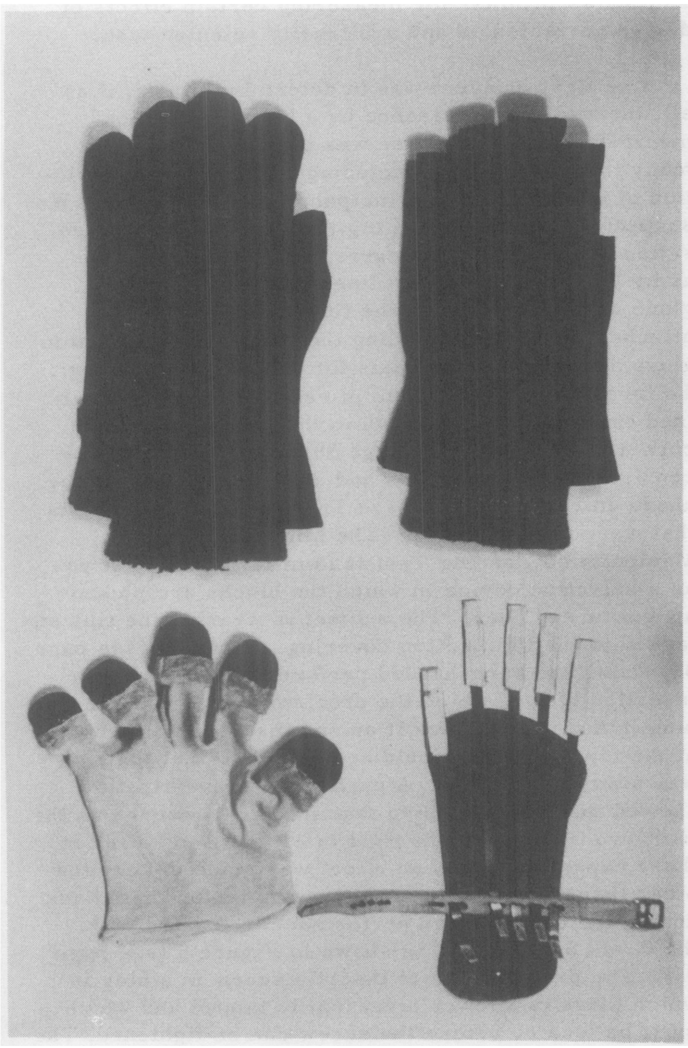

Figure 2

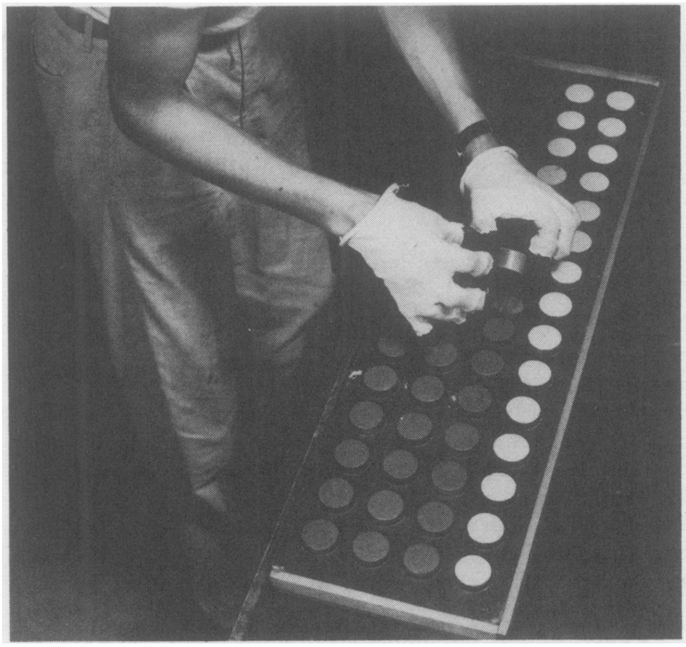

Figure 3

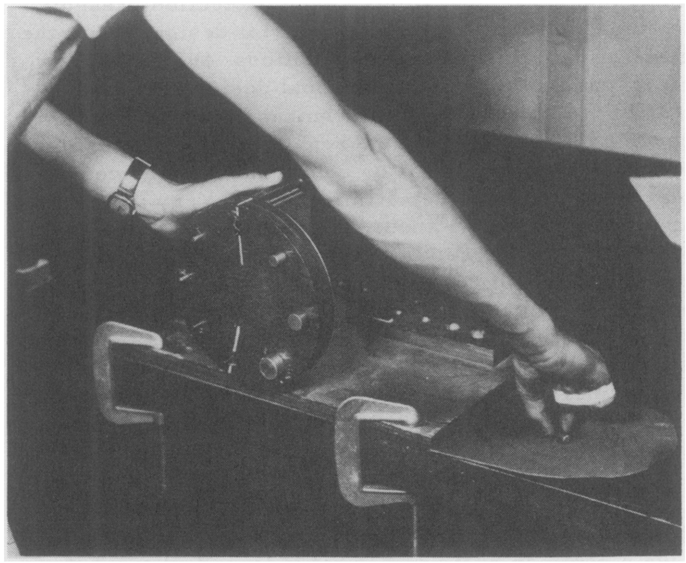

Figure 4

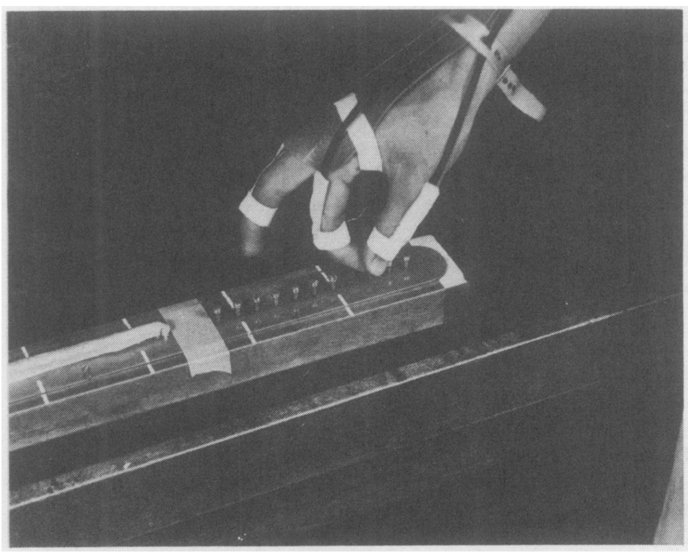

Figure 5

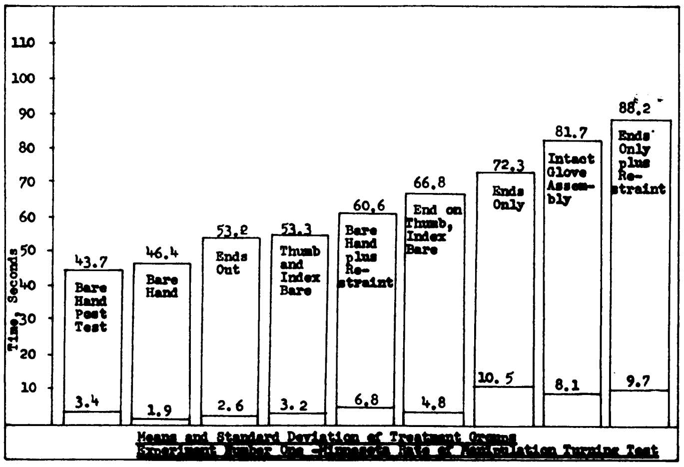

Figure 6

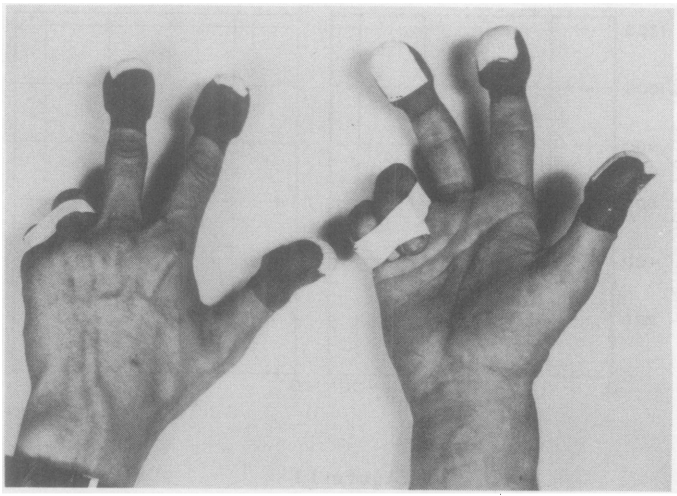

Figure 7

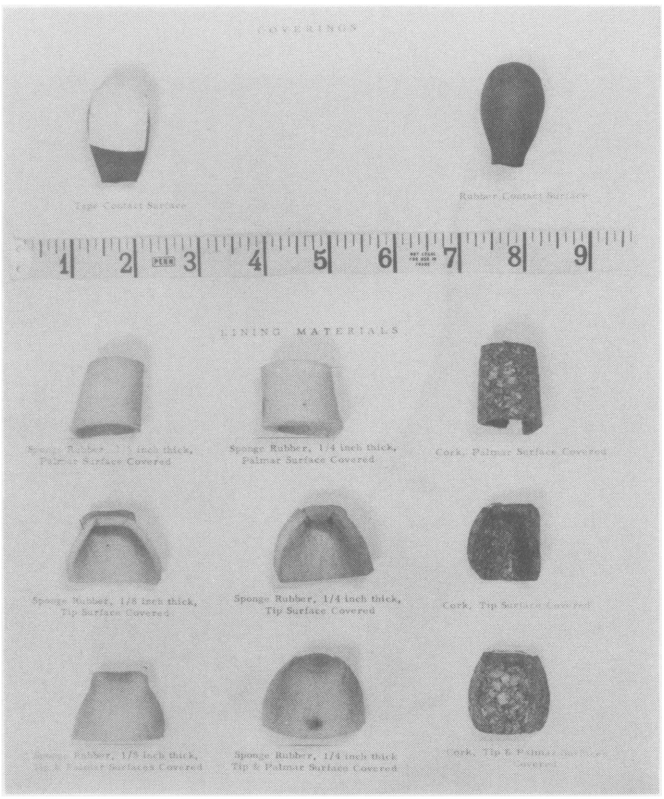

Figure 8

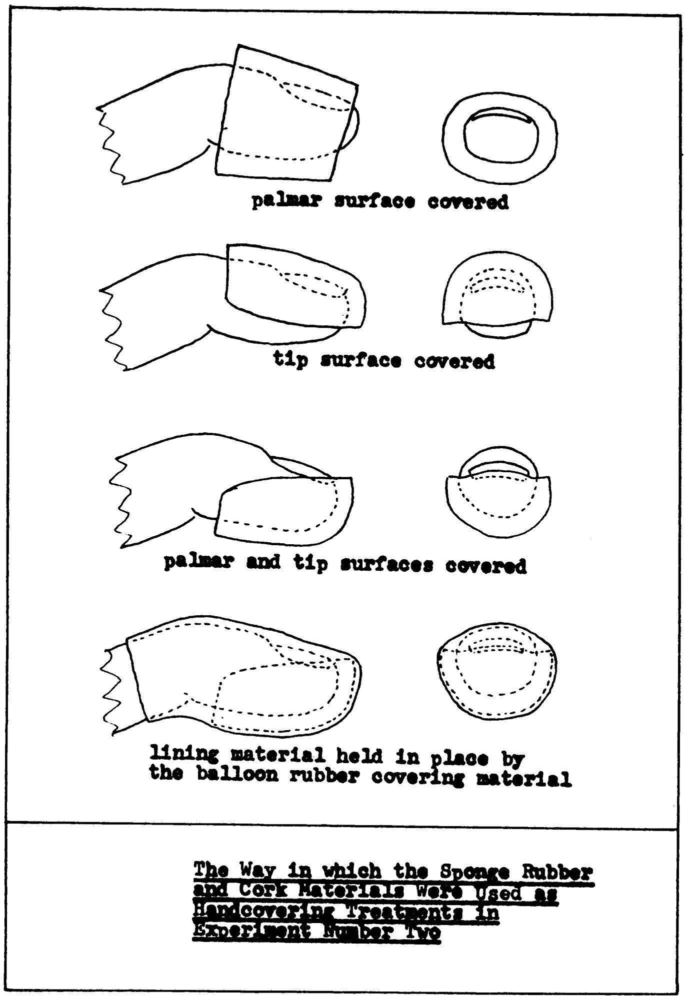

Figure 9

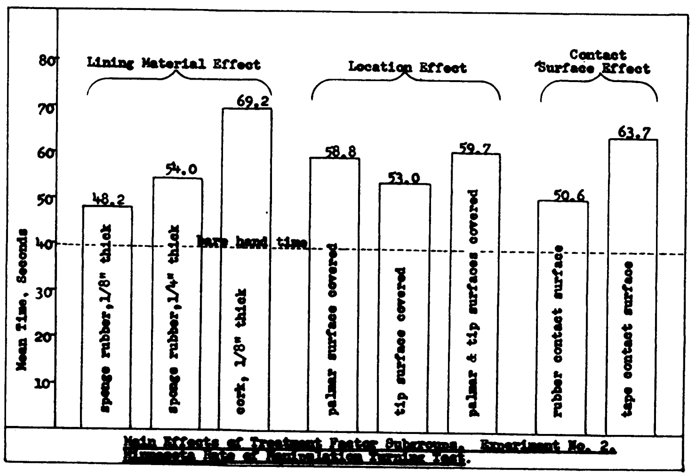

Figure 10

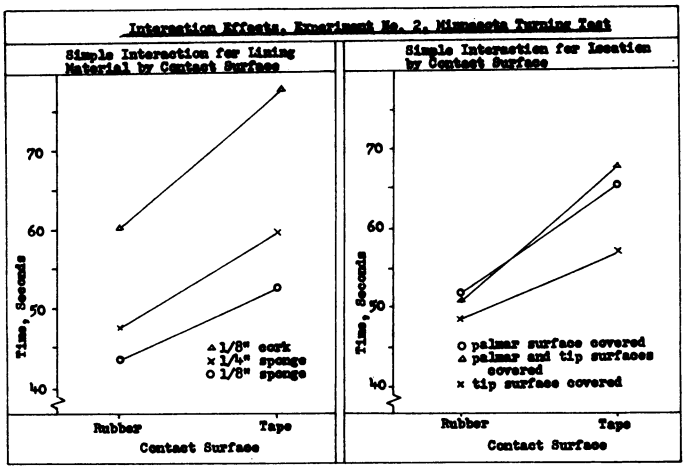

Figure 11

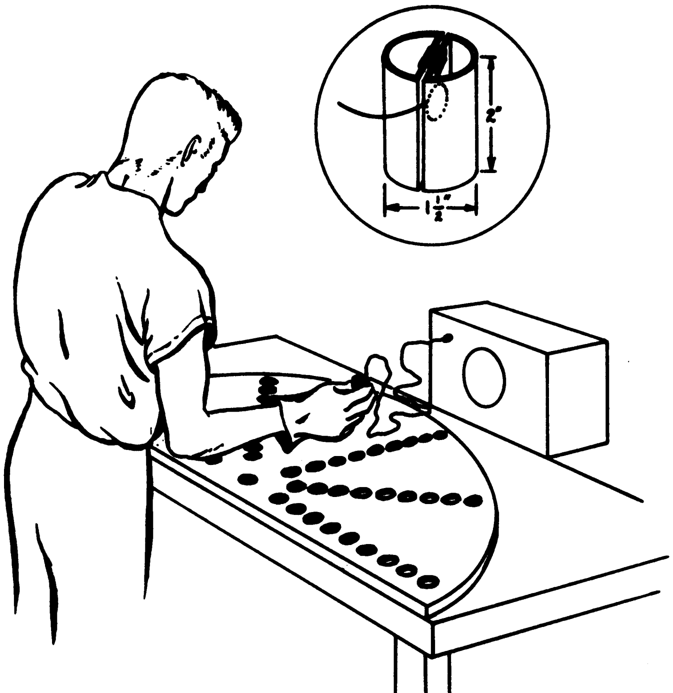

Figure 12

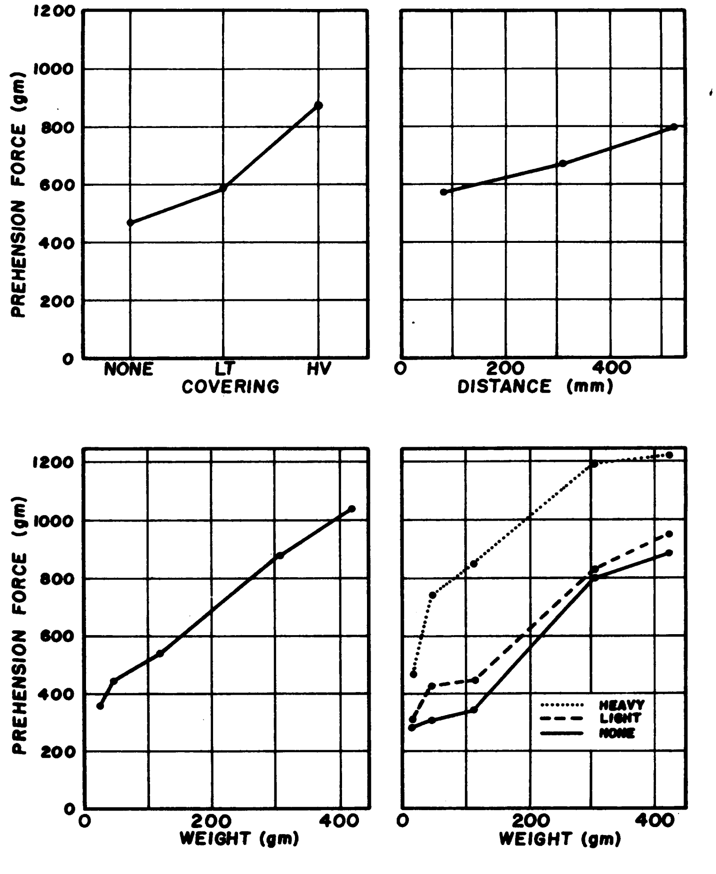

Figure 13

Figure 14

Figure 6 (see page 39) shows the experimental results for eight subjects. These results are representative of the results for the Minnesota Rate of Manipulation Turning Test for all three of the tasks. An extra bare hand test was included after all the tests were run on a given subject. You will note that with the ends of the gloves off and with the tips of the fingers sticking out, the performance was almost as good as the bare-handed test. When the ends only are worn, the performance is almost as bad as with the intact glove assembly. The differences between ends alone and the intact glove assembly were not statistically significant so we may assume that our problem with these tasks probably lay in the tips of the fingers. You will note that restraint does have an effect, and it has a little more effect when added to the ends only, but the proportionate effect of restraint is small relative to the effect of the ends of the gloves. From this we concluded that the sensitivity of the tips of the fingers was a crucial variable. We did additional experiments to verify this but this represents some of the main evidence.

In a second line of experiments we wished to investigate the effects of materials and frictional characteristics of contact surface on the finger tips. Since we knew by now that the tips of the fingers were crucial, this experiment was conducted with tips alone. These tips consisted of the ends of rubber balloons that had been clipped off; a piece of adhesive tape was attached to change the friction of the surface. They are shown in Figure 7 (see page 39). The balloon was turned inside out so that the thickness remained constant when the rubber was in contact and then turned inside out again so that the tape was in contact for the tape contact conditions. The lining and materials that were inserted were sponge rubber 1/8" thick, sponge rubber 1/4" thick, and cork 1/8" thick, in order to have "flexibility" as a variable. The insertion was made in such a way that it was inserted in different positions on the finger. The materials are shown in Figure 8 (see page 39).

Figure 9 (page 39) shows the placement of the tips. The materials were placed with the palmar surface covered, the tip bare, and the tip surface covered, with the palmar surface of the fingers bare, and both the palmar and tip surface covered. The same tests were used as previously. Figure 10 (page 39) shows the characteristic results from the main effects on the rate of manipulation turning test. The dotted line represents the bare hand time, for reference. Each of the variables had an effect, and this effect was most pronounced in the case of the cork liner. There are many qualifications that may be placed on the fact that the cork acted this way. We do not have time here to talk about them but Mr. Sheridan's thesis [2] is on file in the UCLA Library. Further details on this part of the experiment may be obtained from his thesis. Figure 11 (page 40) shows some of the inter-actions that took place. In combination with the frictional surfaces, the various lining materials showed different effects. These interactions were statistically significant. We find that with respect to lining material the worst case is again the cork; especially with the tape in contact with the object. The poorest results with the rubber were when the palmar surface was covered. With the tape they occurred when the palmar and tip surface was covered. These results were typical for the other tests in the experiment.

This completes the summary of the first two experiments. From the second experiment we can conclude the frictional surface of the glove is a very important variable, that the way in which the glove material is placed around the finger tip is an important variable, and the kind of material of which the glove is constructed from the standpoint of its flexibility and movement with respect to the finger is an important variable. We can also conclude that these variables interact in a complex manner.

In a third set of experiments we wished to determine what the effect of glove materials and configurations would be on the force with which one grasps objects. Figure 12 (page 40) shows the experimental setup which was used. A hollow cylinder was constructed so different weights could be placed in it, and the subject's task was to move it into a position along the radii of the workboard on verbal commands from the experimenter. The independent variables of mass, direction, distance, and type of handcovering were investigated. In this case, the "heavy condition" handcovering consisted of the leather glove and liner you saw in the previous experiments. As the "light condition," a surgeon's latex glove was used, and a "bare-hand condition" was used as a control. The results of this experiment are shown in Figure 13 (page 40).

We see in Figure 13 that even the surgeon's gloves have an effect. The direction variable was the only main effect that was not statistically significant. The covering was important, the distance that the person reached was important, the mass that he lifted was important, and there was a significant interaction between mass and the kind of handcovering which the person wore. The latter occurred especially at the lower levels of weight where tactile discrimination was poor. The discrimination appeared to be proportionately much poorer with the heavy glove than it was with the surgeon's glove, or the bare hand. Though prehension forces were measured under these rather limited conditions, it appears to be clear that you squeeze objects harder with a glove on than you do otherwise. This suggests that you may use more effort to get cues so that you can do the task properly. We wish to investigate this further, and to do this we have developed a device with which we are just beginning to collect data. Mr. J. R. Zweizig of our laboratory is responsible for building this device. It is shown in Figure 14 (page 40), mounted on a subject. We call it the "muscle force transducer," and with it we can measure the force with which people manipulate objects, reasonably independent of the object and independent of interference with the movements of the hand itself. Obviously, from what we have found, we cannot put transducers on the fingers because they would interfere with the sensitivity. We are measuring the integral of force, and converting it to average force over short time intervals. We believe this technique may have considerable potential as a measure of skill, but cannot draw any conclusions yet.

REFERENCES

1. Teichner, W. H., J. L. Kobrick, and E. R. Dusek. Studies of Manual Dexterity: I Methodological Studies. EPD Report No. EP-3, HQ. QM R & D Command, Natick, Mass., 1954.
2. Sheridan, T.B. An Experimental Study of Physical Criteria for Evaluating Handcovering Designs, M.S. Thesis, Dept. of Engr., UCLA, 1954.

MODERN MAINTENANCE METHODS IMPROVEMENT AND CONTROL TECHNIQUES

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Today, the increasing complexity of processes and equipment in modern industry presents a real challenge to everyone charged with responsibility for maintenance. This challenge can only be met through modern engineered maintenance techniques. Each of us should ask the questions: are we prepared to meet this challenge, and how best can we utilize the latest engineering techniques and technological improvements in our work?

Before I tell you how we seek to answer these questions in the Du Pont Company I need to tell you something about the company. Du Pont is primarily a chemical manufacturing company with sales approaching $2 billion annually. Approximately 95 percent of DuPont products, in sales value, are sold to other manufacturers for further processing and only 5 percent reach the consumer under a Du Pont label.

To produce these products there are over 70 plants located in 26 states. Total investment is about $2 billion. Employees number about 85,000 excluding 15,000 more employed at government plants operated by Du Pont. Average investment for each employee is about $24,000. Employee benefits are equivalent to about 20 percent of wages and salaries. Safety performance is about nine times better than the chemical industry as a whole and 15 times better than all industry.

Du Pont, like much of industry, is undergoing a rapid, evolutionary change in its maintenance pattern. In the not too distant past, production facilities were not mechanized to the extent they are today. Equipment and machines used were more simple in design and therefore, easier to maintain. In a process industry, production was then more often by batch methods than by continuous methods. These factors all contributed to making maintenance costs a minor part of mill cost and, naturally, management seldom recognized maintenance as an important engineering function. Today, processes are far more complex, involving high temperatures, high pressures, precision equipment and minimum process hold-up. The need for precise quality control looms large in the competitive market and the demand for minimum investment with maximum utilization of production facilities is the theme of all management. Accompanying all of this growing challenge to the maintenance head has been the growth of automatic control equipment and the great trend to continuous processes. Each of these new developments demands increasing maintenance expenditures and skills to keep equipment in continuous operation and insure maximum profits. The result is that maintenance is today an important segment of mill cost and more and more it is skilled engineered maintenance that spells the difference between profit and loss.

There is no uniform Du Pont maintenance control system. The maintenance personnel in the respective plants may range from as few as three or four to as many as twelve hundred. Operating practices among industrial departments vary widely. This is a result of company policy since production of a related line of products is the responsibility of what we call the industrial departments. There are 10 such departments, each under the direction of a general manager. Each of the general managers has virtual autonomy in the operation of his particular department. He is responsible for the research, development, production and sales of the products within his department, utilzing the services of the staff or auxiliary departments, as we call them, to the extent he deems necessary. Paralleling the industrial departments are a number of auxiliary departments which provide more or less uniform and across-the-board services for the company.

The Central Engineering Department is one of the auxiliary departments and provides, among its services, study and consulting assistance to the industrial departments for the solution of technical problems. It is a primary function of the Maintenance Engineering Section, of which I am a member, to improve the position of the Du Pont Company in relation to the maintenance of existing and future facilities. This includes maintenance measurement, methods, procedural work, mechanical problem analysis, mechanic training, shop layout and machine tool selection, lubrication, packing and gaskets, and many related services. In order to understand the problem in improving the maintenance position it is necessary to review the changing pattern in modern industry over the past 15 years. I think the Du Pont Company is a representative example of modern industry today.

COMPANY GROWTH PATTERN

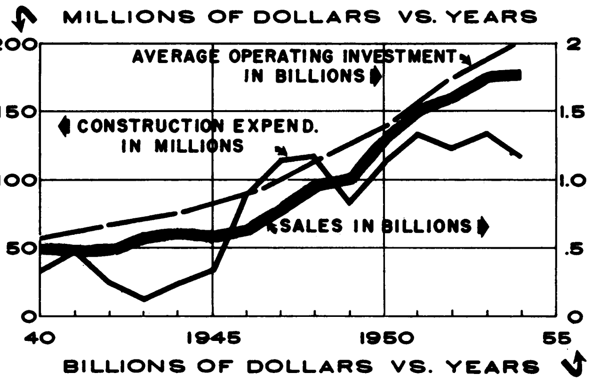

Figure 1

Here is the beginning of the company story where we see the relationship between sales, investment, and construction dollars versus years from 1940 to 1955. These curves illustrate that the Du Pont Company of today is not the company of the nineteen-forties in size of investment, volume of sales, or rate of growth. Therefore, it follows that the responsibility of the works engineer in 1956 for protection of permanent investment is substantially greater than it was in the forties.

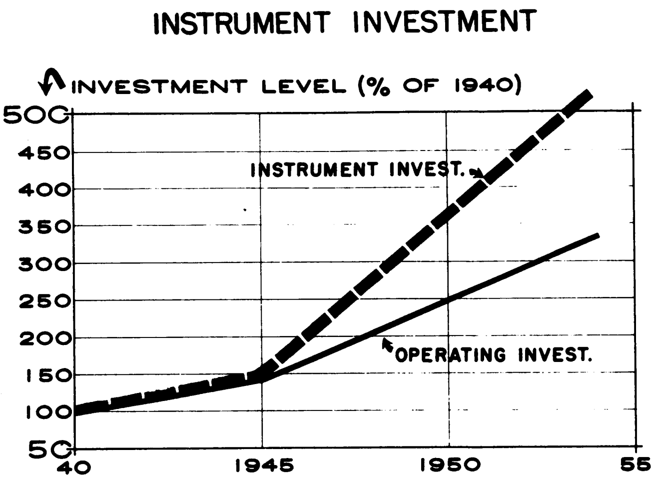

Figure 2

While the company grows in size, what about complexity? If we are willing to accept an increase in instrumentation investment as representing an increase in process complexity, we have an indication of what is taking place in the Du Pont Company. Figure 2 shows the relationship between permanent investment in the Du Pont Company and the rate of increase in instrument investment. Here we see that although the permanent investment has been increasing very rapidly, our rate of increase in instrument investment is even more rapid. So we see that not only has the manufacturing plant become larger but it has also become far more complex.

I am sure the Du Pont Company is representative of not only the chemical industry but also other modern industry as we know it today. Evidence indicates these same changes are taking place in many other companies. Recently, I saw a magazine article which indicated that the total cost of maintaining facilities in industrial plants in this country would increase by one billion dollars in 1955. The article went on to state that this is an increase of 9 percent over the previous year and it was expected that cost would increase by at least another 10 percent during 1956.

Admittedly, some of the problems of maintenance engineering in the mid-fifties parallel those of the mid-forties. However, in some areas vast changes have transpired in the past ten to fifteen years. Some of the most striking differences are in the fields of:

1. Employee relations and safety
2. Continuity of operation and product quality
3. Mill cost and return on investment
4. Engineering and start-up of new facilities

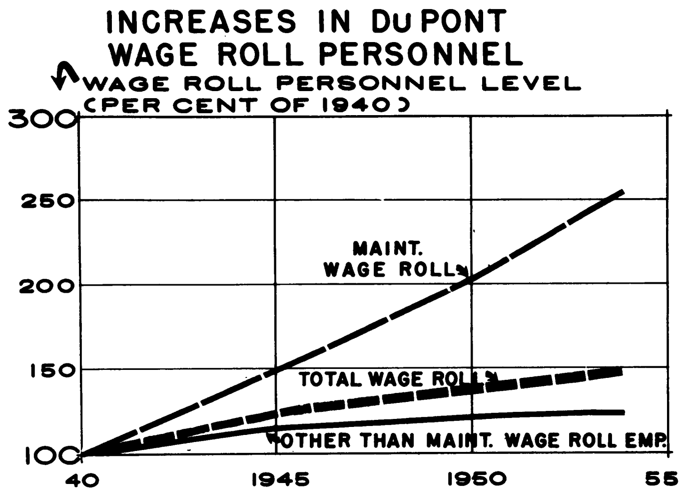

Figure 3

Figure 3 shows that, since 1940, the total increase in company wage roll personnel has been approximately 150 percent of the 1940 base. If we extract from this curve total maintenance employees, we find that the so-called "all others" curve has increased to only 125 percent of the 1940 base. Now, let's look at the maintenance labor curve for the same period and we will find an increase in the maintenance labor wage roll of 250 percent, or maintenance labor roll in the Du Pont Company is increasing twice as fast as all other wage rolls.

Today the maintenance wage roll includes those who will not only maintain facilities but also help to assure continuity of operation and product quality. Therefore, it is of extreme importance that proper techniques be employed in the field of selection, training and upgrading of this maintenance force.

Back in the nineteen-forties the maintenance head was usually interested in hiring into his organization the highest level of journeymen craftsman skill available. Today, we are still interested in hiring the best skills available for a growing organization. However, we should be equally concerned with the proper selection of new employees to assure high ability to absorb specialized mechanical training. This is extremely important due to the complexity in processes and equipment in plants today. We are concerned, therefore, that our maintenance mechanics can maintain the equipment in our plants. Much of this equipment is unique to us. Other companies are faced with similar problems. To achieve adequate training, proven techniques should be employed that will rapidly increase skill levels with minimum expenditures per employee.

In our company we have found that the most effective training is obtained by a formalized program based on each plant's requirements. This is just as important for experienced personnel as new employees. The program is administered by plant personnel and is presented at the plants on company time. While the training is designed to develop necessary skill to maintain the specific equipment on the plant, we have found it desirable also to train on basic job fundamentals. This includes those items each mechanic must know, such as, the use of small hand tools, machining and layout techniques, necessary shop mathematics and blueprint reading. This we call Part One Training. We then follow this with Part Two Training which covers job information and instruction on specific equipment and components to be maintained at the particular site. The entire training program averages from 120 to 200 hours for each mechanic, depending on the skills involved.

We have obtained the following benefits from this formalized training:

1. Approximately 12 percent increased personnel effectiveness.
2. Improved safety performance by both new and experienced employees.
3. Smoother and accelerated start-up of new or expanded facilities.

Our experience has shown that the approximate 12 percent increased effectiveness is obtained from better job knowledge and morale. We do not know what percentage can be attributed to each. However, our objective is to assist our wage roll employees to work smarter and not harder. Since all administrative controls are improved through this training, idle time is reduced because material is available, jobs are better planned and scheduled, and better tolls are provided. An example of the relationship between the safety

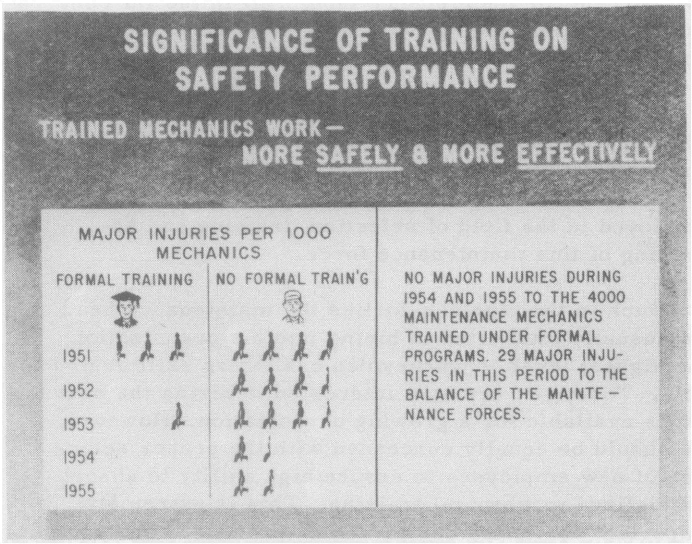

Figure 4

performance of employees trained under formalized training programs of our company and those who were not trained is extremely significant. In the years 1954 and 1955, mechanics trained under the formalized program, which included approximately one-third of the total mechanics, did not have a single major injury. The other two-thirds of the maintenance forces in our company have been involved in 29 major injuries in the same period. Something has occurred to upset the frequency pattern in the trained mechanics. A similar effect has been found in the minor injury frequency for this same group of trained employees.

Proper selection and training of employees should be followed by proper upgrading, that is upgrading of mechanics by testing techniques. The trend in our company is to develop as many qualified top grade mechanics as possible instead of levels of skills, such as A, B, and C mechanics. The formalized training programs provide all maintenance wage roll personnel the opportunity of improving their skills so they may be upgraded to the highest skill level possible. Upgrading techniques should be so designed as to provide mechanics an opportunity to demonstrate their qualifications for higher rates rather than place the burden upon supervision to prove that they are not so qualified. This upgrading technique also provides the mechanics with factual information on the requirements which they must meet in order to obtain the maximum rates commensurate with their skills. Only in this way can a maintenance organization be assured of qualified mechanics to maintain the complicated equipment required today.

In a modern maintenance organization where proper selection, training and upgrading techniques are employed, equal care and thought must be given to selection and training of foremen. They must not only have a better understanding of personnel and a high regard for safety, but they need a far greater understanding of the application of engineering techniques required to complete their jobs successfully. It is in this latter field, the application of engineering techniques to the maintenance job, that many foremen today are woefully inadequate. In order to impart such information to foremen, proper training is required and programs to this end should be developed for application in all instances.

Let's look now for a moment at the second area of increased responsibility for the works engineer of today, that of continuity of operation and maintenance of product uniformity.

As a result of these complex processes, maintenance within Du Pont, as in other places, has become big business. In fact maintenance has become a multi-million dollar undertaking in the Du Pont Company. Not only are the dollars expended on maintenance many, but because of the complex processes and high investment, production losses from unscheduled equipment downtime can in some cases amount to substantial sums that far overshadow normal maintenance costs. If this problem is not solved early in each new plant or unit it may be difficult to secure adequate return on investment.

Two of the factors in continuity of operation of integrated plants are: how much downtime for maintenance and how frequently should maintenance downtime be scheduled? This is extremely significant since it can influence to a great extent total equipment outage time. Unfortunately, outage time means loss of production which can be reflected in lost profits and increased mill cost. The optimum preventive maintenance schedule is one which gives minimum total downtime. The total downtime in this case is the probable emergency outage from component failures plus the known planned shutdown time. The application of statistical techniques to maintenance provides a very useful tool in developing information to provide the best answer to these two problems. It can assist in avoiding an excessive risk of random outage on an emergency basis, and on the other hand an excessive downtime from too frequent planned shutdowns. Let me give you an example from a continuous process plant in our company. It was established that a planned shutdown frequency of 300 hours would provide 82 per cent mechanical equipment attainment. Shutdowns more or less frequent than 300 hours would decrease the machanical equipment attainment. The shutdown frequency could not be extended until component design or materials of construction improved. By using statistical techniques, the optimum planned shutdown frequency can be established based on the risk involved in obtaining shutdowns on an emergency basis prior to the scheduled shutdown. When the shutdown frequency has once been determined then it is possible to optimize both maintenance labor and maintenance material required for the shutdown. In addition, to determine the actual frequency for shutdowns, the application of statistical techniques will also provide the economic justification for this scheduled shutdown.

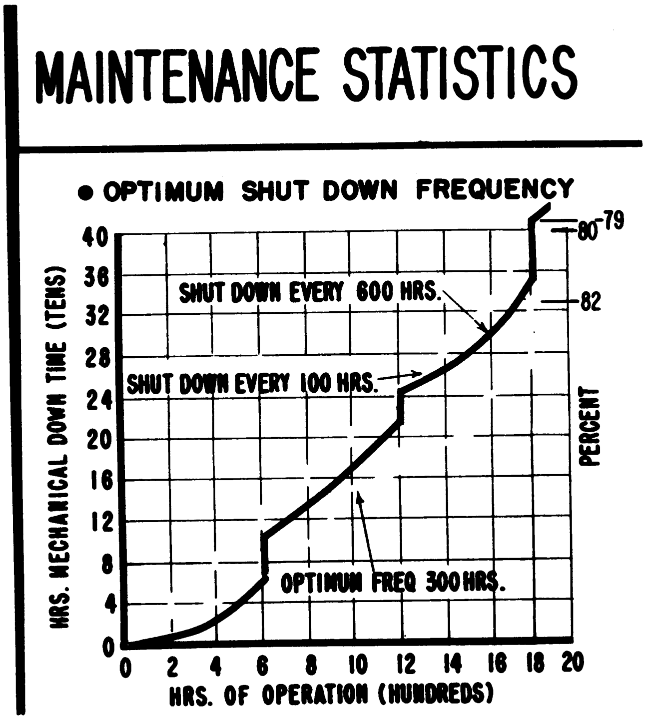

Figure 5

Another important factor in the operation of the continuous plant is the reduction of downtime due to maintenance reasons. We choose to refer to this entire field as corrective maintenance. The basic information for any corrective maintenance program normally stems from good equipment history which provides information as to the equipment, machines, or components which are breaking down causing frequent shutdowns. Here again, statistical analysis provides a wonderful technique to establish priority for corrective action. Unfortunately, the statistical technique cannot be applied until certain historical information has been established through the equipment history system. Once established, however, statistical techniques can be applied to establish economic justification for changes in design, material or methods.

Another facet of increasing responsibility for maintenance heads is that of continuity of product quality. It has been found on many occasions that uniformity of operation is a step to uniformity of quality. Much of modern processing involves higher temperatures and increasing speeds with higher pressures or lower vacuums. Such practice makes it almost mandatory that truly engineered techniques be employed by maintenance organizations if uniform operations of continuous plants is to be secured. For example, in regard to improved surface finishes required for higher speeds, the proper extrapoliation of production machining techniques plus the increased use of carbide tooling by maintenance shops will permit greatly improved finishes. This will also permit many pieces to be machined at higher rates than permitted by the grinding required previously. Further application of high speed machining techniques would raise average machining rates in most machine shops two-fold and secure a 25 percent reduction in required shop equipment and man power. In a similar manner the translation of production welding techniques such as inert gas, tungsten arc process to the fabrication of piping systems, would improve the quality of welds, reduce the danger of leakage and cut the cost of construction and maintenance. Improved lubricants, mechanical seals, packing and gasketing material will be necessary if minimum downtime is to be achieved. As we pointed out previously, the application of these new techniques and the inclusion of these new materials and equipment requires additional training for our people.

Next, we will explore briefly the maintenance head's new position in relationship to mill cost and return on investment. In our growing, complex company it is almost axiomatic that the cost of maintaining our permanent investment is increasing rapidly. In the past ten years these costs have increased approximately from forty million to one hundred million dollars per year, or a two fold increase.

These are some significant aspects of this increase in maintenance dollars. The cost of maintaining facilities has been increasing at a rate faster than total operating costs, and total permanent investment. Therefore, maintenance costs are becoming an increasingly important ingredient in mill costs.

If I were asked the question, "is $100 million a year too much to maintain the permanent investment in the Du Pont Company?" I would have to answer, "I don't know." Because essentially we are not interested in maintenance cost alone. Essentially, our job is to manufacture a product, usually by a chemical process, put it in a bag, so to speak, and sell it at a profit. Profit, in general terms, is the difference between sales price and mill cost. What we are essentially interested in then, is reducing mill cost, regardless of what happens to maintenance cost. If we can reduce maintenance cost and reduce mill cost simultaneously, fine. But how many cases are there in the company today where maintenance costs should be increased to secure reduced mill cost? A reduction in equipment downtime, improved continuity of operation, better machine performance to improve quality, all of these might involve increased maintenance cost and actually resolve themselves into decreased mill cost per unit of product. Now if we set the goal of a good maintenance job as a reduction in mill cost rather than a reduction in maintenance cost, we lose some of the old scales by which we have attempted to determine maintenance performance.

On existing facilities the maintenance head first must have a technique to evaluate the over-all performance of his organization which will indicate the effect on the mill cost of the product. When the current performance is once established, he must be able to determine the most effective improvement program for his particular organization and then have a yardstick by which to measure any improvement resulting from execution of his program. Any method developed to evaluate a plant maintenance performance must take into consideration many variable factors which affect that performance.

In our company, we have plants with many different processes. These include simple batch type chemical processes, textile plants, metal working plants and complex continuous processes. Consequently, it has been necessary to develop a technique which would apply to these different types of plants. We have found that regardless of the process or plant operating conditions, maintenance responsibilities can be divided into four broad functions--planning, work load, cost and productivity. Planning indicates how well the maintenance organization is handling its administrative functions. Work load indicates how well the maintenance organization is controlling its backlog and handling the work required by production and other parts of the plant. Cost indicates how much it is costing the maintenance organization to handle its planning, control its work and provide the necessary services to the plant. Productivity indicates what the maintenance organization and the plant obtain from money spent to control the various phases of the maintenance work.

While many factors can be listed under these broad functions, we have found that four factors can be selected for each function to provide a finite measure of performance. This establishes a total of 16 individual factors for use in evaluating a plant's maintenance performance.

SUMMARY OF FACTORS

PLANNING & WORK LOAD

FACTORS	CURRENT	GOAL
PLANNING		
1. PERSONNEL EFFECTIVENESS	65%	80%
2. MAN HOURS OF WORK/WEEK PLANNED & FORECAST	50%	85%
3. MAN HOURS OF WORK/MONTH-EMERGENCY	15%	4%
4. MAN HOURS OF WORK/MONTH-OVERTIME	8%	2%
WORK LOAD		
5. CREW WEEKS OF CURRENT BACKLOG	5	3
6. CREW WEEKS OF TOTAL BACKLOG	8.5	5
7. MAN HOURS/MONTH-PREVENTIVE MAINTENANCE	10%	25%
8. MAN HOURS/MONTH-DAILY MAINTENANCE	90%	75%

Figure 6

Figures 6 and 7 show a representative list of 16 factors divided by function for performance evaluation of a conventional chemical plant. As an example, the four factors selected to evaluate planning performance are:

1. Personnel effectiveness
2. Man hours of work per week planned and forecast

SUMMARY OF FACTORS

COST & PRODUCTIVITY

FACTORS	CURRENT	GOAL
COST		
9. DECREASE OR INCREASE MAINTENANCE UNIT COST	+15%	-10%
10. MAINTENANCE COST AS PER CENT OF INVESTMENT	10.5%	6%
11. MAINTENANCE $-DIRECT & GENERAL MAINTENANCE	65%	85%
12. MAINTENANCE $-INDIRECT MAINTENANCE	35%	15%
PRODUCTIVITY		
13. RATIO DELAY	55%	75%
14. FORECAST EFFECTIVENESS	40%	75%
15. MECHANICAL DOWNTIME	12%	3%
16. INCREASE OR DECREASE IN UNITS OF PRODUCT/MAINTENANCE DOLLAR	-17%	+12%

Figure 7

3. Man hours of work per month-emergency
4. Man hours of work per month-overtime

Representative factors are also shown on figures 6 and 7 for work load, cost and productivity. Organizational performance for ~~any factors~~ developed can be represented by a numerical value. As an example the current value for personnel effectiveness was determined to be 65 percent. For man hours of work per week planned and forecast the current value was 50 percent. Based on analysis the attainable goal for personnel effectiveness was established at 80 percent and for man hours of work per week planned and forecast at 85 percent. Similarly current and goal values were developed for all 16 factors.

Appropriate scales must be developed so that these values can be plotted on a diagram to provide both a measure of performance and accurate indication of improvement.

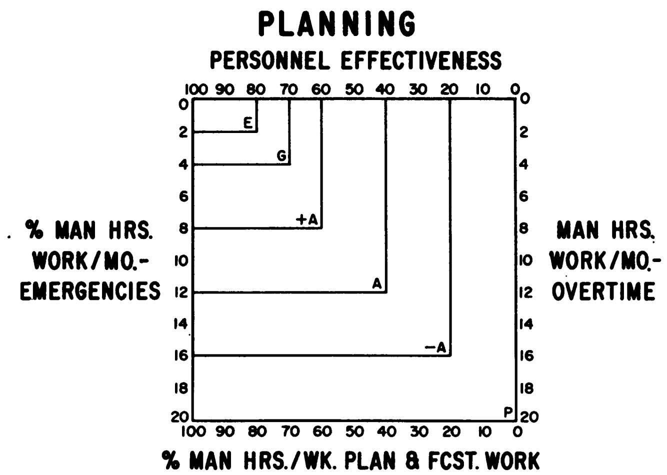

Figure 8

Diagrams can then be developed for each of our four major functions. Figure 8 shows a diagram developed for the planning function. The four factors selected to represent the planning function with their appropriate scales are shown on the four sides of the diagram. In addition, you will note there are six fields marked E, G, A, A,-A and P. These fields have been established, based on experience plus a review of the existing conditions on the plant at which the maintenance performance is to be determined. They represent degrees of performance between excellent and poor. The values for each factor can be plotted, connected by a line and the intersection will represent the performance for the planning function.

In order to determine the over-all maintenance performance a fifth, or composite diagram, can be constructed from information on the four diagrams developed for planning, work load cost and productivity. In Figure 9 the four major functions are shown as the four factors

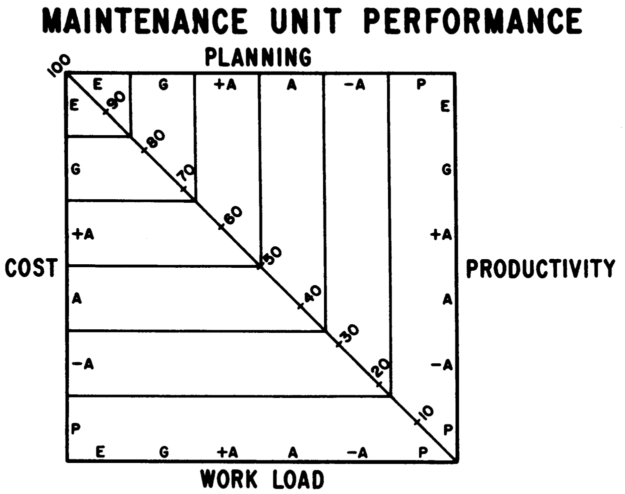

Figure 9

on the sides of diagram. The performance for each function determined on their diagrams can be plotted, connected by two lines, and the intersection will provide the over-all maintenance performance. You will also note a diagonal line divided from 0 to 100. By drawing a perpendicular from the intersection of the lines an actual point value for performance can be obtained. This is a base performance from which improvement can be measured.

Time does not allow a detailed explanation of this technique. However, for those interested in additional details there is a complete description by W. S. Luck of our organization in an article in the January issue of Factory Magazine.

By proper analysis of the information developed through these diagrams, a program for continued improvement by the maintenance organization can be formulated. Using the current maintenance performance as a base point, a method of measuring improvement in execution of the program is also provided. A maintenance organization once equipped with this type of information can then do its essential job of bringing about a reduction in mill cost by operating maintenance on a business-like basis.

Probably the most important and essential ingredients, to allow the maintenance head to accomplish this objective, are those administrative controls such as planning and scheduling, backlog control, job analysis and preplanning and weekly forecasting. Of course, the most essential ingredient is the work order procedure. This is the whole backbone of maintenance administrative controls. A work order procedure must be properly designed and initiated before the other controls can be effective. In our company, we have found that a job methods planning program sometimes referred to as maintenance measurement or craft measurement can provide the necessary yardstick to strengthen and improve the other administrative controls. In our job methods program, we utilize predetermined time values to provide an accurate estimate of time required to do the job after it has been properly analyzed and planned according to the best method sequence of operation and using proper materials. Of course, an accurate estimate of the time required to do the job will in turn strengthen the weekly forecasting, daily scheduling, backlog control, the determination of crew sizes, distribution of maintenance manpower and skills required. At the completion of any job the effectiveness can be calculated by dividing the predetermined time standard by actual labor expended. Deviations from predetermined time standards can be investigated and the necessary corrective steps taken to eliminate or reduce any impediment to completing the job in the predetermined time.

The other major area where the maintenance head in the company today is facing a problem that is undergoing a rapid transition, is in that of engineering and starting-up new facilities. Today he has increasing responsibilities:

1. To see that the basic data that are provided for design take into consideration all of the maintenance factors that are concerned with modern processing.
2. To make certain that minimum investment is required in order to permit maximum return.
3. To review design to be sure that design recognized maintenance requirements in order that he can assure optimum maintenance to provide continuity of operation.
4. To recognize the problems in the actual mechanical startup of new facilities.

Let us examine in more detail only the first and last of these four factors.

First, let's look at the maintenance heads responsibility in the development of basic data for design of new facilities. If a new location is involved, the area should be carefully surveyed by qualified, experienced personnel to analyze the type of personnel relations problems existing in the area, to determine how training programs should be established, and to evaluate what machine, instrument, electric, and other repair facilities are available. Further, this survey should determine the cost and availability of these established repair facilities and how they can best supplement our facilities in order to have minimum equipment investment. We should not, for example, install a large vertical boring mill if it is to be used only a few times a year, particularly if there are similar facilities in the neighborhood where we can shop out the job and save ourselves thousands of dollars in permanent investment. Real advantages can be gained from a careful review of many other items such as mill supply and spare parts requirements. Before the fact, shutdown schedules and job methods should be developed to determine the correct number of maintenance employees required. All of these items, and others, influence shop size, locker room needs, spare parts requirements, tools needed, and other factors that substantially influence investment.

And now a word about the fourth factor. It is probably in the area of actual plant start-up that a maintenance head today faces one of his major problems and here careful planning can do much to assure the company of early return on new facilities. Proper selection and training of mechanics, the development of proper job techniques, the application of improved engineering practices will all contribute to reduced trouble during the start-up period. Actual start-up of new facilities is not a normal problem that operating organizations face. In the past few years, in the start-up of new facilities for our own commercial operation, for certain licensees, and plants we build for the government, many improved techniques have been developed that assure minimum difficulties in the start-up period. Included are such techniques as pre-start up inspection and testing programs which at one site have been said to have expedited start-up by three months.

In summary, the challenge to the maintenance head is great. His responsibility to his management has changed in many respects in the past fifteen years. He is faced with the need for improved tools, for better knowledge, and for improved techniques. The old days of the sledge hammer mechanic have been replaced by modern engineered techniques of a high order. Today maintenance is big business in our company - a $100 million a year business, and one that has been growing about $10 million annually. It is composed of the fastest growing labor segment and consequently the big problem of employee relations and safety at Du Pont, is shifting from the production to the maintenance organization. The maintenance head's contribution to improved continuity of operation and product uniformity in an integrated modern chemical process plant is as great as that of the production superintendent. His relationship to cost has changed from one of concerning himself only with maintenance cost to that of obtaining a decrease in mill cost, and his responsibility for the start-up of new facilities has grown immeasurably. Perhaps in the plant of today, and surely in the plant of tomorrow, it is the maintenance head who is the key to early start-up and assured continuity of operation, and consequently he is the real key to profit and return on investment. Do you provide this vital member of your team with modern maintenance knowledge, techniques, and service in order that he may most adequately discharge his responsibilities in the modern industrial plant?

PREDICTIONS OF DELAYS IN A MATERIALS HANDLING PROBLEM[1]

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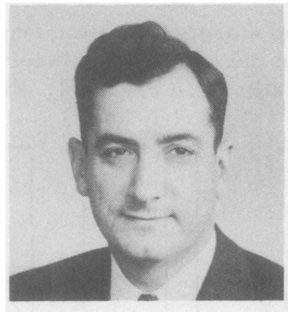


The research reported in this paper has application to a broad range of materials handling and processing problems - for example, the balancing of a line production system. However, the work has been inspired by a specific materials handling problem - the loading and unloading of maritime cargo. Thus, the material is presented as a cargo handling application.

A cargo handling research project, sponsored by the Office of Naval Research, has been active in the Department of Engineering ever since 1951. The objectives and a general description of the research were presented to the Fifth Industrial Engineering Institute in 1953, and a report on the use of work sampling, or ratio delay, on the waterfront was presented to the Sixth Industrial Engineering Institute in 1954. Because the time is limited, the general aspects of the problem will not be reviewed. The discussion is confined to the method which has been devised for simulating the movement of cargo by means of a high speed digital computer and to the results which have been obtained to date.

Cargo handling is one of the most complex materials handling systems, and the simple idealization or mathematical model described here will not account completely for the behavior of the actual system. However, it does provide a basis for a reasonable level of prediction. Of course, the prediction can be made more accurate by including more of the variables, because the behavior of the actual system is the limit of the behavior of the idealized systems as the idealizations are extended step by step, each progressively including more variables, or at least more accurately describing their effect. The following description emphasizes the transfer of physical objects between a land carrier and a ship by means of men and machines.

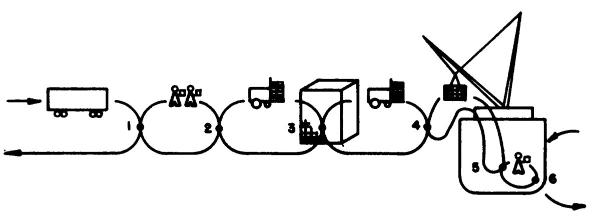


FIGURE I. EXAMPLE LOADING SEQUENCE

A diagram of an example loading sequence is shown in Figure 1. The shipment arrives at point one by rail; it is unloaded one carton at a time by laborers and palletized near the car door. A fork-lift truck picks up the loaded pallet and moves it to an assigned position in the transit shed. After a period of time in storage, the pallet is then moved by a fork lift truck to the apron. Here, the pallet is hoisted by the hook over the side of the ship and into the hold. In the hold the pallet is unloaded by the hold men, one carton at a time and stowed. This system may be represented as a sequence of links and nodes. The path of the transporting agent is the link and the region where the unit of cargo is transferred from one transporting agent to another is the node. In the example shown, the transporting agents are the rail car, the laborers, the fork lift truck, the hook, etc.

For the situation where there is no gain or loss at any of the interior nodes, attention can be directed toward the links, in particular toward the productivity of the individual transporting agents in each link. The productivity, measured in tons per hour, of the entire system is equal to the productivity of the slowest link. In fact, if the productivity of the slowest link is defined in terms of the working time only, the productivity is even less. For example, consider a two man operation. One man can move a bag from A to B every two minutes and the other can move the bag from B to C every three minutes. In this case, the second man controls and the average rate of movement of bag will be slower than one every three minutes. How much slower and why are the subjects of this paper.

Productive activities (using conventional industrial engineering terminology) can be grouped into four categories. They are 1) pick-up, 2) transport loaded, 3) release, 4) return empty. In other words, at any instant of time the transporting agent must be engaged in one of these productive activities or in a delay state. These delays have not been considered as avoidable and unavoidable, but as internal or induced depending upon their cause. A delay that results when a transporting agent cannot pick up a load because there is nothing to pick up or cannot set the load down because there is no room has been called an induced delay. All other delays such as breakdown or stoppage in the link have been called internal delays. If P, L, R, E, represent the average time required to perform the elementary operations and D the time of induced delay, the productivity of a transporting agent is $R = \frac{W}{P+L+R+E+D}$, where W = amount moved by the transporting agent each trip.

Time per cycle and productivity are inversely related, and for convenience time will be considered rather than productivity. For the case where there is

1. This research was sponsored by the Office of Naval Research under contract Nonr 233 (07).

no storage, the time required by the transporting agents in the consecutive individual links can be shown graphically as in Figure 2. Field studies have shown that the

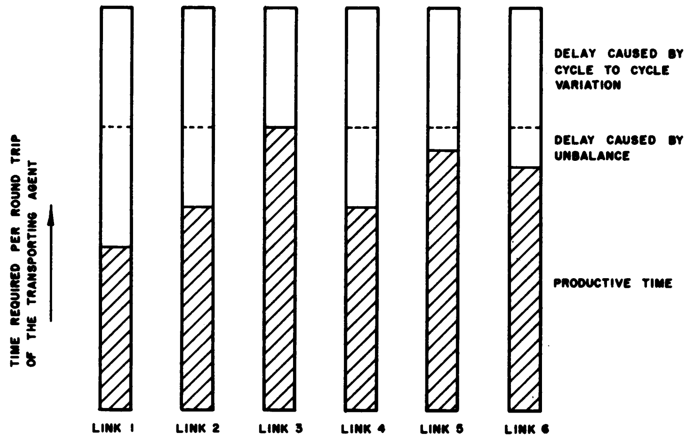
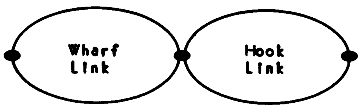


FIGURE 2. TIME CHART

time per cycle is considerably greater than the working time of the slowest link. Even the slowest link must wait on occasion for one of the connecting links to catch up. This can be explained if P, L, R, & E are considered to be random variables, not constants. For example, consider the case of two links shown in Figure 3. In the system shown, the average working time of



	Wharf Link	Hook Link
Mean Operating Time	2 min.	3 min.
Range of Cycle Operating Times	1 to 3 min.	2 to 4 min.

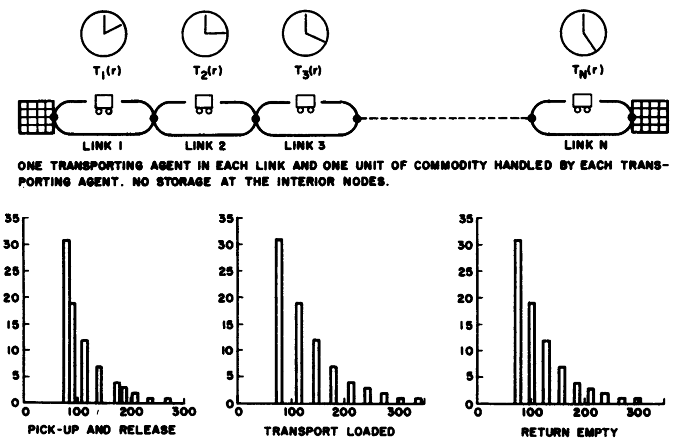
FIGURE 3. A HYPOTHETICAL RELATIONSHIP BETWEEN TWO LINKS

the hook link is longer than the average working time of the wharf link. The wharf link, therefore, is expected to have a certain amount of induced delay. However, because there is a range of individual cycle times for each of the two links, there are many specific cycles where the wharf link takes longer. Thus, the hook link must wait. Field observations have verified the existence of such cycle to cycle variation.

The time bars ✓ shown in Figure 2 ✓ are divided into three segments: productive time, delay caused by unbalance, and delay caused by cycle to cycle variation. Calculation of the delay caused by unbalance is relatively simple, provided sufficient methods study data are available. Calculation of the delay caused by cycle to cycle variation is not so simple, but the Monte Carlo technique provides a means for making a very good estimate of the delay even for complicated systems. The Monte Carlo technique may be compared to a method of determining the balance of a coin by tossing it many times, keeping an account of the outcomes and examining the ratio of heads to tails. Likewise the time required to move one unit of commodity through the system, including delay, can be calculated by using particular values of P, L, R, and E which are selected in a random manner. When the calculation is repeated many times, say 2500, the result is a good estimate of the average delay encountered. Although such calculations would be laborious if performed manually, they can be readily carried out on a high speed digital computer.

Using the Monte Carlo method six parameters which are involved in the computation of productivity have been explored. The parameters are: 1) the number of links, 2) the arrangement of the links, 3) the number of transporting agents in each link, 4) the number of units of commodity handled by each transporting agent, 5) the amount of storage that is permissable at each node, and 6) the individual distributions of element times required to perform the basic operation.

As an illustration of the method, consider the program for investigating the influence of number of links. The system is shown in Figure 4. There are N links



DISCRETE PROBABILITY DENSITY FUNCTIONS FOR THE PRODUCTIVE ELEMENT TIMES COEFFICIENT OF VARIATION ≈ 0.5

FIGURE 4. VARIABLE NUMBER OF LINKS

in series, one transporting agent in each link, one unit of commodity handled by each transporting agent, no storage at the nodes, and a distribution of element times as shown. The internal delays are included in the productive activities. This accounts for the long element times which are included. Associated with each link is a clock which keeps track of the cumulative time of the transporting agent. In order to relate the unit of commodity, the cumulative time is written as $T_i(r)$ to indicate the clock time after the transporting agent in the ith link has finished delivering the rth unit of commodity.

All transporting agents are started at points A. Values of E, P, and L are selected at random and added successively to T (O). Because no storage is allowable, the transporting agent in the first link can not release the first unit of commodity until the transporting agent in the second link is in position. Therefore, a value of E is selected at random for the second link. $T_1(0)$ and $T_2(0)$ are compared and both are made equal to the larger. Next another value of P is selected, added to both $T_1(0)$ and $T_2(0)$ because the pick-up time for the second transporting agent is considered to be equal to the release time of the first. $T_1(0)$ now becomes $T_1(1)$. This process is continued until the first unit of commodity has gone all the way through the N links.

At this point, all of the transporting agents have returned to their starting points A and the clocks read the time at which the transporting agent returned there $T_1(1)$, $T_2(1), \ldots T_n(1)$. This process is repeated 500 times, and the time, including delays, for 500 units, $T_1(500)$, is compared with the time that would have been required if all transporting agents operated at their mean value. The difference between the two times is the delay, and the ratio is an index of efficiency.

Some results[2] are shown in Figures 5 and 6. Each point on the curves represents the average for 2500 units of commodity. The coefficient of variation, i.e., the ratio of the standard deviation to the mean, has been found to be a most significant parameter.

Figure 5 illustrates the influence of the number of links on the ratio of productivity to working time. It is interesting to note that a materials handling system involving many links, such as a bucket brigade, is not slowed down by the addition of a few more links. However, when there are only a few links, each additional link reduced the overall productivity.

Figure 6 illustrates the influence of the number of units of storage. As expected, even a small amount of storage significantly reduces the induced delay.

In summary, a technique has been developed for the prediction of material flow in a system where the material is moved from one place to the next by means of a sequence of movements and handlings. There are many interesting conclusions that may be drawn not only for the cargo handling system but other materials handlings and other materials processings systems as well.

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2. The calculations were carried out on SWAC, the high speed digital computer at the Numerical Analysis Research Project on the campus of the University of California, Los Angeles. NAR receives its financial support from the Office of Naval Research.

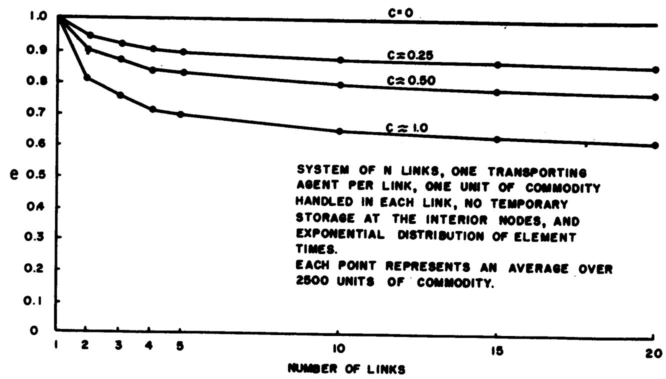

FIGURE 5 INFLUENCE OF NUMBER OF LINKS

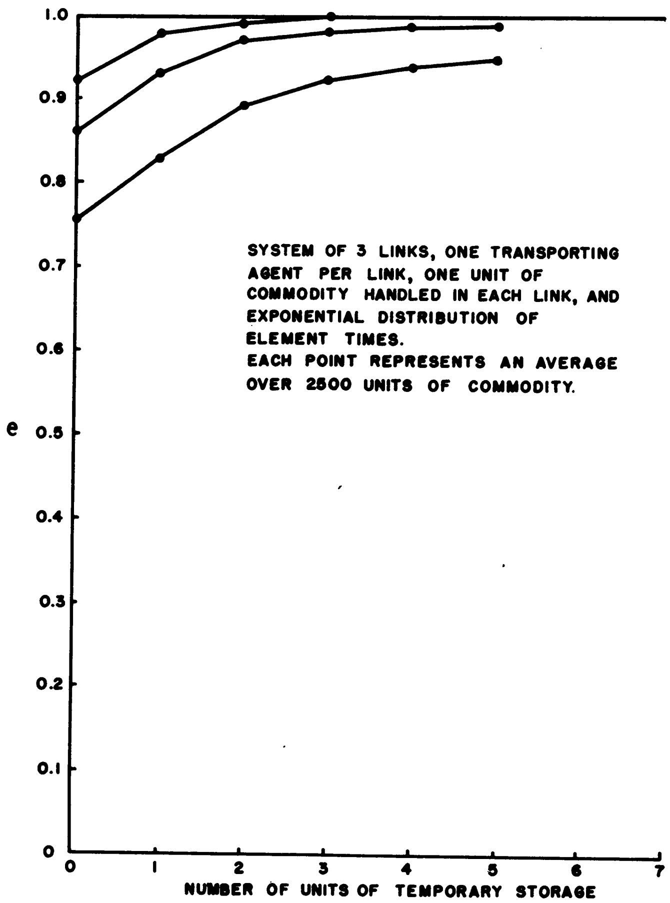

FIGURE 6 INFLUENCE OF STORAGE

ATTITUDES, MOTIVATIONS AND INDUSTRIAL PRODUCTIVITY

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Over the past fifteen years I have had the pleasure of working in fairly close association with industrial engineers in a number of organizations. From this association I have gained a considerable respect for the work they do. I admire their free-wheeling imagination when it comes to inventing new and better ways for the performance of work. I admire particularly their persistence in advocating change and improvement.

But industrial engineers do have problems, and many of them stem from the fact that their work affects people. Any one who aims to change the way things are done is likely to find himself embroiled in friction and controversy, particularly when, as in the case of industrial engineering, the proposed changes require adjustments by many people in their economic status, their security and prestige, and their daily relations with people at work. These are not minor difficulties to be brushed aside. All too frequently, the gain in cost or efficiency inherent in the industrial engineer's work is nullified or substantially reduced by the human factors in the situation. It takes all of the skill and understanding of the engineer and of management people generally to resolve such human problems. Most of you are all too painfully aware of the crude methods and outmoded tools you have to deal with human problems associated with technological change. As a social scientist, I am often asked, in effect, when the social sciences will "get on the ball" and come up with ideas which will allow full utilization of the technological developments presently available.

We all realize that high productivity, as we know it today, is not merely a matter of machines, materials and methods. Nor is it merely a matter of individual motivation for the person engaged in productive work. It depends upon group effort, on people working together in an efficient and effective way, and upon the organization of this work into an integrated whole. There is a highly complicated social system - a pattern of human relationships - involved in every productive enterprise, and every enterprise depends for its success upon the development of ways to enlist the full cooperation of many individuals in a group effort.

On the whole, especially here in America, we have done extremely well in solving this problem. Our man-hour productivity is now higher than it has ever been in history, and it is rising steadily. Our standard of living is higher than was imagined possible a few decades ago, and beyond the comprehension of most of the people of the world. While much of this increase in productivity can be attributed to our abundant natural resources, high technical skills, advanced equipment and other such factors, it is true also that the results would not have been achieved without great skill in the organization and management of cooperative effort and certainly they would not have been achieved without means for mobilizing the collaborative effort of millions of individuals.

The picture is not complete without mention of our achievements in satisfying the non-economic needs of our people. Our factories produce more than automobiles, refrigerators and television sets. There has also been produced a widespread feeling of satisfaction among people who work in the factories and offices; a feeling that things are good - that they have a good deal for themselves personally. In spite of the great concern shown in some quarters about the evil effects of routinized, impersonal life on the assembly line, the fact is that most people like their jobs. We recently asked several hundred people - a cross section of adult men - some questions about their work, about how they liked their jobs, and what part their work played in their lives aside from providing bread and butter. The great majority said they were, on the whole, satisfied with their jobs. Only 15 to 20 per cent (more in some kinds of work than in others) expressed dissatisfaction. About eighty per cent said they would continue working even if they no longer needed the income. These figures do not suggest that our high productivity has been obtained at the cost of a demoralized work force.

While it is pleasant to consider these achievements of productivity and personal satisfaction with productive work, we must not be led to believe that what we have is good enough. We have plenty to be dissatisfied about. Even while we are still in our most productive year in history, we see around us many things to cause concern and many things that encourage us to set our goals higher. Let me just mention a few:

1. In the survey just mentioned we found that about a fifth of our respondents were not satisfied with the jobs they had. This is about thirteen million dissatisfied people. Furthermore, of those who expressed general satisfaction with their jobs, a majority thought that, given a chance, they would prefer to be in some other line of work or on some other job.

2. Every year there are in American business and industry about 30 to 40 million voluntary employee separations - that is quits and discharges. Each one represents a failure on the part of management to provide something the employee needed, or a filure on the part of the employee to meet minimum demands of his job. While some job mobility is necessary and desirable, our present

rate seems to be unnecessarily inefficient and wasteful.

3. Our productivity - however high - is not near the limit of our capacity even with present methods and facilities. Proof of this can be found in any organization. It is common to find, in a work crew, some men producing up to twice as much as others, with no apparent advantage other than a will to do so. It is common to find some production department or section consistently turning in unit cost performance far superior to others enjoying the same facilities, for no apparent reason other than those concerning human factors.

I need not say more on this point. All of you are well aware of the fact that the way our organizations are currently run is something less than perfect. We have a great deal yet to learn about motivation and productivity.

One hope and challenge lies in the fact that we are now in a position to apply to problems of human relations in organizations, the scientific techniques and principles that have been so productive in other fields. In the past few years, techniques for attitude measurement, for sampling of populations, and for statistical analysis of complex relationships have permitted a beginning in the scientific analysis of human motivations in organizational settings.

The findings that are beginning to emerge are of considerable practical importance as well as of scientific interest. Some of the findings throw doubt upon current managerial assumptions and practices, and suggest new ways of approaching the solution of old problems. I will illustrate the general nature of these findings and suggest some interpretations as they bear on employee motivation and productivity. In doing this I will choose to consider only three out of many specific topics which might have been used to illustrate current developments in the area of organization management. I shall refer first to some aspects of economic motivation, then to some problems in social structure of the factory, and finally to some human aspects of developments in the field of automation.

FINANCIAL INCENTIVES

Most organization managers consider economic return to be the basic source of employee motivation. In nearly all organizations the system of differential pay, provisions for promotion and upgrading, and variable pay based on output are considered central to the motivational system. Yet little is known about the effectiveness of financial motivation and the conditions under which it is of maximum effectiveness. We do know quite a bit about the conditions under which financial incentives may fail of their objectives and something about where the root of the problem might lie. Let me mention a few basic facts about financial motivations.

It is clear that high pay in itself does not produce satisfaction with the organization as a place to work, or even with the amount of pay itself. It is common for us to find situations in which higher pay (within a generally favorable scale) appears to be related to lower satisfaction with pay. The factors operating here are complex, and I believe, for example, that the expectations of the employees regarding pay may determine whether a given wage is satisfying or not. There is evidence that higher paid employees are generally the long-service employees whose pay, while objectively high, may be low in relation to needs or expectations. In some situations, higher pay goes with kinds of work that are less satisfying and thus high pay may be offset by other considerations which result in a net loss in satisfaction for the person who qualifies for a presumably "better" job.

The idea of incentive pay based on performance relative to some standard raises a number of problems as to the perception of what the standard really is, and how it is accepted. The standard of performance, however well established and explained, is likely to be perceived differently by different people. One study in a machine factory shows that, even though the formal standards are well known and actual performance relative to standard is reported to the employees daily, there still are great discrepancies in perception of how reasonable the standards are, what the "real" standards are and how others perceive the standards. Even the supervisors, in many cases, do not believe that the management really considers the standards to be reasonable. Only in high-production crews are the standards seen as reasonable and attainable by both supervisors and men.

While the installation of a piecework or other form of incentive pay plan often results in a substantial increase in productivity, it is common that such plans are resisted or even totally rejected. Even in the case of a successful installation by current standards of success, the performance of the men under the system is likely to be far short of the level which engineering studies show to be attainable. For one thing, some people seem for one reason or another to be immune to financial incentives of a high order. Some, on the other hand, respond according to our theory of economic motivations and produce at levels which maximize pay. When you plot the distribution of earnings for a group of men on individual incentive, there commonly appears a wide spread of earnings, often with a pile-up of men at the high end and a similar pile-up of men at the extreme low end. Such a distribution of performance does not reflect ability, but something else. It has been estimated, roughly speaking, that perhaps ten per cent of the men in a crew will respond to financial incentive with maximum performance while a larger proportion will not even try to meet the standards. There typically is a middle group which seems torn between the objectives of minimum and maximum performance and settles for the objective of just making out.

Now, let me add one more element to the picture. One might think that men who produce at different levels under an incentive plan are merely finding the level of output which best balances, for them, income and energy expenditure. This is clearly not the case. While it is true that men on incentive feel that they are working harder and are under more pressure than men not on incentive, the amount of pressure felt has no relationship to actual output. It seems unlikely that men who produce at low levels under an incentive plan do so because of lack of ability or because of unwillingness to experience pressure or because they do not want extra pay. These factors no doubt play a part in some individual cases, but we must look primarily to other factors in trying to explain why an incentive plan ordinarily does not fulfill its expectations.

There have been in recent years a number of experiments in connection with productivity and incentive pay that might give us a clue as to important directions for future work. Let me describe a couple of them.

The first concerns operation under a piece-work plan in a clothing factory. In this factory, job changes occurred frequently and nearly always were accompanied by a sharp drop in productivity both for individuals and for work groups. The experimenters felt that this was a phenomenon of group standards and not a result of the unavoidable difficulties of changing to a new job. Three experimental groups were set up to allow group standards to operate in different ways. A fourth group, called the control group, was treated the same as such groups had been treated in the past.

The control group went through the usual factory routine for change over. The production department modified the job, and a new piece rate was set. A group meeting was then held in which the control group was told that the change was necessary because of competitive conditions, and that a new piece rate had been set. The new piece rate was explained by a time study man, questions were answered, and the meeting dismissed.

Experimental group one was changed in a somewhat different manner. Before any changes took place, a group meeting was held with all the operators. The need for the change was presented. A management representative then presented a plan to set the new job and piece rate. This plan was essentially the same as the usual one except for one important modification: a few representatives of the group were elected to help work out the new method and new rate.

Experimental groups two and three went through much the same kind of change meetings. However, since the groups were smaller, all operators were chosen as "special" operators; that is, all operators were to participate directly in the designing of the new jobs, and all operators would be studied by the time study man. It is interesting to note that in the meetings with these two groups, suggestions were immediately made in such quantity that the stenographer had great difficulty in recording them.

In the period which followed, the control group showed the usual drop in productivity and did not return to their normal level for several weeks. Group one, with limited group participation, showed a drop and then a fairly quick recovery. Groups two and three, with full participation, showed practically no drop and went at once to a higher level of productivity than before the change.

We have here a striking demonstration of the effect that group participation in decision and the cooperative establishment of a group standard may have upon productivity. It should be added that there were, in connection with the experiment, evidences that the morale of the experimental groups showing high productivity was better than that of the groups showing lower productivity. High production apparently was not obtained at the expense of employee dissatisfaction.

My second case for illustration is similar, but involves a single crew of women operating a spray-paint line in a toy factory. This group had been the source of considerable difficulty in connection with maintaining a steady flow of parts through a series of integrated departments. They worked at a conveyor taking parts off the hooks, painting them, and replacing them on the conveyor which then carried the parts through a drying oven. The technical factors in dryer design set limits on the speed of the conveyor, with considerable variation possible. Output could further be controlled by leaving some hooks empty.

A group piece-work system designed to raise productivity and pay generated serious difficulties of familiar kinds. The operators complained that the line was too fast, that the standard was unreasonable, that no one could make out under the system without unreasonable exertion and pressure.

To work out this knotty problem, the management took an unconventional step. They arranged for a series of informal discussions among the operators, supervisor, engineers and a consulting psychologist. The outcome of the discussions was a general agreement, reluctantly arrived at, to transfer control of line speed and daily pacing of operations to the operators themselves. A control was placed at the work place of one of the girls. The girls would decide among themselves how fast to work, when to stop, how to vary their pace during the day. You will all understand why the supervisor and engineers were uneasy about this arrangement.

What happened is simple enough. The girls within a few weeks were producing about 100 percent over standard, operating the fully-loaded line at nearly maximum speed. They enjoyed their work. They had fewer complaints. Dissension within the group disappeared.

As in my previous example, something important happened when the social relations among the people involved were changed. In a situation of self-imposed responsibility, with provisions for joint determination of production goals, the operators somehow found it possible to assume a new attitude toward their work and toward those they worked with. Without technological change, they were able to do more with less feeling of pressure and fatigue, and of course, with very substantially increased earnings.

TRANSITION FROM INDIVIDUAL TO GROUP FOCUS

By this time I am well into the second topic on which I wish to comment, namely the relationship between the social structure of the factory and the performance of people in complex situations. An important shift has occurred during recent years in our conception of where the roots of employee motivation might lie. Although it has been almost twenty years since the famous Mayo and Roethlisberger studies at Western Electric demonstrated how the informal work groupings in a plant tend to set work goals and standards for their members, we have been rather slow in recognizing the value which the working man places on the approval of his associates and the importance which his identification with his work group may have on his attitudes and performance.

Both in advanced managerial practice and in research, we are coming to appreciate the fact that a man cannot be understood if we regard him only as an individual; we must regard him also as a part of a social setting in which he is influenced not only by management but also - perhaps more so - by his associates at work.

In the two examples just cited in which employee attitudes and performance under incentive systems were radically changed, you will note that in both cases the change accompanied the introduction of a new form of social organization among members of the work teams. In both cases the social organization was altered in at least two ways; (1) the allocation of additional freedom to the employees in the determination of their affairs, and (2) the provision of a social mechanism which permitted collaboration or joint participation in decision-making. The psychological meaning of these changes is not entirely clear, but it seems apparent that there are available within the work group forces which have an important bearing on how the individual member will behave.

It is commonly assumed by management people and workers alike that the effects of work group pressures on the member are to restrict productivity. We all know of cases where individual rate-busters are brought into line by the work group; we soon discover in any organization that there are many ways for a work group to resist increased productivity. What we often overlook is the fact that the same kinds of group pressures often have the opposite effect, and are a major element in the support of high standards of productivity.

We recently completed a study in which we examined some of the differences between factory work groups which had developed a high degree of team spirit, or group cohesiveness, and work groups in which this kind of team spirit had not been developed. Over 250 supervisors and 6,000 men cooperated in this study. One of the principal findings was that the members of the "high cohesive" teams are less likely to be anxious and tense about their work; and in addition they somewhat less frequently reported worries about personal affairs in relation to their job. That is, the mental health and adjustment of workers depends upon having warm, cooperative feelings within the work group.

However, when we looked at the productivity of the high cohesive teams, we got something of a surprise. It is clear that the power of the cohesive work group to influence the productivity of members may be very positive and constructive; the highest producing groups were characterized by a high degree of cohesiveness. However, the reverse was not true in all cases; many of the high-cohesive groups proved to have the lowest productivity. From this we must conclude that the development by a supervisor of a high degree of team spirit or cohesiveness is not in itself a good thing; whether the results will be positive or negative depends upon the supervisor's capacity to channel the influence of the group into constructive directions. If the supervisor fails to do this, the power of the group may be directed towards interference with administrative plans or towards interference with the productive goals.

PRACTICAL TEST OF RESEARCH FINDINGS

I have described a few illustrative cases in which our research seems to raise questions about the traditional assumptions of management regarding the financial aspects of employee motivation and which suggest possible new ways of dealing with the problem through alteration of the social system. Are these findings merely interesting, or are they useful as well?

The way to find out is to put them to the test of actual application under conditions where the results can be carefully measured. This is no small task when one is concerned with problems as complex as employee motivation because a satisfactory test of the ideas must involve changing the habits and attitudes of many people in real, live organizations. Nevertheless, it can be done, and I will summarize one instance in which it has been done.

Early in the research program of the Institute for Social Research we were stuck with the fact that many of our findings appeared to contradict some of the widespread assumptions of management. A scheme of contrasting conceptions of motivation and productivity was worked out. To put it briefly, one scheme says that high productivity will be obtained by simplifying jobs, providing the best equipment, specifying operations and jobs in detail, setting engineered standards of performance, providing for regular and close appraisal of results, and applying pressure when performance is below standard. These are the principles of management which are prominent in management thinking and are widely applied today. A contrasting scheme might hold that effective performance stems from actions designed to generate feelings of responsibility among employees, greater participation in decisions that affect them, additional autonomy among employees in working out the best ways to do their jobs, and the development of productivity standards by mutual consent. The first scheme implies strict work routines, increased pressure and close supervision. The second implies emphasis on objectives, relaxing of supervisory control, more freedom in work routines.

An experiment to test these contracting managerial patterns was set up in a business firm. Four divisions were involved, alike with respect to size, kind of work and quality of staff. In two of the divisions, decision levels were pushed down and more general supervision was introduced. The supervisors were trained in leadership techniques emphasizing group action rather than individual action. The other two matched divisions were given a further dose of "scientific" management; steps were taken to increase the closeness of supervision and to rationalize operations and set careful standards of performance. The principal change here consisted of introducing time standards and taking the steps indicated by the results. The standards showed the divisions to be overstaffed by about 30 per cent, and the managers were asked to try to reduce the staff by about that amount. This was done by transfers and no one was dismissed.

The experiment required about two years, including the planning phase, six months for introducing the changes, and a year during which productivity and other factors were continuously observed. Employee and supervisory attitudes were measured before and after the experimental period.

Both experimental changes led to substantial improvement in performance. Both approaches to improved productivity were about equally successful in terms of salary costs which were reduced about twenty per cent.

But, there were important differences between the two situations in other respects. Employees in the second program, with more freedom and authority, developed an increased sense of personal responsibility to get the work done, while in the contrasting program the effects were the opposite. Attitudes toward the high-producing individual became favorable in the situation of freedom and authority and became less favorable in the contrasting situation. There were other changes of similar kinds. In general, the experiment showed that the two contrasting approaches to productive motivation provide alternate ways of about equal effect. However, in one case this gain in productivity was accompanied by resentment, dissatisfaction and general deterioration of morale.

In a sense, this experiment can be thought of as a test of the relative effectiveness of a technological approach to cost reduction versus a human relations or organization approach to cost reduction. The contest in this case looks like a tie, with some valuable by-products coming with the organizational approach. Can we look forward to the day when these two approaches can be carried out simultaneously in a mutually compatible way so as to gain the advantages of both?

NEW MANAGEMENT TECHNIQUES FOR TOMORROW

The problem of gearing our management and supervisory practices to the requirements of technological change is, in my judgment, going to become more critical in the coming years. We saw and heard earlier today an exciting story about automation. The pace of technological change is stepping up, and even the blind can see radical shifts in the character of managerial practice as a factory moves toward ever-increasing automation. The methods of organizational management with which we have come to feel comfortable are going to become at least partially outmoded. Let me mention a few ways in which advances in new manufacturing and accounting techniques will force a revision of our management techniques.

To begin with, a highly-automated plant with heavy investment can not lie idle two-thirds of the time. Three and four shift operations will become more common. The percentage of the work-force on afternoon and night shifts will increase. In a highly automated plant, it is less likely that the night shifts can get along with a skeleton supervisory staff, and with an increasing percentage of the managerial and supervisory staff spread over the several shifts, the problems of coordination will be multiplied.

A second aspect of this problem has to do with the nature of the jobs themselves. It seems common that technological change tends to raise the average complexity of individual jobs. There are more control personnel, more technical specialists, and fewer doing routinized tasks. In one plant this process has progressed to the point where many of the supervisory staff no longer feel fully capable of actually doing the work of their subordinates; they had a command of the basic equipment and processes, of course, but can not be expected to have a personal familiarity with the tasks. The supervisors are more dependent than is commonly the case upon the technical competence and responsibility of their subordinates.

Under automation there is likely also to be an intensification of some of the problems that already plague us as to relations between line people and the several staff and service branches of the organization. The line supervisor who already feels swamped and hedged in by staff people hasn't seen anything yet. The ratio of staff personnel to line personnel will increase and the line supervisor will become increasingly dependent upon his staff resources while at the same time being confronted by more numerous and more complex problems of achieving a satisfactory working relationship with them.

To sum up, the increasing pace of automation is going to put a special demand upon the administrative and supervisory apparatus of our organizations, and these demands will in general involve changes of three kinds: (1) greater reliance upon the initiative, cooperation and responsibility of the non-supervisory force, (2) stepped-up machinery for coordination among supervisors in different departments and on different shifts, and (3) a radical improvement in the relations between the line supervisors and the staff and service units on which they will be dependent.

I do not view these changes with alarm, but only with interest and some excitement. They constitute a challenge which can and will be met, partly through trial and error but to an increasing degree through the application of theory, experiment and quantitative analysis to problems of organization management. A clue to the general pattern the solution might take is seen in the research to which I have referred briefly, and further, I believe that the solutions will be consistent with current general trends in the pattern of human relations that characterizes our industrial and business world.

In the search for ways to assure high productivity consistent with the potential of new manufacturing techniques, many managements have been inventive and ingenious. They have come to see that the simple application of executive authority is less effective than it used to be. They begin to see that decisions affecting many, for sound psychological and social reasons, can often be arrived at best through consultative and participative methods. Responsibility for decision is being widely dispersed through the organization.

In turn, many managements are finally facing up to the fact that men are not easily purchased. While high wages, incentive earnings, and extensive benefit programs have become a necessary and desirable condition for effective organizational life, they are not alone sufficient. Some of the rewards of the working man, the supervisor and manager must be in the form of satisfactions derived from the individual's function in the social system of the factory.

I like to believe that we are coming to a more mature conception of the relationship between man, a creature of many motivations, and the complex business organization with its own set of manifold needs. We are coming to see that cooperation is best enlisted when a man is in a situation where common problems can be jointly resolved; when he is brought into the realities of organizational life through programs that keep him informed and in turn allow him to have his say; when organizational life is so arranged that his needs for warm personal associations can be met and turned to positive ends instead of defensive and obstructive ends.

To live with such a conception of the motivations and needs of employees is a difficult and exacting task. It requires more highly skilled managers and supervisors than we now have. Yet it is being accomplished in many organizations. We are no longer surprised to find organizations where the principles of individual autonomy, collaboration, and participation are practiced with good effect. At high levels in most organizations, this is now the pattern rather than the exception, and an increasing proportion of the lower-echelon members of organizations are being accorded the dignity and opportunity to which they aspire.

By some quirk of poetic justice, it appears that the machine - once feared as a destroyer of individuality - may now, because of its complexity, become the compelling reason for restoring some of the human and personal qualities which in the past have been drained from our organizations.

ENGINEERING SYSTEMS ANALYSIS

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I am speaking to you today under some handicap on the subject of Engineering Systems Analysis, because the work in this relatively new field of applied mathematics has developed mainly in connection with military systems, and the security needs of national defense prevent me from talking freely in terms of examples which would indicate the details of the work being done. My own experience in this field is confined almost entirely to military systems and I am obliged to talk to you in generalities. However, I believe that I can explain the general character of the work being done, the necessity for the analyses made, explain why, historically, the activities in this field have developed around military systems and, from these explanations, draw parallels with private industrial activities which may provide you with some understanding of the possibilities of application thereto.

The diverse efforts now being loosely characterized as Operations Research have some similarities with Engineering Systems Analysis and, after describing the latter, I shall draw some comparisons as to techniques, motivations, and subject matter.

First, let me describe the general character of a military engineering system.

There is an objective stated, consisting of the objects or targets against which the military system is to be deployed, and a certain environment under which the system is to operate. These data are translatable into physical relations and parameters defining the vulnerability of the targets and the operating conditions for the military system. For example, it may be determined that the destruction of a typical target, which we may think of as an enemy bomber, requires the detonation of a given type of anti-aircraft shell within a certain distance of the target. As part of the operating conditions, other characteristics of the target have to be specified, such as speed, operating altitudes, range, maneuver capability and radar cross-section.

There is a military system under study and, within the state of engineering arts, there are various engineering configurations available for assembly into the system. For the bomber example, the military system may consist of a highly integrated series of links including the acquisition radar, tracking radar, computer, director, gun, shell, fuze and other components. The potential properties of these sub-systems may be converted into another set of physical parameters describing the performance possibilities available to the designer of the military system.

There is a strong interdependence between the two sets of parameters specifying the objective and the performance characteristics of the various parts of the military system being studied. In the bomber example, the parameters defining the performances of the sub-systems depend upon the range, speed, altitude, maneuver capability and radar cross-section properties of the target.

Not all of the parameters are certain numbers. Many of them define statistical properties which have to be represented by random variables, that is, variables which take various values with specified relative frequencies. For the military system which we have taken as an example, it is essential that many of the performance characteristics, such as those related to the radars, computer, shell and fuze, be random variables with specified probability distributions derived from statistical experiments.

Now, all of these data have to be assembled into some logical system and, at first, the complexity of the problem may appear overwhelming. The role of engineering systems analysis is to put some order into this complicated set of physical relationships and perform analyses to guide the engineering development of the military system. How is this done? The most fruitful point from which to start an anlysis is the end result of the system. For this end result we may seek a quantitative definition of performance and then trace back the dependence of this quantitative measurement upon the parameters defining both the properties of the components of the military system under consideration and the targets against which the system is to be deployed. At first, it may be necessary to simplify this chain of dependencies by fixing some of the parameters at standard values which represent likely magnitudes and reduce the problem to one of considering only a few things at a time. This process of simplification cannot be done arbitrarily. It must be guided by engineering intuition aimed at fixing those parameters which appear to have least effect upon the end performance of the system. Then, for this simplified configuration we have to express quantitatively the dependence of our measurement of end result upon the variables remaining. Eventually it is necessary to verify the nonsensitivity of the system to the fixed parameters.

Returning for the moment to our example of a military system for destruction of enemy bombers, the quantitative measurement of end performance is the "kill probability" or relative frequency with which the bomber will be destroyed within a specified time interval of system operation. This probability clearly depends upon

Editor's Note: Dr. Shephard spoke at the Berkeley Sessions only.

the accuracy with which the shell may be delivered against the bomber and, in turn, this accuracy depends upon the performance of the various engineering components of the system. Incidentally, the most accurate system is not always the optimum system. It often turns out that the dispersion of fire has an optimum different from zero. On the operational side, the kill probability depends upon the target approach altitude, physical structure, and evasive tactics. My listing of dependencies is not complete. They are given merely for illustrative purposes.

In a talk of this kind I cannot take you through the details of constructing a mathematical model of an engineering system. For some problems upon which I have worked it has been possible to write down explicit formulae defining the dependence of end performance upon the design parameters of the system. For others it has been necessary to express the dependence in logical terms which can be analyzed by simulating the operation of the military system on a digital computer. In most cases it has been necessary to use digital computer simulation and here the calculation is often a Monte Carlo procedure. That is, one where, as the computer simulates the operation of the system, it chooses values of the variables at random in accordance with the relative frequencies of the associated probability distribution. Then, by repeated simulations it is possible to calculate the relative frequencies of various end performances of the system. You might think of this digital computer calculation as an activated flow chart going through the motions of the system and recording the results of its trials. By varying the design parameters it is possible to measure the effect of design choices upon the performance of the system. In this way, effectively, centuries of trial and error experience may be accumulated in a few hours. Can you imagine what this means for technological development--how the pace may be increased, if these methods are effectively adapted? I can begin to see the effects upon the design of military systems, and the results are very reassuring for our national defense.

Let me turn now to a description of what comes out of an engineering systems analysis, assuming that you have some idea of what it is. First, for some feasible set of design parameters the end performance of the system can be calculated. Further, the dependence of this end result upon the performance of components of the system can be estimated by the variation of design parameters, which shows in which directions design alterations may be made to increase most effectively the end performance of the system. In this way the most profitable lines of component development may be discovered. Not all lines of development are equally feasible, for some may be pushing the frontiers of the state of the art more than others. For a given end performance of the system, exchange relations between the performances of complementary components may be calculated showing how increased performance of one may be substituted for another when it appears that the increased performance of one may be developed at less expense or in a shorter period of time. Also, different arrangements of the same systems or competing systems may be compared. On this basis, engineers may analyze a host of design alternatives without having to design, develop, and try out each one in the field. Finally, to achieve a given objective, the requirements upon the components of a particular configuration may be clearly set forth.

One important by-product of the variation of design parameters is the discovery of those for which the end performance of the system is not sensitive. Then the performance of the components represented by such parameters may be lowered. This decrease of designed performance, where possible, is important for a complicated system. It lowers costs. Moreover, generally speaking, reliability is often increased when performance is lowered. It does not pay to design components to a higher standard of performance than is required.

At this point it seems appropriate to distinguish between operations research in the original sense of the term and what I have been describing as engineering systems analysis. When military systems are employed it is useful to analyze the advantages of changed methods of operation to fit the circumstances confronted in actual combat. During the last war such studies were undertaken by an analysis of statistics gathered during combat, but the data available were at most fragmentary. Today, behind the design of military systems, a paper war is being fought using the calculations made for systems analysis, with hypothetical operations studied to select the tactics and strategy. The data gathered from such studies furnishes a wealth of operational data which may be useful in combat when time is of the essence. This sort of effort is operations research as it applies to military systems.

To summarize, operations research was undertaken on a large scale during World War II to guide military commanders in the most effective use of already established systems. It was primarily directed to problems of logistics and strategy.

On the other hand, engineering systems analysis is primarily directed toward the optimazation of the design of complicated engineering systems. It embraces both design and operational factors, and one important objective of Systems Analysis is to seek designs which are efficient over as broad a class of operating conditions as is possible. In this connection, it is important to have the consideration of operating conditions encompass the role of humans, their fatigue and degradation of performance during stress, and the reliability of other components in the system.

Before I pass on to a discussion of the circumstances which motivate complicated engineering systems analyses and an explanation of why these methods have been developed in connection with military systems, let me tell you of an amusing incident which happened during one of our recent studies. We had a problem running on our digital computer, simulating a rather complicated system. The machine had been running through the same calculation for several days, faithfully giving us the results of millions of operations under various circumstances. We decided that we had enough information, cleared the problem out of the machine, we thought, and put in a new one, pushed the start button, and, after some time it appeared that the machine was doing the old problem. No matter how hard we tried we couldn't get it off the problem on which it had been running for many days. We checked through its circuits and everything appeared to be in order. Still we couldn't get it off the old problem. Like the sorcerer's apprentice, things had gotten out of hand. Finally, after several hours of tinkering, we found the key word and the machine finally accepted the new problem and faithfully did its chore.

It is interesting to examine the circumstances under which engineering systems analysis has developed for military systems. Why have we gone to such lengths and what are the motivations for this effort?

First, military systems are complicated engineering arrangements composed of highly interlocked components. They are costly, take years to develop, and require efforts to push beyond the frontiers of technology. Many alternative ways of accomplishing a given objective are possible, and it is essential to use the most advanced technologies for the purpose of gaining or maintaining military superiority. Hence, preceding the development of a military system, it is necessary to make thorough studies, because, once a development is committed, there are large expenditures involved and strong risks of obsoleteness. The engineering systems analyses made to support military developments have been undertaken by military agencies since World War II with courage and insight. Competence in this activity is rapidly developing, with important effects upon the strength of our national defense. These accomplishments are clearly a case of necessity being the mother of invention, and curiously enough I find the military to be modestly unaware that their achievements in this area are generally beyond what has been done in private industry.

Second, the possibility of testing the effectiveness of military systems by actual use is very limited--indeed, in some cases, they cannot be field tested except by use in a war. For this reason it has been essential to make elaborate and thorough systems studies for the purpose of evaluating the military potential of proposed developments. To support these analyses, much data has been gathered by laboratory and statistical experiments, and these data have made it possible to undertake intricate analyses.

Third, and most important, it is not possible to properly analyze a military system without treating it as an organism in which the functioning of the parts and their relation to one another is governed by their relation to the whole. This organic conception is the distinguishing attribute of an engineering systems analysis, wherein the functioning of the components is studied by their relation to each other in the functioning of the entire system, including the operational factors.

From this short review of the circumstances which have prompted the development of Engineering Systems Analysis for military purposes it is possible to draw certain parallels which may give us some insight into the possibilities of private industrial applications.

The first serious, large scale engineering systems analysis undertaken was that done by the Bell Telephone System during the last 25 years. Faced with a rapid expansion of subscribers spread over increasingly large areas, it appeared that more operators and more equipment would be needed in future years than the industry could provide--more in the sense of huge central offices, filled with large numbers of employees and sitting astride massive networks of telephone cables. Under these circumstances, the Bell Laboratories began to study the problem of communication as one of building an automatically operating organism, with an eye to the interrelationship of the parts of a complex whole which was at the same time strongly aware of the functioning of these parts in relation to the end purpose of the whole. This sense of organic interrelationship has led to the development of one of the most completely designed systems yet produced by man--one in which as you lift the telephone receiver, the machinery of the system identifies your line and indicates go ahead by the dial tone, counts the pulses as you dial, remembers the number you are calling while it seeks the best path of communication by testing the paths open, and then rings the number--this simultaneously for millions of customers in some cases. But this is not all. It makes a record of the calls, remembers who made them and for how long. This elegant engineering system was developed by coordinating research on components with a far reaching analysis of their mutual functioning in the whole.

Backed by this kind of experience, the Bell Laboratories and Western Electric set up a Laboratory at Whippany, N. J., at the request of our government, to develop fire control equipment for the Navy. In this work, engineering systems analyses were performed by analyzing data obtained from simulation on specially designed analogue computers. Similar kinds of systems analyses were used to guide the design of Nike guided missile systems now being produced by Western Electric.

This bit of history serves to illustrate the motivation for engineering systems analysis and indicates the kind of accomplishments which may be obtained by using a systems concept in design.

Another parallel is the development of automatic production processes. Most complicated production processes are only fully understood when they are regarded as organisms and, if they tend to become more and more automatic with less human activities, we have a situation comparable to that faced by the Bell System and military planners. The investment for automation would be large. There would be engineering data available, or at least capable of being assembled, which could be used as a basis for a systems analysis. Once committed, the process cannot be changed without disturbing the relations of its parts to one another as they function organically for the whole. If the process fails to operate smoothly, human activities could be re-introduced, but then the automatic character would be lost and the resulting mixture might be less efficient than conventional methods of production. Here, it seems advisable to undertake a thorough engineering systems analysis before embarking on the venture of full automation. Through pilot plants, automatically operating chemical and refining processes have been developed, but behind the pilot plants there has been a kind of engineering systems analysis made in the calculations of chemical engineers. The foregoing example is somewhat extreme, because I have postulated full automation. But in many processes now operating there are large elements of automatic functioning. Modern material handling systems are examples of such. In my opinion, it seems possible by the right kind of systems analysis to acquire on paper a large amount of experience which may be useful in the design and arrangement of these systems.

Modern transportation systems are an additional example of processes which require elaborate study before major expansion or alteration should be undertaken. The handling of traffic in large cities is another situation requiring Systems Analysis and Operations Research before great advancements can be made in coping with this problem.

On the product side, many industries are now involved in supplying components used in various parts of our national defense effort and supporting this supply by research on new devices. The contribution of this output and research can be enhanced by using Systems Analyses to guide the development of the product.

As the engineering systems of our private economy become more and more complicated, and indeed this seems to be an irreversible historical process likely to be interrupted only by an atomic war, it will be essential to perform Systems Analyses which view them as complicated organisms.

One problem of concern to all of us is that of civil defense. Here we have all of the elements previously described for military systems. The investment would be large and, once committed to a plan, we cannot easily alter it. It is necessary to plan on paper for an eventuality which cannot be tried out in advance of its need. The defense cannot effectively be developed in a piecemeal fashion. It must operate as a highly integrated system under extreme circumstances. In order to face up to this problem, serious operations research and engineering systems analyses must be undertaken.

I turn now to the matter of analytical techniques for both operations research and engineering systems analyses. One mathematical technique developed during the last ten years is that called linear programming. In its original form this theory provides a means of finding optimum combinations of components when their functioning can be expressed by inequalities involving linear combinations of the numbers or intensities of use of the components. Such formulations are essentially static in character in the sense that they assume the functioning of a doubling of any amount or intensity of a component will be twice that of the original amount. In the extreme, the theory would predict that, if one had an optimum process going, the optimum arrangement of a process with twice the original scale of operation could be obtained by duplicating the original process.

Since operations research concerns itself essentially with studying the operation of already established systems, linear programming has found a ready audience with increasing indication that it will be effectively used, because it is a good approximation for minor perturbations of a system.

Recently, non-linear forms of mathematical programming have been developed which attempt to overcome the limitation of constant returns to scale. The mathematical solution is much harder to obtain and presupposes a statistical data foundation which does not appear to me to be obtainable except by simulative or actual operation at various levels of end performance--in contrast to linear programming which is based on simple input-output ratios. Here I find myself led back to an engineering systems analysis which seeks engineering data on the organic functioning of components.

More recently, the work of Richard Bellman and others at the Rand Corporation on Dynamic Programming is devoted to a mathematical theory for the study of a sequence of operations, each of which transforms a system from one state to another yielding information to guide future course of action. The transforming operation is taken to be a stochastic process. This kind of theory may lead to useful methods of analyzing multistage processes and it is worthwhile to seek applications of Bellman's theory. The mathematical problems of Dynamic Programming are novel and of interest in themselves.

Preceding these three techniques in time, game theory was initiated by Von Neumann and Morgenstern to analyze optimum strategies for the play of games, and it has been further pursued in the research of Dresher and others at Rand. This approach is potentially of important use in Operations Research, particularly for military systems, because a suitable analysis of strategies may substantially change the operating concepts and consequently the functioning of the engineering systems used. For logistic problems of private industry a study of various operating strategies may likewise lead to new methods of operation; however, I do not know of any case in private industry where an analysis of strategies by the mathematical theory of games has been effectively made. The work of Bellman on dynamic programming, although it is as yet an idealized treatment, is one kind of extension which may be made to treat alternative operations in an engineering system as strategies.

As a mathematician I find these theories interesting and stimulative of a general viewpoint which is directed toward an analytical approach. It is unwise to overrate them because the abstract formulations of mathematics are not easily applied. In my work I have only rarely been able to use these theories, primarily because the actual systems studied are too complicated to be represented in the idealized forms of the theories. Basically, the tools of a systems analyst seem to be the calculus of probabilities, the general theorems of mathematical analysis and an understanding of the numerical methods possible with digital computers. Also, since much of the background work for a systems analysis is concerned with the translation of engineering and physical data into mathematical relations, an understanding of statistics and the design of experiments is essential, because the data worked with is derived from laboratory and statistical experiments. Beyond this I cannot set down a program of study. Each analysis seems to be a case study in itself. Eventually, general theories may be developed, but they are not now available. Behind all of these techniques, a real understanding of engineering subject matter is important. By themselves, the symbols of mathematics are pretty thin stuff for the solution of practical problems, but the logic of mathematics is a powerful tool for organizing engineering and physical data and making systems analyses of the same.

Other techniques such as information theory and servo-mechanism theory are particularly useful in the detailed design of engineering systems. The first is important for communications systems, since it is devoted to the problem of optimizing the rate of information transfer per unit band width, and the second is a general treatment of the transfer of mechanical motion with given response and stability criteria.

Finally, I would like to express the opinion that modern digital computers provide the most important analytical tool for both engineering systems analysis and operations research. The difficulty of using explicit mathematical formulations is great, because actual systems are too complicated to be so represented unless they are abstracted out of all recognition. Most engineering systems and operational procedures can be represented logically in terms of a flow chart. This flow chart can be introduced into the logic of a computer with as many feedbacks as is necessary and with associated physical data to carry out a simulative procedure. By simulation and intelligent variation of physical parameters, it should be possible to analyze a tremendous amount of experience related to the design and operation of a system. This is possible by computers with speeds of operation many times greater than the real time operation of the system being studied, without the disadvantage of having to interrupt an established organization. Analogue computing devices have been developed to simulate complicated systems, but this approach is often less efficient, in the long run, than the use of a general purpose digital computer, because only restricted types of alterations of the system can be studied without substantial re-design of the analogue set-up, whereas, the digital computer is completely flexible in this respect, provided a certain amount of mathematical ingenuity is used.

A CASE STUDY IN PRODUCTION CONTROL

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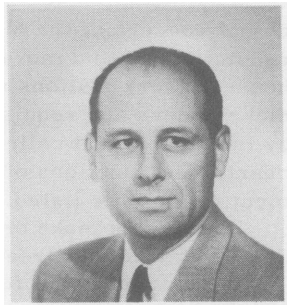

I am going to tell you about two problems we had at North American and the ways we solved them. Both pertained to the availability of tools and parts at work stations when needed or, to be a little more accurate, the lack of availability. I'm telling about two cases because the solutions are so closely related, one being a sequel to the other. As it developed the solutions were both accomplished by reorganizations or reassignments of responsibilities - with a few little procedural twists that I think will interest you. I should warn you that our solutions are not unique, also that you may not agree with them. And although they worked well for us, they might never be applicable to your situation.

Here I am reminded of a story that was going around our plant a few months ago. The story is about a tired business executive who had been having a very rough time at work and thought what he needed most was a good rest. At home there were two 'teen-aged' children to keep things stirred up, so he decided to spend a week in the hospital. When he had been admitted and was settled in his room, his doctor came to visit him. "Doc", he said, "I've heard of a treatment called 'Twilight Sleep' to take away your pains and make you forget your troubles. That's just what I need." The doctor said, "I'm sorry, Bill, I can't let you have any 'Twilight Sleep' ...... it's just for labor." The executive jumped out of bed and started shouting, "Everything for labor and not a damn thing for management."

Our solutions may not be useful to you but I want to show you that the method used to develop them has universal application. I will discuss this later.

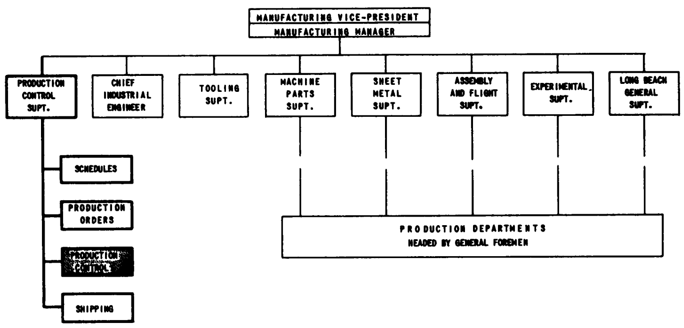

FIGURE 1 ORGANIZATION CHART

The first case occurred in 1947, so I would like to start by telling you a little about North American at that time. We had come through the drastic manpower reductions immediately following the war and were hiring again. Total employment was 13,000 people. In the Manufacturing Division, which included the production operations and the usual supporting functions such as tooling, maintenance, production control, and industrial engineering, there were 9,000. The Manufacturing Division organization was quite orthodox. I've shown it in Figure 1 in very abbreviated form only to make my remarks a little more clear.

Reporting to the Manufacturing Manager were eight superintendents; one for Production Control, one for Industrial Engineering, one for Tooling, and five for the production operations. Two of these were concerned with making parts and the remaining three were in charge of assembly operations. Each superintendent had six to eight general foremen reporting to him.

We were producing four post war airplanes. The records show that we were meeting our schedules and keeping our costs competitive but not without considerable effort. Although delivery schedules were being met, there were frequent times when individual tools, parts, or subassemblies were behind schedule, with the usual results. Extra manpower or overtime was needed in the department that had missed schedules. Personnel in the assembly departments had to be reassigned to less familiar work in order to avoid idle time while waiting for the late items. When the items did arrive, extra effort was required to install them "out-of-station." A large expediting and follow-up group was necessary to expedite the delayed items to the point where they were needed.

A good case study in the textbook makes the student find the significant symptoms, establish the problem and develop a solution. Today I don't have time to be subtle so I will tell you what we considered to be the basic problems and then give you the solutions immediately. We concluded that the conditions I have already mentioned were only symptoms and that the problem was the fact that the majority of production supervisors were openly critical of our production control system. To explain this more fully, I must go back and tell you more about the functions performed by the Production Control department shown there on the organization chart with the heavy shadow around it.

A typical airplane requires about 40,000 individual tools such as templates, dies, fixtures, and jigs. It contains about 12,000 different parts made at North American from these tools and another 4,000 supplier manufactured items ranging from sheet stock to forgings and from rivets to radios. In 1947, totals, considering the several airplanes being produced, were nearly 4 times these figures or a grand total of about 250,000 individual items to be handled, stored, and issued.

The fabrication of tools and parts is authorized and scheduled by individual "make" orders for each tool or lot of parts. The purchase of the supplier items is controlled by the Purchasing Department and is of no direct concern of the Manufacturing Division, but the requisitioning and movement of these items from warehouse to work stations are our responsibilities. All make orders and requisitions are prepared and printed by the department called "Production Orders" on the chart. The functions of the Production Control Department can now be listed.

1. Receive make orders and requisitions from the Production Orders Department and place them in appropriate files.

then,

2. Put make orders for tools in work as scheduled.
3. Store completed tools and issue to production shops when required.
4. Withdraw raw material from the warehouse.
5. Put make orders for parts in work as scheduled.
6. Move parts between fabricating departments and deliver to the assembly departments.
7. Store parts in the assembly departments.
8. Withdraw purchased parts from the warehouse and store in the assembly department.
9. Distribute and file engineering drawings at appropriate locations.
10. Prepare control reports.

and finally,

11. Expedite all late items.

In summary this organization operated the Production Control System.

Now back to a further description of the problem - the widespread criticism of the system. Tool making departments felt that fewer tools would be finished late if their make orders were handled more effectively. Parts fabricating departments felt that make orders were being mishandled and that follow-up efforts to secure late tools or raw material were inadequate. Assembly departments felt that parts and purchased items were not stored effectively and impending shortages not recognized in time for follow-up activities to obtain the parts before assembly operations were delayed. Assembly supervision were able to call their colleagues in fabricating departments or in the Purchasing Department and secure quicker relief than thru normal production control channels.

Several outgrowths of the problem should be mentioned. The supervisors in the Production Control Department were under constant pressure for better and more service, so they tried to secure better and more personnel. The attempt to secure better personnel led to frequent disagreements with the Wage Administration Department regarding proper classifications - the Production Control Department maintaining that the employees were performing a more skilled job than the classification that Wage Administration felt should be applied. The requests for more personnel, although resisted by management, had expanded the Production Control Department to 957 employees. The ratio of production control personnel to direct workers had reached 11.2 per cent or one for each 9 direct workers. Production supervisors who openly opposed the system obviously weren't making effective use of it. Subordinates of these production supervisors sometimes even ignored or by-passed the system, adding to the difficulty. And finally, the criticisms had been voiced so often that they had become a stock answer for any trouble. The system had become a "scapegoat".

Our solution was to completely decentralize the Production Control Department. I will tell you about the remedies that had been tried and then describe the final solution. Complaints about the system were common during World War II, so after the war, care was used to staff the Production Control Department with the most capable supervisors and personnel available. And although management closely watched the budget for this department, the services were never arbitrarily curtailed. Management had stood firmly behind the Production Control Department in many cases and had judged the production departments at fault. However, to be perfectly fair in such cases, the Manufacturing Manager had to spend excessive time analyzing such disputes. As you can see from the organization chart, this could only be done at the Manufacturing Manager's level. And when production departments had been found at fault and censured for their unfounded criticism of the system, supervisors became reluctant to make constructive criticism in other areas where it was very desirable that they do so. In aircraft production, supervisors are expected to take very active part in the development of production designs and effective tooling and production methods. North American has always put great emphasis on this type of participation by supervisors. It is accomplished through constructive criticism of the designs, tools, and methods provided by responsible engineering groups and by actual participation in many decisions. It was very important that we do nothing that would discourage this initiative.

A partial decentralization of the production control organization was considered and actually approved. In the plan, assembly departments would perform their own parts storage and follow-up and three separate departments would handle production control for the tooling, machined parts, and sheet metal superintendents. Other aircraft companies were known to be using a similar method. But before proceeding with this plan, it was concluded that a complete decentralization would be no more difficult to effect and would more thoroughly overcome the problems I have described.

Now here is the way it was done. The functions of distributing blueprints and transporting parts between departments were not changed. All other functions were completely decentrailized, each person merely being transferred into the production department he was then serving. There were practically no functions that could not be handled in this manner so no retraining of personnel was necessary. One Production Control Supervisor was assigned to each production department to serve as a staff advisor for the department head. In this way all of the first and most of the second echelon supervisors from the disbanded department were effectively utilized. Other supervisors were reassigned to appropriate salaried positions in such departments as Scheduling, Planning, Purchasing and Industrial Engineering. Fortunately we were in a period of expansion so no one was hurt. I can only think of one supervisor from the production control organization who has left the Company. I mention this because some managements might fear a loss of personnel from a move of this sort.

In concluding the case, let me tell you briefly how the solution has worked out. First, I think production supervisors were surprised and a little startled at the rather drastic step management had taken. The decision was made quietly with no advance rumors. However, they quickly accepted their new responsibilities. Only one of our superintendents still half seriously accuses me of unloading all my problems on my colleagues - I was the Production Control Superintendent at the time. Production department heads were encouraged to make improvements in the system where they did not disrupt other departments and to make these improvements known to the rest of the organization for their possible use by others. A number of significant simplifications were accomplished, usually in eliminating records that were previously created by lack of confidence between groups.

Within a year the ratio of production control personnel to direct workers had dropped from 11.2 per cent to 10.1 per cent a saving of nearly 100 people. This reduction had been possible through simplification and elimination. It has been further helped by the fact that production supervisors do not staff their production control groups to handle peak loads. Direct workers have been trained to handle temporary assignments of production control work, when necessary.

As Industrial Engineers you might be interested in one by-product of the decentralization. We were concerned that some departments might immediately add excessive numbers of production control personnel to their departments - so the Industrial Engineering Department was asked to work with the supervisors to develop a method of measuring production control load. Several factors are used such as the number of make orders received, tools stored, parts received and stored, and orders being expedited. Standards have been established for each. Periodic counts of the load factors are made and multiplied by the standards to give a reliable measure of personnel required. The method has been found so useful that it is now used extensively in all burden and system type departments in the Manufacturing Division.

But the most significant outcome has been the much better understanding of production control problems by production supervisors. They now know from first hand experience the problems of making a system operate properly. They will honestly criticize an awkward or unnecessary system but give vigorous support to all our vital procedures. The relations between departments are significantly improved. Supervision in departments with common problems are communicating more effectively and working together to solve their problems at much lower levels in the organization. And, of course, we have fewer excuses. For every conscious spoken excuse there had been two subconscious excuses used to rationalize a job poorly done. But now the "scapegoat" is dead.

This concludes my first case. The second one occured in 1952. Decentralized production control was now five years old and supervisors had acquired an excellent first-hand knowledge of production control principles.

This problem was evidenced by the repeated occurrence of annoying parts shortages. Here is how it came into form.

At North American the superintendents meet with the Manufacturing Manager for an hour or two each week to discuss problems of general interest and to facilitate communications up and down the organization. Many significant points of policy and practice have been formulated in these weekly meetings. One of our superintendents had been investigating some parts shortages affecting his operation. Ordinarily we don't discuss specific shortages or delays at these meetings unless they are indicative of a general condition of interest to all. He had decided to make this a matter of general interest and although it wouldn't be proper to quote his exact words, they expressed considerable annoyance at the amount of time he had been forced to spend on these shortages. In acrimonious terms he strongly suggested that something be done. After some discussion, it was decided that a sample of parts shortages would be taken and a case history prepared for each part in the sample. We decided what facts should be recorded in each case history and the manner in which they should be presented. As the histories were compiled, they were discussed at the weekly meetings. The group quickly became so interested in the project that a separate meeting was held each week for discussing this project alone.

Here I would like to mention again that I am certain that this constructive attitude and approach would never have existed in the old organization. At these meetings there was no time spent discussing who was at fault. All effort was devoted to an objective evaluation of the case histories and a search for the underlying conditions that caused these shortages or permitted them to occur. Here were 13 superintendents applying their combined years of practical experience to the solution of a common problem and, I might add, a very elusive one.

At first there seemed to be no apparent pattern to the case histories. The usual causes were well represented - an unexpected rejection, a late drawing, a material shortage, a new tool that did not produce as expected, a broken tool, limited capacity in a critical machine operation - they were all there. A few of the shortages were found to be unavoidable such as the mandatory design change for safety reasons, and these were investigated no further. But as the remainder were analyzed more carefully, a significant fact finally became clear.

Here was the problem. There had invaribly been enough time to meet assembly requirements for these parts if we had started <u>corrective</u> steps when difficulties were <u>first</u> encountered. We had been waiting too long.

After a few more meetings we were in agreement as to why this was happening and here is our explanation. Several significant facts were first established.

1. The schedule for each part was not keyed to the exact day when it was required in the assembly process, but instead was keyed to the earliest step in each assembly and then to the nearest week.
2. To avoid large numbers of small orders for losses and rejections, each lot was scheduled two to three weeks ahead of the assembly requirements.
3. When assembly schedules were set over for such reasons as changed customer requirements

or contract stretch-outs, the schedules for parts were frequently not changed. This was usually justified in terms of keeping enough schedule pressure on these parts to be sure they were available when needed.

These three facts together resulted in thousands of orders that were scheduled much earlier than needed. Tooling, fabricating and subassembly departments had sensed this weakness in the schedule and were not expediting parts to meet schedules. Expediting was not being started until assembly departments were nearly out of parts and had started vigorous follow-up action of their own. We had fallen back to the principle that the squeaky wheel gets the grease and we knew that some supervisors "squeaked" louder than others. Thus instead of schedules we had priorities, and frequently distorted priorities at that. To express this quantitatively, there were over 22,000 orders behind schedule but only 4,000 of these were being expedited. In summary we had generated large quantities of orders scheduled unnecessarily early which resulted in a loss of confidence in the parts schedules. When normal delays occurred, we did not take corrective action until an assembly department expressed an interest in the behind schedule part. But then it was often too late to avoid an actual shortage in the assembly department.

Having agreed on the nature of our problem, the superintendents worked for another month on a plan of corrective action. Committees of shop general foremen and representatives from Scheduling, Planning and Industrial Engineering were used extensively on the specific parts of the plan. Superintendents consulted with their general foremen each week between meetings to assure that our solution was practical and acceptable to shop supervision. I know of many general foremen who in turn discussed the subject with their subordinates. By the time our plan was completed, no less than 150 supervisors and a score of industrial engineers had participated in its development and were thus familiar with both the problem and the solution.

Here is the solution we developed. Expressed simply, we do a better job of preparing schedules and then work to them. Actually this required a number of different steps which I'll now describe. First, all schedules were made more accurate. Additional personnel were added to the Scheduling Department to more carefully key the schedule for each part to the assembly sequence. The storage time, as a hedge against losses and rejections, was retained but more closely controlled. It never exceeds three weeks. When a schedule change affects assembly departments, parts schedules are adjusted immediately. If a part requires work by several departments, a completion schedule for each department is shown on the order so that the first department will not use up all of the available time thus forcing the other departments behind schedule.

Some design improvements or other urgent programs are so important that they should be performed on an expedited basis with shorter than normal schedules. Formerly these were given regular schedules which meant that early operations were behind before they even started. A method of variable schedule times was provided so that everyone was given a fair share of the total time available. This minimizes the feeling that "schedules are impossible anyway, so why try?" You can see that all of these refinements were aimed at increasing confidence in the schedules.

This confidence was fostered still further by asking supervisors to develop the schedule times to be used for scheduling parts through their operations. These times are normally determined by industrial engineers or by the Scheduling Department. Supervisors have also determined to what degree these schedule times can be reduced to handle the urgent programs just mentioned. In preparing the master plan for building the first of any new airplane, superintendents and production general foremen participate actively in developing the plan. All this has not only established a confidence in the schedules but has created a friendly competition to see who can commit to the tightest program and then prove he was right by finishing a day or two ahead of schedule.

To motivate an "on schedule" attitude at all points in production, we have adopted the philosophy that the schedule for the <u>first</u> operation in making the <u>first</u> tool is just as important as the delivery schedule for the complete airplane. One of the most effective means of promoting this philosophy has been the bi-weekly review, by the Manufacturing Manager and superintendents, of the behind schedule counts in every department. We find it uncomfortable to be "high men" in this game. In this way the Manufacturing Manager has continually confirmed to the entire organization his personal desire that behind schedule conditions in early operations receive immediate attention when they occur. Unfavorable trends in early operations actually receive as much as or more attention from the Manufacturing Manager than delays in later operations.

Each department is expected to remain on schedule and to take necessary steps to prevent others from forcing delays on it. For example, fabricating departments depend upon the Production Orders Department for make orders and the Tooling Department for necessary tools, so fabricating supervisors are expected to work closely with the supervisors in these departments to avoid delaying conditions before they occur, not just to follow-up on specific shortages. Even the Production Orders Department is expected to work toward the elimination of conditions causing them to release late make orders. They have worked with Engineering to minimize forgotten drawings and to establish which drawings are needed first. They have also worked with shop departments to establish better parts accountability thus minimizing the last minute loss or rejection that requires a late replacement order.

To motivate immediate corrective action when delays occur on specific parts, a significant procedural change was made. When any department determines that their operation on a part cannot be finished on schedule, they are obligated to make arrangements for expediting the part through other departments until schedule has been regained. If it is certain that a part cannot be finished in time, the making department must forward notice of the delay to the assembly department. This is very significant when considered in the light of our basic problem. The making department takes the initiative and does not wait for the assembly department to start follow-up. In fact, one of the first steps taken to incorporate the new program was to transfer most of the follow-up personnel out of assembly departments. A few were assigned to Scheduling, but the majority were transferred into parts making departments to strengthen schedule controls and the expediting effort at that point.

Here might be a good point to tell you the name we gave to the program. The name is meaningless unless you have a picture of the problem and our solution. We call the plan "Parts Control Through Schedule Application". We do a better job of scheduling and then work to the schedules.

I have intentionally avoided a discussion of procedural mechanics because I know the changed philosophy is much more significant. I will, however, mention a few. When a part cannot be finished on time, the notice to the assembly department is prepared by pasting a label to the face of the production order. The promised completion date is written on this label. A photographic copy of the order is then forwarded to the assembly department. The label remains attached to the order to advise others that it is late and to show the promise that has been made.

If the promised date on the behind-schedule order is so late that the assembly department can't possibly work around the shortage and assemblies will fall behind schedule, supervisors may protest the promise in writing indicating on their protest the required date. The making department must reevaluate their promise and if the required date cannot be met, supervision in the making department must personally telephone the assembly department and "make their peace".

When an assembly department has received neither parts nor a delivery promise, the form used to initiate an investigation is not called a shortage notice. It is a request for schedule investigation. You can see that if everyone had operated accordingly to plan, the only thing that could cause such a condition is an error in scheduling.

I have already mentioned the variable timespreads used when urgency requires a part to be made in less than normal times. So that personnel performing the work can recognize these orders as they move through the shop, they are identified as to how much the schedule has been shortened. This identification should not be confused with a priority. It doesn't give the schedule any added importance.

In measuring performance to schedule, each order is not given the same weight. Instead the number of days it is behind schedule is considered. One part 20 days behind is more serious then 10 parts each 1 day behind.

To make schedules more clear to the direct workers, orders have colored bands attached and color keys are conspiciously displayed throughout shop areas. By this arrangement, anyone can tell at a glance whether the order is due in the current week, or how many weeks in the future.

Several improvements of an industrial engineering nature were made. To meet schedules, departments are expected to use an alternate method if optimum tools are not available. In some cases, departments had been overspecialized, so added space and small quantities of general purpose machinery were provided to permit them to use alternate methods in emergencies. Overspecialization had also led to a condition where many parts passed through several departments before being finished. This had increased control problems and exposure to delays. An industrial engineering study was made and machinery reassigned so that movement of the parts between departments has been reduced to a practical minimum. In several cases, procurement of additional equipment was justified.

Our extensive training of personnel may be of interest. I have already mentioned how the superintendents, general foremen, and many other supervisors, were thoroughly familiar with the problem and the solution. All supervisors, leadmen, and production control personnel were given further training before starting the new plan and have continued to receive training as conditions indicated the need. Training was accomplished in many ways such as meetings, memos and procedures, classes, and on-the-job training. Our Training Department reports that a total of 9,800 manhours of classroom discussion have been provided in the three years since we started and I'm sure there has been more than an equal amount of on-the-job discussion.

Programs of this sort often grow stale if they are not continually measured and appropriately stimulated. To do this, complete measuring devices have been established to answer such questions as:

1. Are assembly departments being notified promptly when a part cannot be finished in time?
2. Are promises reliable?
3. Are the requests for schedule investigation being handled promptly?
4. Are excessive numbers of parts being scheduled with short spreads?

These measurements are discussed every two weeks by the Manufacturing Manager and the superintendents. Weak spots due to poor execution can be given necessary attention through line supervisors. Problems arising from changing conditions are handled by a permanent Steering Committee who keep the whole program current. For example, as the new philosophy has become a more permanent part of our thinking, simplifications have been possible.

Now you ask, "How well has it all worked out?"

A quantitative evaluation of this program is difficult. We have a smaller ratio of production control personnel than when we started. For example, the ratio of production control personnel and direct workers is now 6.9 percent as compared to 11.2 in 1947. This is not entirely accurate because scheduling costs have gone up slightly. More significant is the reduced number of behind-schedule orders in our system at any time. A comparison to 1952 is meaningless because at that time most of the 22,000 orders weren't properly scheduled. We now have 3,000 behind-schedule orders, many of which will be expedited sufficiently so they will be finished on schedule. All this means fewer delays in assembly departments and means our "decks are clear" to handle important rush programs such as a change to a new model, incorporating urgent design improvements, or a sudden schedule acceleration to meet the requirements of our customers. The fact that new engineering designs are being put into production in less time than ever before is largely possible because of "Parts Control Through Schedule Application."

Oh, I'm not saying we have no shortages. One of our superintendents was in my office yesterday just before I left. He wasn't at all happy about some parts one of my departments had failed to finish on time.

In closing, I want to say a few words about the method of arriving at our solutions. I'm referring to the broad participation by supervisors and others while a project is still in the problem stage. A psychologist could explain why this works as well as it does, but I will only say that it has proven very effective. The steps are clear. First, expose as many as possible to the problem in an atmosphere of objective study. At this point any discussion of solutions should be avoided, especially if there is a tendency to undermine the objective atmosphere. Then, require continued group participation in arriving at solutions, not just because its a democratic process, but for much better reasons: to utilize effectively all the backgrounds and practical knowledge of personnel in your organization and to build confidence in the solution. And finally, conduct thorough discussions with everyone who will be called upon to contribute to the execution of the plan. We have often said that our solutions may not be the best or the only way to handle the problems, but they are doing an effective job for us because our people believe in them. A superintendent was telling me last week about one of his general foremen. Joe argues for hours when some new idea is being discussed but when the decisions are reached and the plan is ready to go, Joe is the most enthusiastic supporter.

Oh yes, the superintendents are talking again. When you ask them, they admit that things have never been so good - but they have some ideas for making things much better.

STIMULATING and MAINTAINING ENTHUSIASM for METHODS IMPROVEMENT

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While preparing the outline of this paper, I was reminded of the incident of the Pennsylvania Dutch farmer who remarked, "Any dumb-head can dig two post holes in a row, but somebody who got too late smart can't dig three in a straight row." In his jargon this means, if a situation is just a little bit intricate, it should be thought out pretty well before starting to work on it.

Trying to outline a program or a procedure for stimulating and maintaining enthusiasm for methods improvement certainly falls into the category of being a little bit intricate. Many of you could already be aware of this, particularly if you have experienced the burst of enthusiasm that usually accompanies the installation of a work simplification program and the gradual decrease in interest as time passes.

This situation, like so many others in present-day industry, is labeled as a human problem. Placing a problem in this category gives the originator the opportunity to say that there is no one solution because somewhere along the line human problems have acquired a reputation of always having as many possible solutions as there are people involved. Your chairman and your committee members must have been aware of this possibility because they have specifically suggested that the Armstrong procedure for maintaining interest in work simplification be described. I was, therefore, pleased to accept their invitation to come to the West Coast to discuss this subject with you. Generalizations are not usually very helpful, even when they are understood, but there is just one thing that is distasteful about using Armstrong as the example--it will mean frequent use of the personal pronouns "I" or "We". Good conversationalists will talk to you about yourself, gossips talk to you about others, and bores talk about themselves. I will try not to be a bore.

THE PROGRAM

The formal methods improvement program at Armstrong had its inception in the latter part of 1944. It was actually started on January 1, 1945, so that it is now slightly over eleven years old. Approximately 400 supervisors are participating in it and well over a million dollars worth of ideas have been submitted and put into effect. This is just the annual saving and does not include the cumulative effect of the installations up until the present time. Neither does it include the value of ideas which were submitted and rejected for one reason or another, or the training received by the participants. This record, I believe, vindicates the thinking that we have a permanent long range program and that there must be some enthusiasm for it. Right now I can see as much more to be done in the future as has been done in the past, only I hope in a shorter time.

The first year was possibly one of trial and experimentation. We had a fair degree of success, certainly enough to cover our costs, but there was a noticeable lack of long range enthusiasm. We definitely noticed a terrific up-surge of enthisiasm and then an equally fast decrease, all in a matter of a few weeks. Unless a project was started and completed within this time, it was never completed and new projects were seldom, if ever, originated.

A study of the situation revealed two principal causes. First, we were covering too much ground too fast. Second, we had placed all of the participants in unfamiliar territory by bringing them into our home office. Either they became homesick, they wanted to do some politicking, or they were more interested in sowing of a wild oat or two that was still left over from earlier years. The more conscientious men claimed that they were just too far away from their problem or project. It was like observing six different national holidays in one week - on a desert island.

These mistakes were considered as a tuition fee by the Company and steps were taken to make corrections. We revised our big program at the home office into a series of short programs and we took each program out to the individual plants. By having a series of short programs, the heavy surge of enthusiasm was eliminated. Instead, there are now a series of short modest surges that repeat periodically. Living conditions for the participants are in a much more normal pattern, at least the supervisors have not voiced the same objections as formerly.

Concentration in a prepared atmosphere may be good for students, engineers and scientists, but it is not popular with supervisors. They like to do their thinking right in their departments, even if it must be done after regular hours. It is a situation like the telegraph operator who couldn't write the Morse Code until he had a telegraphers key in his hand.

I suppose that all of you have seen, as I have, beautifully prepared brochures on complete methods programs. They have been printed in multi-colors with superb drawings of cartooned examples. These brochures usually tell the whole story in one pamphlet, starting with economic theories on why methods are necessary, through how to perform them, to who will benefit from them. They are designed to be text books too and are used as such. Each participant gets the full treatment in from a few weeks to a few months.

The Armstrong program is different. We prepare no brochures and it takes us months and sometimes years to cover the same ground that others cover in weeks.

Our objective is to develop continuous constructive thinking on a succeedingly higher plane and a steady trickle of practical ideas - not just give a course of instruction that will result in a surge of all kinds of ideas followed by stagnation. A surge of ideas has other disadvantages too. Most ideas require capital, design, installation, testing, etc., and all of them cannot be put into effect at one time. Most plants have just so many man and machine hours available for development work and these jobs must be scheduled according to some priority along with regular work. The ensuing delay then becomes a matter of importance because of the company's apparent lack of optimism and enthusiasm. Any company, regardless of size, can soak up just a limited number of ideas at any given time.

The Armstrong approach to methods improvement is to take just one of the subjects that appears in the usual work simplification brochure and make a complete program out of it alone. For example, our first program concerned only the subject of process analysis. We did not touch upon motion economy, operator analysis, multiple activity or any other specialized subject such as material, scrap or maintenance. All the men were asked to do was to analyze the flow of work through their department for the purpose of eliminating unnecessary handling, storage or delay.

The supervisors were divided into groups of approximately ten active participants. The group attended a preliminary meeting lasting from $1\frac{1}{2}$ to 2 hours. This meeting was held on Company premises, on Company time, and presided over by the plant manager. The conference leader, who in every case was an industrial engineering representative, acted as the instructor. He followed the frame work of a general outline into which were inserted specific instructions, illustrations, films and examples that were apropos to the particular plant operations or commodities.

Following this preliminary discussion, the conference leader then spent up to one day with each participant giving individual, on the job, advice and guidance. The time was spent in selecting a job for study, making a breakdown of the job, analyzing the breakdown and preparing alternate proposals. We then held a second discussion to exchange ideas and to permit the plant manager to observe what progress was being made.

After the second meeting, the conference leader then made the rounds again. This time it was for the purpose of selecting the best proposal and either applying the new method or making specific plans to do so. This also required a time of about one day per man. The key point is that the participants receive not only instruction, but also advice, guidance and technical assistance as well.

Finally, we held a third discussion period for the purpose of summarizing the proposals for the plant manager. If possible, the stories are dramatized a little bit. Each man tells his own story and outlines his proposal stating the requirements for installation, the advantages and disadvantages and the estimated savings and costs. The conference leader prepares the written summary giving credit to each participant for his accomplishment - but taking no credit for himself.

The plant manager now has a list of proposals submitted by his supervisors which is composed of the improvements they want to make. It is not a list of directives which the manager has issued. His job is now to maintain their enthusiasm by expediting the installation of their proposals and to stimulate additional future proposals by taking positive action.

If one month is required to process a group of ten men, then by simple mathematics it should take 40 months to process 400 men, which is the approximate number of Armstrong supervisors scattered throughout 18 plants. Actual performance was at the rate of 36 months, or three years, by using some part-time help. This period of time could be reduced by adding one or more full time conference leaders, but the three-year interim between programs has turned out to be just about right - not for management, but for supervision. They seem to enjoy a repeat program of this type at this time interval. Consequently, there is little difficulty in winning their cooperation and enthusiasm, particularly if the same leader appears on the scene for subsequent programs and provided he did a good job the first time.

THE TRAINING

Some of you may be thinking, we tried that business of a series of short specific programs and it didn't work any better than the comprehensive program. If this has been your experience, ask yourself this question, "What did we do about preliminary training?" If you haven't already tried the training aspect, perhaps what Armstrong has done will be of interest to you.

Armstrong does not wait until a man is a supervisor before he is given training on how to think and act like a supervisor. He is given some training long before that time and considerably more training afterward. The preliminary training begins when he has reached the status of "Leader". A leader is an individual authorized by management to give detailed instructions to the members of a group to obtain the co-ordination necessary for the group to operate effectively. A supervisor is any individual having authority, in the interest of the employer, to hire, transfer, suspend, lay off, recall, promote, discharge, assign, reward, or discipline other employees, or responsibility to direct them, or to adjust their grievances, or effectively to recommend such action, if in connection with the foregoing, the exercise of such authority is not of a routine or clerical nature, but requires the use of independent judgment. (1)

A leader in our Company represents the top level of <u>production</u> (not management) personnel. He is presumably the best, the most skilled, or the most dependable man on the crew. He is not necessarily the man with the longest service. His primary job is to instruct and co-ordinate the other members of the crew in their duties while <u>he works with and is a part of the crew.</u>

(1) From the Labor Management Relations Act of 1947 (Taft-Hartley Law)

Last year, a group of 75 key men, mostly leaders, were selected from the 3,000 production employees of our Lancaster Linoleum Plant to receive preliminary training as potential foremen. These men were not promised that they would be foremen, they were merely told that they were potential candidates.

The group was divided into three sections to accommodate shift workers with each section meeting one full eight-hour day per month over a six month period. All meetings were held on Company property and on Company time at no loss of earnings to the individual. The Company also provided replacement operators for each man attending the conference. The discussions included such subjects as Company history, Company objectives, employment practices, safety, human relations, report writing, and job methods.

The human relations aspect involves the review and discussion of a group of cases selected from 24 different case problems based on Company files which have been dramatized and recorded on sound-slide film. This series is known as "Human Relations in Supervision". McGraw-Hill has been licensed to reproduce and sell copies of these cases to other companies. Report writing covers instructions on how to prepare production logs, short business letters, maintenance requests, etc.

The equivalent of a full day is spent on "Job Methods". This includes economic philosophy and definitions of terms such as "Productivity", "Standard of Living", "Technology", "Capital Investment", etc. Generally speaking, it is instruction on "why" we need a continuous stream of methods improvements - not how to perform them - that comes later. We illustrate the "why" by using examples of methods improvement from our own Company and by citing facts and figures on commodities used by everyone in every day living. For example, a 9 x 12 Armstrong Quaker Felt-base rug retailed for $14.50 in 1925, and required that a man work 26.5 hours to pay for it. In 1955, the average retail price was $12.50 and he only had to work 6.9 hours to say, "Wrap it up." Not only that but it was a prettier rug of much higher quality. As a start toward "how" to develop methods improvements, we suggest an informal approach using the questioning attitude.

Groups of this size and nature have been started through a similar training every second year. These men have acted as feeders for our supervisory group and have kept us supplied with good men over the past years. The big pay-off is still coming in the future when our older men retire and must be replaced. We feel sure that the younger men will be even more receptive to new ideas than our older men have been. Not only that, but we are sure that they will take a greater share of the initiative in developing new methods.

When a leader or key employee has been selected to fill a supervisory post, he is given what we call Foreman Pretraining. This is the second phase of his training and consists of six to ten weeks of "on the job" instruction and "supplementary assignments" working with the plant staffs. Under ordinary conditions, he works with the man whom he is to replace, but if this is not practical, he receives his instruction from the general foreman. Working with plant staffs includes learning the payroll procedure, production reporting, incentive administration, quality requirements, and other technical phases of the job.

The third phase of training comes after a man has actually taken over a supervisory position. Twice each year, in the spring and fall seasons, all men who have attained the status of a foreman within the previous six month period are sent to one central location to participate in what we call our "Production Management Course." This course provides two full weeks of intensive supervisory training. The Company pays the cost of travel and living expense in addition to the regular salary of each participant, if travel is involved.

A wide variety of instruction is given at this time which includes such subjects as:

a. Company policies, company organization, basic economics, interpreting company reports and financial statements.

b. What employees want from their jobs, human relations, training employees, giving directions, foremanship.

c. Supervisory planning, tackling problems (processing, scheduling, quality), basic engineering, safety and fire prevention.

d. Development, organization and objectives of labor unions, supervisor and union steward relations, grievances.

e. Methods analysis, job classification, production incentives.

Approximately 20% of the Production Management course is devoted to instruction in methods analysis despite the fact that many other important subjects are included. The "Leader" program explains "why" methods improvements are needed, but the "Production Management" program supplies the "how". Knowing why may make doing easier, but know-how will make doing possible.

Instruction is provided in the use of flow diagrams, process charts, activity analyses, motion economy and other related techniques that are the basic tools of methods engineering. Some practice is also provided in actual application by the use of motion picture film or by observing relatively simple operations. The real opportunity to use this training to advantage comes later during the regular methods improvement programs.

A by-product of the methods training is the knowledge gained by the supervisor on how to use all staff services. Foremanship today requires the ability to co-ordinate service as much as it does to direct people. Present day management provides many services that were unheard of, at least by name, not too long ago. There is of course Industrial Engineering that is relatively new in many plants in addition to other services in the same category such as Quality Control, Production Planning, Physical Testing, Cost Accounting, etc. If a foreman is to use these services to advantage he must be taught how to keep them working for him - otherwise he will be working for them.

Three important stages of training have now been described, namely:

Leader Training
Foreman Pretraining
Production Management Training

With this background, a foreman ought to be able to do a job and that, quite frankly, is what is expected of him. All of this training has its purpose; the Company management was not just trying to be benevolent and nice. Leo Durocher once said, "Nice guys don't win pennants" and Armstrong is out to win a pennant every year. Good to excellent performance is expected of every supervisor. We believe that, if we are to be a better company than our competitors, then we must beat them man for man at equivalent positions and at all levels - not just at the top.

Our regular methods improvement programs are not training programs. They are the real McCoy and are for the purpose of reducing costs. In addition to the savings which result, they sometimes separate the men from the boys. It is of course realized that every good supervisor is not necessarily a methods engineer and fortunately there are other yard sticks for measuring individual performance. But the ability to develop a new method, or to make a method proposed by another work successfully, is an excellent barometer.

THE INSTRUCTOR

It could easily be that in your plant a terrific amount of training has already been done. Let us suppose that you also have a good program. What additional item or ingredient is then needed to produce successful results? That ingredient is the instructor or conference leader.

If a chain is only as strong as its weakest link, it also follows that a methods improvement program can only be as effective as the instructor. The finest of programs and the best of participants do not in themselves insure success. An excellent instructor is also required. He should be a combination of teacher, engineer, and salesman.

As a teacher he should be a creative coach and somewhat of a dramatist. Dr. Roy K. Marshall was this sort of individual. The Ford Motor Company's television program, "The Nature of Things", was most enthusiastically received because of his ability to take something complicated and describe it in simple terms. He retained the interest of his audience not because of his jokes or his radiant personality, but because of his simple direct approach to problem solutions.

Without doubt, the conference leader should be an engineer or at least someone with equivalent technical experience. He should be able to make simple sketches and drawings of gadgets. He should be familiar with a wide range of processing and handling equipment and be able to visualize how this equipment could be adapted to other uses. If there is any information or ability which he does not possess, then he should at least know where or who is the most logical source.

If the instructor has not had training experience then he should at least be the friendly type of individual. The Dale Carnegie influence should be there because ideas are best generated in an atmosphere of friendliness. In the course of performing his assignment, the associations will possibly range from the lowest classification of production employee to the plant manager. He must feel equally at home with either party and be able to command their respect and confidence. No man can persuade people to do what he wants them to do, unless he genuinely likes people, and honestly believes that what he wants them to do is to their own advantage.

The question could be asked, "Where are such supermen to be found?" First of all, the man need not be a superman, and second, there is probably one or more candidate in any industrial organization. There are always individuals who enjoy instructing and working with other people. Then there are others who are gadgeteers and who enjoy working with equipment. Either type of individual can be trained to perform those functions not included in his education or experience, if he is interested. A good engineer can be taught how to instruct or a good instructor can be taught how to be an engineer. The former method may accomplish the desired results a little quicker than the latter. Someone who is well liked and held in high regard by his associates is the most likely to succeed.

THE MANAGEMENT

Suppose that a company has developed a fine overall program, given good basic training to its supervisors, and provided an excellent instructor. What else is needed? Naturally that would be management participation. There are many ways in which management can participate and although it violates a basic principle to take a negative approach perhaps in this instance a better explanation can be given by stating a few potential management errors.

A bad atmosphere is created if management continually allows other activities to take priority over methods activities after these activities have been scheduled. Postponed conferences and other interruptions without a stated reason, that is a good reason, will be interpreted as a definite sign of the lack of interest by management. Providing inadequate facilities and using substitute instructors can also be included in this category.

Assigning improperly trained personnel to methods programs or excluding certain personnel from them for inadequate causes can be a management error. Remarks like, "What is he doing in here?" or "Why wasn't so-and-so included?", do not add to the possibilities of a successful program.

Another potential management failure is permitting staff domination. Sometimes it is advisable for certain staff heads or certain staff members to attend meetings since they will most likely be asked to render their services. Their purpose should be mostly to listen and to give advice when asked for it. They should not act as judges and they should not ask a lot of questions outside of their own field of endeavor just for their own personal benefit. Time is precious and their responsibility is to provide service - not ask for it.

One of the most dangerous situations is where at the start of a program on a new subject a remark like this is made, "Why should I submit any more ideas when the last one I turned in hasn't been put into effect yet and I've never been told why." Management could have missed the boat here by improper followup. There is also the possibility that the foreman is at fault. Some of them still think that when they turn in an idea, whether complete or not, that it is the responsibility of someone else to put it into effect. It is top management's job to correct this situation when its presence is indicated.

An even more dangerous condition exists when this statement is made, "All I got for my last proposal was bawled out because I didn't think of it sooner; this program is a good way to get your throat cut." This is a definite management error of commission and not omission. The program should not appear as a threat or as a finger pointing at supervision and it is just as necessary to give proper staging to the introduction of a program as to the program itself.

These are just some of the things that management should not do. When it is considered that little or no gain can come from doing those things we ought not to do, there is no reason for doing them. It is much better to think and act upon the things that can be done. Finding the right combination is difficult enough to do without hunting for the wrong one. For example, a baseball manager has 362,880 possible batting orders with a team of nine men. A methods improvement program with nine participants has the same potential.

Somewhere in this paper the subject of "awards" must be discussed. The management section is most likely the proper place since the payment of awards is a management prorogative. The first question is, should awards be paid to supervisors for methods improvements? If the answer is yes, then there is the problem of deciding how or on what basis to make the award. If the answer is no, then there is no problem except to explain why the answer is "no." This could be more difficult and even more expensive than paying a small award.

Armstrong fits into the second category. We pay no awards for methods improvements to any supervisor unless it is completely foreign to and outside the jurisdiction of his responsibility. An example of this would be a suggestion by a foreman on how to improve sales or advertising.

First of all, a foreman or a supervisor at Armstrong is considered to be a management representative. As a management representative it is the foreman's job to constantly improve the operations under his responsibility. To believe in better methods is practically a condition of employment and to participate in their development is a job requirement.

Second, all of our foremen have been given intensive training in management, methods, etc., much of which was described in an earlier section. This is in effect a free education, the cost of which is absorbed by the Company. The Company will also pay the cost of any successfully completed course of education taken at a recognized school, college or university outside of business hours. The subject must, of course, be related to the job. This free education is in effect the equivalent of an award.

Third, there are other phases of management in addition to methods where a foreman can perform outstanding service. These services may not seem as valuable as methods and yet they may be more difficult to perform. Measuring their real value may be impractical if not impossible and the Company holds that, if awards cannot be evaluated and paid for certain accomplishments, then they should not be paid for other. Then too, there is the difficult situation of evaluating the savings and the corresponding awards to be paid where the installation has required the contributions or the cooperation of others.

Armstrong prefers to recognize outstanding performance through merit salary increases and promotions to more responsible positions.

THE KEY

The key word of the subject is "Enthusiasm". How to get it. How to keep it. These are the problems.

Hitting a peak of enthusiasm for a special occasion isn't too difficult. Maintaining a level of enthusiasm after the peak is much more of a problem. For example, people get steamed up over Christmas and can be stimulated to buy things that they would never think of under ordinary circumstances. If Christmas came every month, this would never happen.

The same is true of the World Series, the Rose Bowl, the Kentucky Derby, and many other events or holidays of national interest that occur just once per year. Interest is high and of short duration - but does recur regularly each year. Promoters take advantage of this situation by always being ready with their goods or their services.

Methods improvement programs are in the same category. Enthusiasm for them runs in cycles and they too cannot be repeated at short intervals with any degree of success. What management should then do is take advantage of the natural cycle by being ready when the time comes.

Everything comes to him who hustles while he waits.

If your company operates more than one plant, then see to it that the peak of enthusiasm at each plant occurs at a different time by planning your methods programs accordingly. If there is only one plant in your organization, then conduct your program by departments. If this doesn't take up sufficient time for enthusiasm to regenerate itself, then wait for it. Assign the instructor to other duties for the interim period. There are always new subjects, fresh examples and improved procedures to be worked on or old problems left over that were not completed. In the meantime, the supervisors should be told that they will be called upon periodically for new and additional proposals on methods improvements.

At Armstrong, each plant prepares an annual cost reduction schedule. Each supervisor knows that he will be asked to contribute items to this schedule. He has learned that the methods improvement programs are an excellent source of ideas for these cost reduction items. He knows that he will be given assistance in developing his proposals and that he will be given credit for his accomplishments.

There is little cause to wonder at a supervisors enthusiasm under these circumstances. The methods improvement program is just like the expert in the booth helping the contestant win the $64,000 question.

Nothing succeeds like success. This is an old axiom applicable to most any situation or individual. Show me any man or group of men who have just successfully reached an objective and I will show you enthusiasm at its height. Success breeds enthusiasm just as the lack of success breeds despair. But enthusiasm will not continue without continued success. Any man is a hero for just a moment - that moment when he has reached his objective. Then the world says, "Let's see you do it again, only better the next time." If he doesn't do it the world soon forgets yesterday's hero. The sports world and the business world are full of many such occurrences.

Think of your own situation. Where does your enthusiasm lie? In places where you have had failures? No - it isn't very likely. Would you continue to attempt to play golf, or bowl, or build a house, or write a song, if you have had little or no success after trying real hard? No - I don't think so. The same is true of methods improvement programs and the individuals participating in them. They, too, want to see success crown their efforts. That is how they become stimulated to try again. Continued success makes them maintain their enthusiasm.

Therefore, if you are thinking of having a methods program make certain that you have all of the ingredients. Leave no stone unturned in your search for the right combination. If you have already tried without much success - try again - even if it is necessary to plant a few cases. The success angle can't be beaten for stimulating and maintaining enthusiasm for methods improvements.

If there is concern about time in connection with methods improvements programs think of the stonecutter hammering away at his rock. He may hit it as many as a hundred times without a crack showing in it. Yet, on the hundred-and-first blow it may split in two. We know that it was not the last blow that split it, but all that had gone before.

Progress is merely the slow process of falling in line with the schemes of the minority and triumph is just "umph" added to "try".

If Armstrong has attained any degree of success with their efforts to stimulate and maintain enthusiasm for methods improvement it is because they have tried to build creativeness into their management program.

They try to sow the seeds of confidence by providing sound basic training; they try to allow time for confidence to grow into optimism and they try to guide the optimism into accomplishment.

THE CHALLENGE AHEAD FOR INDUSTRIAL ENGINEERING

A. F. Vinson
Vice President-Manufacturing
General Electric Company
New York, New York

Any complete analysis of all the future developments ahead of the industrial engineer in America is certainly beyond the limitation of our time schedule today - and beyond the ability of your speaker. It is, however, a welcome assignment for, after a brief experience as a product design engineer, I have been brought up in the manufacturing end of the business and am delighted to talk about the unparalleled opportunity that today lies ahead of manufacturing engineers and industrial engineers in our competitive economy.

Let's consider the opportunity aspect first, and then look at two specific areas of manufacturing to evaluate the outlook for the future.

Just what opportunity does lie ahead of the industrial engineer? A casual review of the trade and business literature during the past year on subjects such as "automation" might lead to a rather gloomy answer. One of our young automation engineers recently remarked that if all the claims and promises of automation which were voiced in just last year's speeches alone were to become realities, then there isn't any future for industrial engineers - there simply wouldn't be any people left for us to motivate, manage, or measure! This very confusion about our mechanical and electronic future in manufacturing led Business Week to say that in some areas automation is 90 percent emotion and 10 percent fact. Maybe this only substantiates an old saying that people can be divided into three classes: the few who make things happen, the many who watch things happen, and the overwhelming majority who have no idea what has happened. All of us here are in the first class, I'm sure. Now, from this starting point of "no future", let's take a realistic look at the real opportunity ahead.

If General Electric is at all typical of today's developments in manufacturing, four things are happening to greatly enhance the opportunity in industrial engineering:

First - The engineering content of the manufacturing job is increasing by leaps and bounds. Even today in several large departments, more manufacturing engineers are required to plan and design methods and equipment than design engineers to create the product itself. As you probably know, also, the engineering profession is on the rise. In 1900, United States industry as a hole employed an average of one engineer for every 250 employees. By 1952, the ratio was down to one for every 60 employees. And, as an indication of the impact of the electrical manufacturing industry on this trend, the comparable statistic for General Electric is one engineer for every 20 employees. There is little doubt that manufacturing technology has a need for and will benefit from the increasing contribution of industrial engineering.

Second - The rapid development of new tools and techniques in the manufacturing function is another door opened to challenge the future: operations research, data processing of all kinds, new work simplification methods, recording instruments, electronic transmission of documents, and a host of others. The industrial engineer truly has a whole new kit of tools for solving the complex problems ahead.

Third - Business expansion has been limited by the ability of manufacturing engineers to plan intelligently and to procure needed methods and facilities. In our case, since World War II we have never succeeded in spending as much as 80 percent of the money appropriated for expansion! The degree of creative planning ability in each operating department has usually established the pace.

Fourth - You are all familiar with the real shortage of trained manpower. We think this is particularly true of the manufacturing engineering field.

These four factors alone assure a continuing broad opportunity for the industrial engineer in even longer than the next decade; but there are still many other encouraging developments underway, and I should like to become rather specific in two selected fields that hold a challenge for industrial engineering: MEASUREMENTS and AUTOMATION.

MEASUREMENTS

First let's consider measurements and, in so doing, limit our discussion to the broad problem of the measurement of productivity. In our industry, this is a vital subject for we confidently expect a demand in the next ten years for double our present production rate. The available workforce, on the other hand, is expected to increase only about 14 percent in this same period. How do you produce twice the volume with only 14 percent more people? Can it be done?

In our basic studies of this question we have developed a new measurement tool which may be of interest. It started about two years ago, when, for the purpose of improving long-range Company-wide forecasts of capital investment and employment needs and using Net Sales Billed as the basis, we developed some preliminary measurements of output - per-square-foot of floor space and per employee.

Our explorations took us into unfamiliar ground since we deliberately turned away from the old well-known yardsticks. As our work progressed and as we came to appreciate the terrific distortions inherent in Sales Billed as a basis for the measurement of output, due primarily to the variations in purchased material content, we finally turned to Contributed Value as a much more sound foundation.

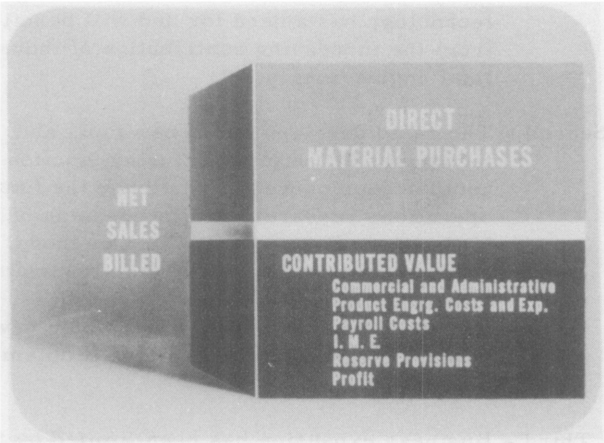

Figure 1

In its simplest terms, contributed value is net sales billed minus all direct material purchases. This means that contributed value includes everything else: commercial and administrative charges, product engineering costs and expenses, all payroll costs, the many indirect manufacturing expenses or overhead such as taxes, depreciation, indirect materials, etc., as well as reserve provisions and profit.

By the time we were through, we had figured the contributed value for our then 81 operating components, with adjustments for inventory fluctuations, material purchases, and adjusted to 1953 dollar values.

The next step was to relate contributed value to each of three factors - floor space, employees, and net sales billed - thereby obtaining a more realistic set of measurements of output.

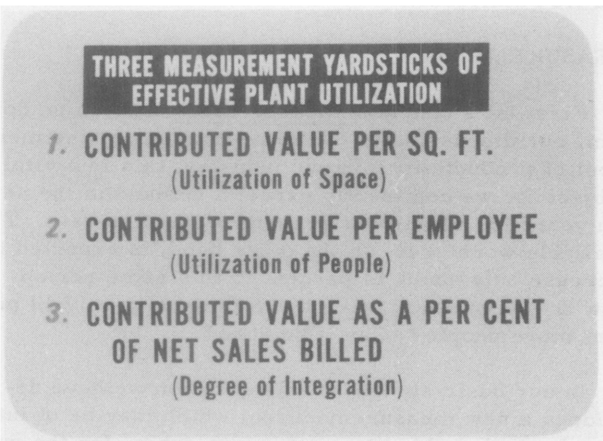

Figure 2

The three yardsticks are expressed as:

First: Contributed value per square foot - the measure of effectiveness of our utilization of space.

Second: Contributed value per employee - the measure of effectiveness of our utilization of people.

Third: Contributed value as a percentage of net sales billed - the measure of the degree of integration of our departmental operations, primarily manufacturing.

Incidentally, from here on we shall use the abbreviation "CV" for contributed value. Now let's see what we found out, starting first with CV per square foot.

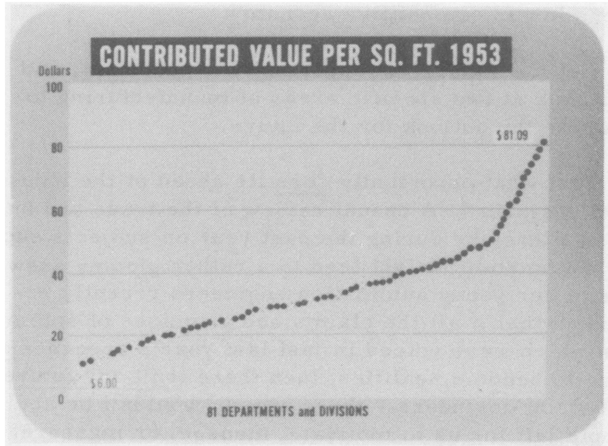

Figure 3

Here are the 81 operating components, each represented by a dot, spread out in order from the lowest 1953 dollar figure of CV per square foot to the highest. Well, not exactly the highest - there's one outfit with 131 dollars that went clear off the top of the chart - but that's the exception. Otherwise the range is from 6 to 81 dollars.

There's another feature here that you may have noticed: those crossed dots. They represent departments that operated at a loss in 1953. In other words, when the gross-margin percentage gets down to zero or below, "X" marks the hot spot! These departments also tend to be in the lower half of the curve - the low range of CV per square foot.

Let's move on to the second yardstick we set up. CV per employee - the measure of effectiveness of the utilization of people. (See figure 4)

Here again we show the same over-all spread of our 81 operating components, but this time the position of each dot represents CV per employee, rather than per square foot. The range for the year 1953 is from $3,400 to $20,600 per employee. Those crossed-dot departments that were operating at a loss are concentrated here also in the low left-side of the curve. You will not be shocked, I'm sure, by our conclusion that low CV per employee is a factor in low profits.

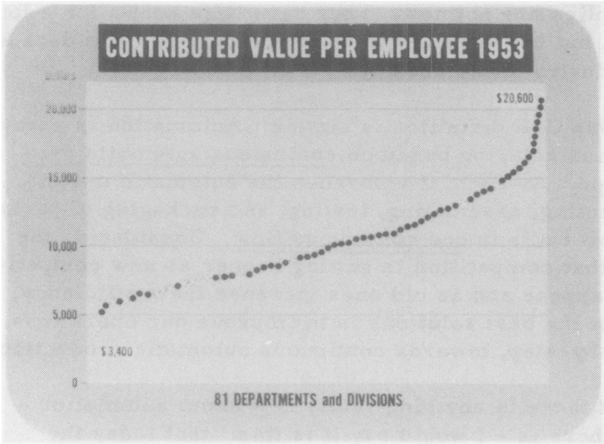

Figure 4

Now let's take up the third yardstick: CV as a percentage of net sales billed - which is the measure of the degree of integration of departmental operations, primarily manufacturing. It is a measure of how far

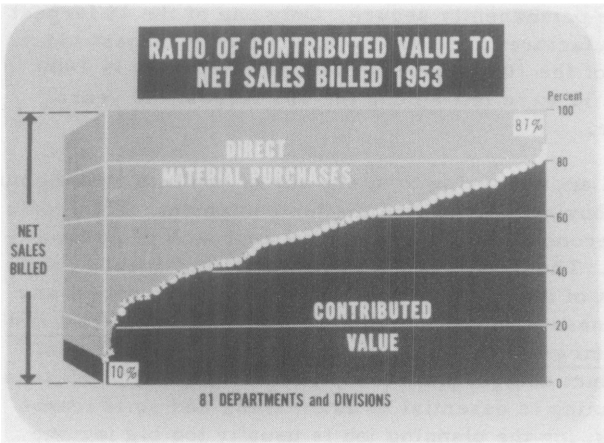

Figure 5

back we go toward basic raw materials in our manufacturing process - or how much we "make" versus how much we "buy".

Graphically, the problem is simplicity itself. You start with net sales billed as 100 percent, and again simply subtract that percentage which represents direct material purchased. The balance, after adjustments for inventory changes, is the CV. In the case of our 81 components, notice the terrific spread in the ratio of this CV to net sales billed; from a low of less than 10 to a high of almost 87 percent. The crossed-dot departments operating at a loss again are concentrated in the low ratios of CV.

This seems reasonable enough if we keep in mind that, in a competitive economy, the customer fixes the price and therefore largely limits the total profit in an end-product. CV measures the degree to which we have chosen to share this total profit with our vendors, who are not in business for the sport of it, either. We cannot expect that our profit will be more than our proportional contribution to the end product.

So much for the showing that our various departments made in 1953. Now let's see how we put this information to work in helping us to more accurately project 1963 requirements for the level of sales we anticipate. In the interest of time, we'll confine our discussion to floor space requirements only, using the CV per square foot yardstick on two departments. The first example is shown in Figure 6.

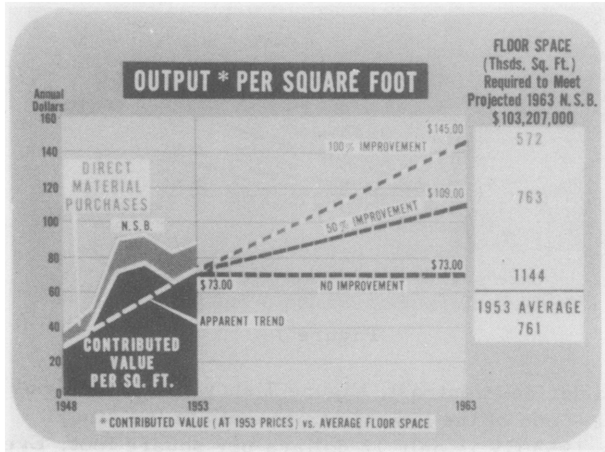

Figure 6

The vertical index is the dollar measurement of CV per square foot. In this example department it is 73 dollars, one of the highest of the 81 components analyzed. This department's share of the Company's 1963 goal in Net Sales Billed will amount to over 103 million dollars. The floor space required to meet this volume will, of course, vary according to the rate of productivity per square foot. Therefore, if they continue with no improvement at the present 73 dollar rate, they will need a total of 1,144,000 square feet - 50 percent more than their 1953 average.

On the other hand, even a 50 percent improvement in CV per square foot by 1963 - up to about $109 - would mean that no additional floor space would be required to handle their budgeted 70 percent increase in business.

The third possibility of a 100 percent improvement figures out to 572,000 square feet which means that they would actually have nearly 200,000 extra square feet available for release to other departments.

You recognize, of course, that it is difficult to forecast a reasonable rate of improvement until you know at least what the past trends have been. And so, Figure 6 also shows their actual performance record from 1948 through 1952. The top white line represents the total net sales billed per unit of floor space. If you will remember our simplified definition, all we have to do then is to subtract the direct material purchases - that's the dark area directly below - and the balance is the amount of CV per square foot. And here it's a very happy picture.

The actual pattern - expressed in 1953 dollars - is a remarkable rise from 28 dollars in 1948 to 73 dollars in '53. Projected to 1963, this apparent trend would be a 100 percent improvement. With this background information, it would now be a simpler job for this department to plan for the future with some degree of assurance.

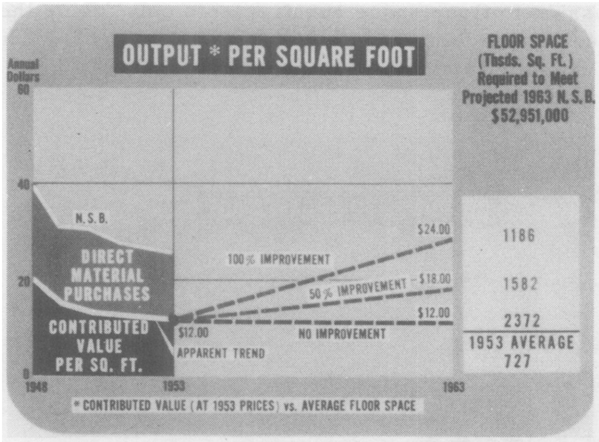

Figure 7

In decided contrast, Figure 7 shows the other extreme - one of the lowest components in the study. Their 1953 CV is only 12 dollars per square foot. Even with a 100 percent improvement to $24 by 1963, they will need a total of 1,186,000 square feet (which is 60 percent more than their 1953 average of 727,000) in order to meet their nearly 53 million dollar share of the Company's goal. And, since their past performance shows a 40 percent decrease since 1948, we really have a problem here.

It is our hope and belief that this measurement tool is another step forward in helping our management to effectively evaluate its performance so that it can better direct its efforts toward what appear to be the weak spots and thus improve their competitive position. This brings us back again to the many techniques there are available: Multiple Shift Operation - Load Leveling - Continuous Flow - Three-dimensional Utilization - Better Methods and Processes - Product Mix - and Quality Control among others. This also brings me up to one of the most important techniques that we have today - the second one I promised to discuss: automation.

AUTOMATION

No subject has been more publicized in recent years than Automation, yet what is it? If you were to assemble all that has been said and written in just the last year, you would find that there are just about as many definitions of automation as there are prople trying to define it. As a result, it has come to mean as many different things as there are points of reference from which it is viewed. It's a great deal like the old Aesop fable of "The Elephant and the Six Blind Men" - each of whom defined the whole elephant in terms of the particular part which he was able to touch and explore.

To some people, automation means mechanization; to others, the push-button factory and materials handling; and to still others, automatic controls, automaticity, and cybernetics - words that conjure up visions of robots running machines and factories without men. Actually these words have little or no bearing on the industrial concept of automation today.

The word itself is a relative newcomer to the industrial vocabulary, but the ideas and thinking to which it applies are not new. They have been known for a long time, but have been applied only during the past decade to industry as we know it.

Our G-E definition is simple: Automation is a way of manufacturing based on continuous automatic production. As such, it embraces the automatic making, inspecting, assembling, testing, and packaging of parts and products in one continuous flow. Considering the fact that competition is getting keener as new competitors appear and as old ones increase their efficiency, one of the best solutions is to improve our operations, step-by-step, towards continuous automatic production.

If there is anything really new about automation - and there is - I would say it is this: that today the principles of automation are being systematically applied by more and more businesses to the solution of their manufacturing problems. And automation is by no means restricted to the larger businesses. Small businesses, alert to the opportunities of Automation, will improve their competitive positions and grow. As for the larger businesses, they must certainly evolve with the times, for no business is big enough to be permanently secure. Only one of the 15 largest manufacturers in 1900 is among the 15 largest today, and of the 100 largest industrial companies in 1909, only 36 were left among the 100 largest, 40 years later.

I am not trying to scare any of you into rushing out and buying a lot of Automation equipment. This could be, economically, a disastrous approach to Automation. The most important items of equipment I can think of are the brains of the top men who direct any business. For Automation begins with an overall and systematic evaluation of the business, its markets, product design, plant layout, materials and processes. Planning is essential to automation, and so is teamwork, for the planning job is usually too big for one man. Too many complex variables are involved.

Now, my somewhat brief remarks on automation have been in the nature of a commercial, for today I am privileged to introduce the first industrial motion picture devoted to the history, growth, concept, and future of automation. I'm proud to say it's a General Electric film, the latest in our More Power to America series which is a continuing "look-ahead" program designed to help increase the productivity of American Industry.

May I therefore present our newest MPA production, "This is Automation".
(The audience then viewed the film).

From what you have just seen, I think it's abundantly clear that, in this broad field of automation, the role of the industrial engineer is vital. Automatic lines must be timed and balanced, flow of materials and parts must be creatively planned. New concepts of wage payment and expense control must go hand-in-hand with the new concepts of methods, equipments, and processes. The automatic factory will probably be feasible mechanically, long before adequate, automatic scheduling and control plans are ready to assure its effective operation.

I also think it apparent that the backbone of this nation's expanding economy and its enviable standard of living has been the ability to produce more goods for more people at less cost. Our productive future correspondingly is the logical extension of our past technological progress, with one important difference - the production demands will be greater than any we have ever known.

In summary, the point I want to stress is that we, as manufacturers, as well as all foresighted manufacturers, are constantly examining new ways to meet the competitive challenge, whether it's through measurements of productivity or by automation. Throughout all of these activities looking to the future, runs the significant thread of industrial engineering.

The challenge ahead is a grave responsibility. It's much like the story of the golfer who had driven into the rough beside an ant hill. Nothing daunted, he lined up carefully and took a tremendous swing. Instead of the ball, however, he hit the ant hill, and ants were flying through the air for 30 yards away. Another hefty swing - and more ants were being knocked all over the fairway. And still another mighty swing - and the result was the same: ants and ant hill all over the landscape.

At this point, one beat-up little ant crawled over to a group of his buddies.

"Fellas," he said, "I think it's about time we got on the ball!"

ROSTER OF ATTENDANCE

LOS ANGELES

ABENDSCHEIN, Irving D.
Firestone Tire and Rubber Co.
Los Angeles, Calif.

ADAMS, Stanley
Crown Zellerbach Corp.
Los Angeles, Calif.

ADLER, Kurt L.
International Rectifier Corp.
El Segundo, Calif.

ADLER, Stewart L.
Service Rock Company
Riverside, Calif.

AGOZINO, J. R.
Rheem Manufacturing Co.
Downey, Calif.

ALLAN, R. A.
Aluminum Company of America
Los Angeles, Calif.

ALLEN, J. E.
Pacific States Cast Iron Pipe Co.
Provo, Utah

ANDERSON, Charles W.
Seaboard Coil Spring Division
Gardena, Calif.

ANDERSON, R. O.
Vitachrome, Inc.
Los Angeles, Calif.

ANDREIKO, Albert
McCulloch Motors Corp.
Los Angeles, Calif.

ANDREWS, E. G.
Bendix Aviation Corp.
North Hollywood, Calif.

ASTLE, Robert
McCulloch Motors, Corp.
Los Angeles, Calif.

AUGUST, Peter
Benjamin Borchardt & Assoc.
Los Angeles, Calif.

AVALOS, Henry
So. Gate Aluminum & Magnesium Co.
Los Angeles, Calif.

BABBE, G. M.
Southern California Gas Company
Los Angeles, Calif.

BAILEY, Philip S.
Goodyear Tire and Rubber Co.
Los Angeles, Calif.

BAKER, J. R.
Baker Oil Tools, Inc.
Los Angeles, Calif.

BARRY, John
Kwikset Locks, Inc.
Anaheim, Calif.

BATCHELOR, W.
General Electric Company
Ontario, Calif.

BATTERSBY, Edwin
Robertshaw-Fulton Controls Co.
Anaheim, Calif.

BAUDER, Baird
Minneapolis-Honeywell Reg. Co.
Gardena, Calif.

BECK, T. A.
Kennecott Copper Corp.
Ray, Arizona

BEHRENS, F. A., Jr.
Pillsbury Mills, Inc.
Los Angeles, Calif.

BENTZ, Fred A.
Sandia Corp.
Albuquerque, New Mexico

BISBEY, Edward J.
Firestone Tire & Rubber Co.
Los Angeles, Calif.

BOLES, M. C.
Ryan Aeronautical Company
Del Mar, Calif.

BOYD, Deigh D.
Bendix Aviation Corp.
North Hollywood, Calif.

BRADFORD, B. Blain
Kennecott Copper Corp.
Salt Lake City, Utah

BRADY, Edward
McCulloch Motors Corp.
Los Angeles, Calif.

BRODWICK, William
A-1 Manufacturing Co.
Los Angeles, Calif.

BRYANT, W. C.
Xylos Rubber Company
Los Angeles, Calif.

BUCK, B. P.
North American Aviation, Inc.
Los Angeles, Calif.

BUCKNER, W. B.
U. S. Marine Corps
Camp Pendleton, Calif.

BURK, Peter W., Jr.
Riverside Cement Co.
Riverside, Calif.

BURNS, W. M.
Hughes Aircraft Co.
Culver City, Calif.

BURT, Sherman
Collins Radio Co.
Dallas, Texas

BUSIK, John
U.S. Naval Ordnance Test Station
Monrovia, Calif.

CAIN, John T.
Utah General Depot
Ogden, Utah

CAMBON, G. E.
Columbia-Geneva Steel Div.
United States Steel Corp.
Torrance, Calif.

CARLSON, C. A.
Johns-Manville Products Corp.
Lompoc, Calif.

CARROLL, Clarence M.
Southern California Gas Co.
Los Angeles, Calif.

CARTER, Wesley
Hughes Aircraft Company
Culver City, Calif.

CASTEEL, J. P.
Preco, Inc.
Los Angeles, Calif.

CERQUI, Donald
California Walnut Growers Assn.
Los Angeles, Calif.

CESER, Richard
McCulloch Motors Corp.
Los Angeles, Calif.

CHICK, Charles
Paul Heinley's
Los Angeles, Calif.

CHILDS, Earle S.
Goodyear Tire & Rubber Co.
Los Angeles, Calif.

CLARKE, R. D.
AiResearch Mfg. Co. of Arizona
Phoenix, Arizona

CLEVELAND, Jack
Robertshaw-Fulton Controls Co.
Anaheim, Calif.

CLOSE, G. C.
Aluminum Company of America
Los Angeles, Calif.

CLYDE, Edgar N.
Trade-Wind Motorfans, Inc.
Rivera, Calif.

COBB, D. L.
North American Aviation, Inc.
Los Angeles, Calif.

COLBURN, Price D.
Reynolds Metals Company
Phoenix, Arizona

COLE, C. K.
Royal Jet, Inc.
Alhambra, Calif.

COLEMAN, E. P.
University of California
Los Angeles, Calif.

COLEMAN, George F.
Coleman Engineering Co.
Los Angeles, Calif.

CONNORS, John B.
Collins Radio Company
Burbank, Calif.

COOKE, R. F.
Willard Storage Battery Co.
Los Angeles, Calif.

COVERDALE, H. M.
Douglas Aircraft Company
Santa Monica, Calif.

COX, John P.
Seaboard Coil Spring Div.
Gardena, Calif.

CUNNISON, Dale
Center Lumber Co.
Riverside, Calif.

CUTLER, Edwin L.
Consolidated Engineering Corp.
Pasadena, Calif.

CUTLER, John
North American Aviation, Inc.
Los Angeles, Calif.

DAHLMAN, R. C.
Northrop Aircraft, Inc.
Hawthorne, Calif.

DALING, Roger
General Electric - Hanford
Atomic Works
Richland, Wash.

DANIELS, Erling A.
Genisco, Inc.
Los Angeles, Calif.

DARLEY, L. J.
North American Aviation, Inc.
Los Angeles, Calif.

DAVIS, Frank W.
Alden Equipment Company
Gardena, Calif.

DAVIS, H. W.
Pillsbury Mills, Inc.
Los Angeles, Calif.

DEBOLT, J. D.
Johns-Manville Products Corp.
Lompoc, Calif.

DECKER, Paul
Minneapolis-Honeywell Reg. Co.
Gardena, Calif.

DEL MAR, Roger A.
Firestone Tire & Rubber Co.
Los Angeles, Calif.

DENNIS, Joseph A.
A. R. Maas Chemical Co.
South Gate, Calif.

DEVINE, John
Servomechanisms, Inc.
Hawthorne, Calif.

DICKASON, Howard M.
Temple City, Calif.

DiMILLE, A. P.
Douglas Aircraft Co.
Santa Monica, Calif.

DISTERDICK, R. H.
Los Angeles County
North Hollywood, Calif.

DOWNEY, Joseph
Richfield Oil Corp.
Wilmington, Calif.

DURNFORD, J. B.
Aluminum Company of America
Los Angeles, Calif.

DYER, A. R.
Richfield Oil Corp.
Wilmington, Calif.

EDOUS, John R.
U.S. Naval Repair Facility
San Diego, Calif.

EIZENBERG, Arthur
Play Products, Inc.
Venice, Calif.

EVARTS, Ed
Aluminum Company of America
Los Angeles, Calif.

EVERLY, Roger B.
El Segundo School System
El Segundo, Calif.

FARMER, Cliff
Minneapolis-Honeywell Reg. Co.
Gardena, Calif.

FEWVER, Gerald J.
Consolidated Western Steel
Maywood, Calif.

FERGUSON, William F., Jr.
Firestone Tire & Rubber Co.
Los Angeles, Calif.

FIELDER, William
McCulloch Motors Corp.
Los Angeles, Calif.

FINLAYSON, F. E.
General Electric Company
Ontario, Calif.

FOREMAN, W.
Aluminum Company of America
Los Angeles, Calif.

FOSTER, William R.
San Diego, Calif.

FOTTER, M. J.
Calif. Polytechnic College
San Luis Obispo, Calif.

FRANSWORTH, Eldridge
Boeing Airplane Co.
Seattle, Wash.

FREDERICK, H. E.
Columbia-Geneva Steel Div.
United States Steel Corp.
Torrance, Calif.

FULLER, Lloyd E.
Sandia Corporation
Albuquerque, New Mexico

GARDNER, Frederick
Hughes Aircraft Company
Redondo, Calif.

GEIGER, G. R.
Ircal Industries
Los Angeles, Calif.

GEORGE, Scotney
Flintkote Company
Los Angeles, Calif.

GERVING, T. G.
United States Rubber Co.
Los Angeles, Calif.

GIBBS, Richard
Minneapolis-Honeywell Reg. Co.
Gardena, Calif.

GILMAN, Mark
Rand, Inc.
Santa Monica, Calif.

GLASER, Frank
Collins Radio Co.
Burbank, Calif.

GODGES, H. F.
Aluminum Company of America
Los Angeles, Calif.

GOLDFARB, Jack
Packard-Bell Co.
Los Angeles, Calif.

GOODFRIEND, Nat
Holly Manufacturing Co.
Pasadena, Calif.

GOULD, James H.
U.S. Army Corps of Engineers
Hawthorne, Calif.

GOVIN, J. F.
North American Aviation, Inc.
Los Angeles, Calif.

GRACIE, J. D.
North American Aviation, Inc.
Los Angeles, Calif.

GRIFFIN, George
Paul Heinley's
Los Angeles, Calif.

GRUBER, Foster M.
North American Aviation, Inc.
Los Angeles, Calif.

GRUMAN, Sidney E.
Hoffman Laboratories
Los Angeles, Calif.

GRUNE, Murray C.
Castle & Cooke Terminals, Ltd.
Honolulu, Hawaii

GULARDO, Robert E.
Northrop Aircraft Inc.
Inglewood, Calif.

GUTHRIE, William A.
Aerojet-General Corp.
Glendora, Calif.

HACKNEY, A. S.
The Garrett Corp.
Los Angeles, Calif.

HAGELIS, James G.
Pomona Tile Mfg. Co.
Pomona, Calif.

HALL, H. H.
Aluminum Company of America
Los Angeles, Calif.

HANSON, Arnold E.
Collins Radio Company
Burbank, Calif.

HARDIE, Paul F.
Rome Cable Corp.
Torrance, Calif.

HARRIS, John Kent
L.A. County Civil Service
Los Angeles, Calif.

HART, Stuart
Addressograph-Multigraph Corp.
Los Angeles, Calif.

HASTINGS, Lt. Col. V. L.
U.S. Air Force
Inglewood, Calif.

HATCH, Ralph
Running Springs, Calif.

HATFIELD, G. A.
National Supply Co.
Torrance, Calif.

HAWKEM, Bill
American Pipe & Const. Co.
Lakewood, Calif.

HAWKINS, Leland
Robertshaw-Fulton Controls Co.
Long Beach, Calif.

HENLEY, R. R.
North American Aviation
Los Angeles, Calif.

HERBST, Walter R.
Consolidated Western Steel Div.
United States Steel Corp.
Maywood, Calif.

HERTFORD, Hayes
Arlington Heights Citrus Co.
Riverside, Calif.

HIGLEY, Robert D.
Kennecott Copper Corporation
Salt Lake City, Utah

HILLER, J. C.
Columbia-Geneva Steel Div.
United States Steel Corporation
Torrance, Calif.

HODGE, G. L.
San Diego State College
San Diego, Calif.

HOOD, John M.
Kennecott Copper Corp.
Ray, Arizona

HOPKINS, R. S.
Applied Research Laboratories
Glendale, Calif.

HOPPOCK, William E.
Sterling Electric Motors
Los Angeles, Calif.

HORNING, R.
Aluminum Company of America
Los Angeles, Calif.

HORTON, B. R.
Aluminum Company of America
Los Angeles, Calif.

HOUSER, E. K.
Rohr Aircraft Corp.
Riverside, Calif.

HUNTER, C. E.
Convair
San Diego, Calif.

HUTH, George B.
Sears Roebuck & Company
Chicago, Illinois

HYMAN, Alvin G.
Servomechanisms, Inc.
El Segundo, Calif.

ISHERWOOD, J. D.
University of California
Los Angeles, Calif.

ISHII, W. R.
North American Aviation, Inc.
Los Angeles, Calif.

JARDINE, Jone E., III
Royal Jet, Inc.
Alhambra, Calif.

JEFFERY, Edward H.
Hoffman Laboratories
Los Angeles, Calif.

JENSEN, W. S.
Preco, Inc.
Los Angeles, Calif.

JOHANSSON, Rolf
Volvo
Goteberg, Sweden

JOHNSON, Earl
North American Aviation, Inc.
Downey, Calif.

JOHNSON, Fred
Minneapolis-Honeywell Reg. Co.
Gardena, Calif.

JOHNSON, La Vern M.
Firestone Tire & Rubber Co.
Los Angeles, Calif.

JUNE, Robert L.
Mattel Inc.
Los Angeles, Calif.

KEEFER, Alfred
Hughes Aircraft Co.
Culver City, Calif.

KEMERER, W. J.
Consolidated-Western Steel Div.
United States Steel Corp.
Los Angeles, Calif.

KENDALL, George
American Pipe & Construction Co.
Alhambra, Calif.

KIERNAN, Russell L.
Hughes Aircraft Co.
Los Angeles, Calif.

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KINNSCH, Don L.
Westrac
Torrance, Calif.

KIRK, J. L.
Aluminum Company of America
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KNIGHT, C. S.
Collins Radio Co.
Dallas, Texas

KOEP, Andy
National Screw & Mfg. Company
Los Angeles, Calif.

KRAMER, Jack P.
Pioneer-Flintkote
Monterey Park, Calif.

KUNKE, William
Pillsbury Mills, Inc.
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KUSHNICK, Clyde
Production Management
Engineering Association
Altadena, Calif.

LARSON, J. R.
Southern California Gas Co.
Los Angeles, Calif.

LAUGHREN, E. D.
Southern California Gas Co.
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LAY, Harry L.
Ralph M. Parsons Company
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LEWIS, James A.
Pomona Tile Manufacturing Co.
Pomona, Calif.

LEYDA, Art
Charles R. Hadley Co.
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LIGHT, Nathan F.
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LOFTIS, Jim
Robertshaw-Fulton Controls Co.
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LOPEZ, Victor C.
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LUEDER, R. B.
Air Logistics Corporation
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MACKEY, H. J.
Thompson Products, Inc.
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MADICK, Daniel
Technicolor Corp.
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MADIGAN, J. E.
Kwikset Locks, Inc.
Anaheim, Calif.

MADISON, Ray S.
Marquardt Aircraft Co.
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MOCSNY, Steve
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MUHLFRIEDEL, W.
Thompson Products, Inc.
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MUSE, J. F.
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MYERS, C. H.
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NELSON, John
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NEWTON, William G.
Beckman Instruments, Inc.
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NOWLIN, D. L.
Southern California Gas Co.
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OSTER, Cletus J.
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OVERHOLTZ, F. Austin
Servomechanisms, Inc.
El Segundo, Calif.

OVERTURF, Kendall
K & O Labs., Inc.
San Diego, Calif.

PAFF, D.
Cherry Rivet Division,
Townsend Company
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PALMER, A. L.
General Electric Company
Ontario, Calif.

PARSONS, Cecil D.
Bill Jack Scientific
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PARTON, James A., Jr.
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Hawthorne, Calif.

PELL, Kermit W.
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PHILLER, Henry A.
Universal-Rundle Corporation
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PHILLIPS, Michael W.
Square D Company
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Electroweld Steel Corporation
Azusa, Calif.

PIERCE, James R.
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Pasadena, Calif.

PIGGOTT, Donald
Servomechanisms, Inc.
Hawthorne, Calif.

PINESS, George, Jr.
Wayne Manufacturing Co.
Pomona, Calif.

POMEROY, R. D.
Southern California Gas Co.
Los Angeles, Calif.

POST, Frank F.
Forest Lawn
Glendale, Calif.

POWER, Mike
Minneapolis-Honeywell Reg. Co.
Gardena, Calif.

PRATT, Lewis K.
Ryan Aero nautical Co.
Rancho Santa Fe, Calif.

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PUSCH, James
Royal Jet, Inc.
Alhambra, Calif.

RANDOLPH, James H.
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RATHMELL, G. H.
Pacific Telephone & Telegraph
Los Angeles, Calif.

RAY, C. J.
North American Aviation, Inc.
Los Angeles, Calif.

REVALON, Eugene J.
AiResearch Manufacturing Co.
Los Angeles, Calif.

RIDDINGTON, F. W.
General Electric Co.
Ontario, Calif.

ROBBINS, Kenneth
Jaysie Manufacturing Corp.
Los Angeles, Calif.

ROBINSON, Bill J.
American Airlines
Los Angeles, Calif.

ROBISON, Stuart W.
American Potash & Chemical Co.
Trona, Calif.

ROCK, R. R.
Pacific Mercury TV Mfg. Corp.
Sepulveda, Calif.

ROGERS, C. R.
Rheem Manufacturing Co.
Downey, Calif.

ROGERS, Robert A.
University of California
Los Angeles, Calif.

ROOT, Lloyd
Crown Zellerbach Corp.
Los Angeles, Calif.

ROSE, Stanley M.
Supermatic Products Corp.
Burbank, Calif.

ROSSCUP, Donald
Robertshaw-Fulton Controls Co.
Long Beach, Calif.

ROTRAMEL, J. M.
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Los Angeles, Calif.

RUGEN, Otto N.
Corps of Engineers, U.S. Army
Los Angeles, Calif.

SAXBY, Gene
Johns-Manville
Long Beach, Calif.

SCHAEFFER, Arthur E.
University of California
Los Angeles, Calif.

SCHARFF, A. L.
Pacific Mercury TV Mfg. Corp.
Sepulveda, Calif.

SCHWAB, George H.
Ryan Aeronautical Co.
San Diego, Calif.

SCHWEICKERT, Karl R.
Hoffman Laboratories, Inc.
Los Angeles, Calif.

SEIDEN, William
Dynalysis Development Lab.
Los Angeles, Calif.

SELOGIE, Lou
University of California
Los Angeles, Calif.

SHARP, Lee S.
Consolidated Western Steel Div.
United States Steel Corp.
San Gabriel, Calif.

SHAW, C. G.
Pacific States Cast Iron Pipe Co.
Provo, Utah

SHAW, Chet
Long Beach Naval Shipyard
Long Beach, Calif.

SHURKUS, Albert A.
Applied Research Laboratories
Glendale, Calif.

SIMMS, Robert
Minneapolis-Honeywell Reg. Co.
Gardena, Calif.

SMITH, D. D.
North American Aviation, Inc.
Downey, Calif.

SIMON, Alvin
Paul Heinley's
Santa Monica, Calif.

SIMPSON, Mark
Genisco, Inc.
Los Angeles, Calif.

SMITH, G. R.
Aluminum Company of America
Los Angeles, Calif.

SMITH, Keith
Aluminum Company of America
Los Angeles, Calif.

SMITH, F. Robert
Johns-Manville Corporation
New York City, New York

STADE, William J.
Richfield Oil Corporation
Wilmington, Calif.

STAIB, Don
U. S. Steel Products Div.
Los Angeles, Calif.

STALEY, Roy
Boeing Airplane Co.
Seattle, Washington

STEWART, E. A.
Hughes Aircraft Co.
Culver City, Calif.

STILLWELL, Gordon C.
Radio Corporation of America
Los Angeles, Calif.

STRYKER, Robert M.
Bendix Aviation Corporation
North Hollywood, Calif.

STUCKY, F. F., Jr.
Pacific Telephone & Telegraph Co.
Los Angeles, Calif.

SUART, A. H.
Packard-Bell Company
Los Angeles, Calif.

SUFFECOOL, Thomas
American Airlines
Hawthorne, Calif.

SULLIVAN, A. W.
Columbia-Geneva Steel Division
United States Steel Corporation
Torrance, Calif.

SUMMERS, A.
Electroweld Steel Corporation
Azusa, Calif.

SUMPTER, James L.
Eastman Kodak Company
Hollywood, Calif.

TAYLOR, Kemper
Firestone Tire & Rubber Co.
Los Angeles, Calif.

TEMBY, Donald
Crown Zellerbach Corp.
Los Angeles, Calif.

THAMMAN, E.
McCulloch Motors Corp.
Los Angeles, Calif.

THOMAS, C. W.
Thompson Products, Inc.
Bell, Calif.

THOMPSON, H. G.
Johns-Manville Products
Lompoc, Calif.

THORNTON, D. J.
Solar Aircraft Company
San Diego, Calif.

TODD, Leonard C.
Douglas Aircraft Company
Long Beach, Calif.

TRUHER, J. W.
Pacific Telephone & Telegraph
Alhambra, Calif.

TSCHAN, W. F.
United States Rubber Company
Los Angeles, Calif.

TWOMBLY, Robert
Borg-Warner Corporation
Los Angeles, Calif.

UNDERWOOD, William
Genisco, Inc.
Los Angeles, Calif.

URQUHART, W. S.
Armstrong Cork Company
South Gate, Calif.

VERRILL, David
The Flying Tiger Line, Inc.
Burbank, Calif.

VOLK, Robert D.
Gilfillan Bros., Inc.
Los Angeles, Calif.

VONDRACEK, Joe L.
Bendix Aviation Corp.
Woodland Hills, Calif.

WALSH, Mary
Ircal Industries
Los Angeles, Calif.

WATT, Allen
Minneapolis-Honeywell Reg. Co.
Gardena, Calif.

WELLS, C. A.
Aluminum Company of America
Los Angeles, Calif.

WESTLING, J. L.
Pacific Telephone & Telegraph
Alhambra, Calif.

WHEELER, Donald L.
Robertshaw-Fulton Controls Co.
Long Beach, Calif.

WHEELER, Richard C.
California Physicians Service
Los Angeles, Calif.

WHITE, W.
Townsend Company
Santa Ana, Calif.

WIBERG, H. E.
United States Rubber Co.
Los Angeles, Calif.

WILCOX, G. E.
Southern California Edison Co.
Los Angeles, Calif.

WILLIAMS, E. L.
Thompson Products Inc.
Bell, Calif.

WILLIAMS, Norman H.
Collins Radio Company
Burbank, Calif.

WILT, David L.
University of California
Los Angeles, Calif.

WINKLER, Joseph
Pacific Tile Company
Long Beach, Calif.

WINTER, Raymond C.
Air Research Manufacturing Co.
Los Angeles, Calif.

WISDOM, Don H.
National Plating & Processing
San Diego, Calif.

WISHAM, Richard G.
Collins Radio Company
Van Nuys, Calif.

WOMBACHER, Burke
Minneapolis-Honeywell Reg. Co.
Gardena, Calif.

WRIGHT, Dale
Aerojet General Corporation
West Covina, Calif.

WULLENWABER, R.
Pacific Semiconductors, Inc.
Culver City, Calif.

WYLIE, M. R.
Bendix Aviation Corporation
Kansas City, Missouri

YATES, Earl
Minneapolis-Honeywell Reg. Co.
Gardena, Calif.

YOUNG, Chris C.
The Garrett Corp.
Los Angeles, Calif.

ZEAMER, Jay
Servomechanisms, Inc.
Hawthorne, Calif.

ZIELLO, Alfred
Hughes Aircraft Co.
Culver City, Calif.

ZIRGES, Glen G.
Firestone Tire & Rubber Co.
Los Angeles, Calif.

ZOOK, J. E.
United States Rubber Co.
Los Angeles, Calif.

ROSTER OF ATTENDANCE

BERKELEY

ABERLE, D. J.
National Motor Bearing Co., Inc.
Redwood City, Calif.

ABRAHAMSON, W. D.
Mare Island Naval Shipyard
Vallejo, Calif.

ACKLEY, Arthur K.
Shand & Jurs Co.
Berkeley 10, Calif.

ALBANESE, John C.
Chrysler Corp.
San Leandro, Calif.

AMEND, Carl I.
Barium Prod., Ltd.
Modesto, Calif.

ARMITAGE, Robert M.
U.S. Air Force, McClellan A.F.B.
Sacramento 21, Calif.

BAGDON, R. J.
National Motor Bearing Co., Inc.
Redwood City, Calif.

BALOG, S. J.
Fibreboard Prod., Inc.
Antioch, Calif.

BARBER, Rex C.
Naval Supply Depot
Clearfield, Utah

BARNES, Fred R.
Montgomery Ward & Co.
Oakland 2, Calif.

BECKETT, P. N.
Matson Terminals, Inc.
San Francisco 5, Calif.

BENSON, H. L.
Tide Water Associated Oil Co.
Associated, Calif.

BERUBE, H. L.
Mare Island Naval Shipyard
Vallejo, Calif.

BEUMER, John
Chrysler Corp.
San Leandro, Calif.

BINDEMAN, H. L.
Lucerne Milk Co.
Oakland, Calif.

BLAIR, Robert J.
Sacramento Signal Depot
Sacramento 1, Calif.

BONN, John
Dalmo-Victor Co.
San Carlos, Calif.

BOOTHROYD, Rodney L.
U.C. Radiation Lab.
Livermore, Calif.

BOTTI, Dino
Jacuzzi Bros., Inc.
Richmond, Calif.

BOWYER, Olive A.
Naval Supply Center
Oakland, Calif.

BRANDT, Robert G.
Alameda N.A.S.
Berkeley, Calif.

BRENNING, L.
United Air Lines Maintenance Base
San Francisco, Calif.

BREW, Robert F.
Western Pacific R.R. Co.
San Francisco, Calif.

BROWN, Arthur H.
Sacramento Signal Depot
Sacramento, Calif.

BROWN, R. M.
Union Oil Co. of Calif.
Rodeo, Calif.

BUCKHOLTZ, I. E.
Preston Construction Co.
San Francisco 5, Calif.

BUCHTER, C. G.
United States Steel Corp.
Pittsburg, Calif.

BUCKWALTER, J. L.
Butler Mfg. Co.
Richmond 1, Calif.

BURGELIN, L. B.
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BURNS, Curt
Cutter Laboratories
Berkeley 10, Calif.

BUSH, R. B.
Lucerne Milk Co.
Oakland 12, Calif.

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Vallejo, Calif.

CAMPBELL, James W.
Stokely Van Camp, Inc.
Oakland 21, Calif.

CARLIN, Carl O.
San Leandro, Calif.

CARLSON, Ken
Pacific Vegetable Oil Corp.
San Francisco 7, Calif.

CARPENTER, H. J.
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CARTWRIGHT, S. P.
Puget Sound Naval Shipyard
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CASHMAN, R. J.
Western Gear Corps.
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CATINO, M. A.
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CHAPPELLE, Richard
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CLEMONS, H. R.
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COLE, R. R.
Friden Calculating Machine Co.
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CONTON, Lee
National Motor Bearing Co., Inc.
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COONEY, L. B.
Naval Supply Center
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COSTELLO, L., Jr.
Scott Co.
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COX, H. A.
Libby, McNeill & Libby
San Francisco 19, Calif.

COX, J. B.
Libby, McNeill & Libby
San Francisco 19, Calif.

CRANDELL, Everett
Detroit Steel Prod. Co.
Emeryville 8, Calif.

CRAPO, G. W., Jr.
Michel & Pfeffer Iron Works, Inc.
South San Francisco, Calif.

CROCKER, A. M.
Union Oil Co. of Calif.
Rodeo, Calif.

CULP, G. J.
Union Oil Co. of Calif.
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CURRAN, William E.
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CUSHMAN, D. M.
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DALESSI, J. M.
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DAVIS, Russell D.
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ERNEST, Arthur R.
Aerojet-General Corp.
Sacramento 6, Calif.

FANNEN, John
Super Mold Corp.
Lodi, Calif.

FARINHA, Claude J.
U.S. Air Force
Sacramento, Calif.

FELZER, William
S. F. Naval Shipyard
San Francisco 16, Calif.

FENTON, George
Mare Island Naval Shipyard
Vallejo, Calif.

FERGUSON, Ernie
Pacific Vegetable Oil Corp.
San Francisco 7, Calif.

FERRITER, William
Rockwell Mfg. Co., Oakland
Lafeyette, Calif.

FISH, Edwards R.
Northwestern Glass Co.
Seattle 4, Wash.

FLEWELLING, George
Lenkurt Electric Co., Inc.
San Carlos, Calif.

FORTIER, Lionel
Naval Supply Center
Oakland, Calif.

FRANKE, Norman P.
Friden Calculating Machine Co.
San Leandro, Calif.

FREEMAN, James
Hiram Walker & Sons, Inc.
San Francisco, Calif.

FROST, John R.
Calif. & Hawaiian Sugar Refining
Corp., Ltd.
Crockett, Calif.

GARDISER, Harry M.
Crown Zellerbach Corp., Western
Waxed Div.
San Leandro, Calif.

GEORGE, A. K.
Rheem Mfg. Co., Wedgewood Div.
Newark, Calif.

GEORGE, J. T.
Sacramento Signal Depot
Sacramento 18, Calif.

GIBSON, William
Kennecott Copper Corp.
McGill, Nevada

GILLILAND, Jim H.
Simpson Logging Co.,
Shelton, Wash.

GRABRISCH, A.
Rudiger-Lang Co.
Berkeley, Calif.

GRAHN, K. A., Jr.
Naval Supply Center
Oakland, Calif.

GRAHAM, Charles W.
Dow Chemical Co.
Pittsburg, Calif.

GRANADA, Frank
Schlage Lock Co.
Hayward, Calif.

GRAVES, Rulon B.
Naval Air Station, Alameda
Oakland, Calif.

GRUENSTEIN, Rolf J.
Ampex Corp.
Redwood City, Calif.

GUGLIEMETTI, M. J.
U.S. Air Force, Civ. Ser.
Sacramento 21, Calif.

GULO, Robley
Schlage Lock Co.
San Jose, Calif.

HABBESTAD, James
Jacuzzi Bros., Inc.
Richmond, Calif.

HAMLIN, Arthur F.
United Air Lines
South San Francisco, Calif.

HARLOW, W. B.
Kaiser Aluminum & Chemical Corp.
Moss Landing, Calif.

HARRY, M. L.
Pacific Coast Engineering Co.
Alameda, Calif.

HART, John P.
Hart & Hynding, Inc.
San Francisco 3, Calif.

HAUSCHILD, A. J.
Western Waxed Paper Divison,
Grown Zellerbach, Corp.
San Leandro, Calif.

HAWKINS, Elmer
Affiliation unknown
Sacramento 21, Calif.

HAWLEY, Jack
The Diamond Match Co.
Chico, Calif.

HECHINGER, B. L.
United Air Lines
South San Francisco, Calif.

HELM, Jack E.
Fulham Bros. of Calif.
Santa Rosa, Calif.

HEYBORNE, Rulon S.
Columbia Iron Mining Co.
Cedar City, Utah

HOLLOWAY, R. E.
Tide Water Associated Oil Co.
Associated, Calif.

HOOPES, L. N.
Lucerne Milk Co.
Oakland 12, Calif.

HORINE, Alfred W.
Naval Air Station
Alameda, Calif.

HOWELL, R. P.
Standard Oil Co. of Calif.
San Francisco 20, Calif.

HUFFSTUTHER, L.
Naval Air Station, Alameda
Oakland, Calif.

HYNDING, Norman C.
Hart & Hynding, General
Contractors
San Francisco 3, Calif.

IVERSEN, Bjorn E.
Fibreboard Prod., Inc.
Pittsburg, Calif.

JACOBS, Austin M.
Kodak Processing Lab.
Palo Alto, Calif.

JENNINGS Radio
Jennings Radio Mfg. Corp.
San Jose, Calif.

JOHNS, Stuart
Cutter Laboratories
Berkeley 10, Calif.

JOHNSON, Richard
Basic Vegetable Prod., Inc.
Vacaville, Calif.

JONES, Wilbur
Glass Containers Corp.
Antioch, Calif.

JOSSELYN, Dudley
Kaiser Aluminum & Chemical Corp.
Oakland, Calif.

KAHN, Roy
Malsbary Mfg. Co.
Oakland, Calif.

KANE, Vincent H.
Price Waterhouse & Co.
San Francisco 4, Calif.

KARLINS, Elliot E.
Detroit Steel Prod. Co.
Emeryville 8, Calif.

KERNAN, R. S.
Matson Terminals, Inc.
San Francisco, Calif.

KIMBALL, K. R.
Mare Island Naval Shipyard
Vallejo, Calif.

KINSER, Robert W.
U.S. Naval Air Station, Alameda
Walnut Creek, Calif.

KINT, Fred
U.S. Naval Supply Center
Oakland, Calif.

KNAPP, Sinclair
Bethleham Pacific Coast Steel Corp.
Alameda, Calif.

KONTICH, P.
United Air Lines
South San Francisco, Calif.

KOWSKI, George
Hiram Walker & Sons, Inc.
San Francisco, Calif.

KROMER, Arthur P.
Ampex Corp.
Redwood City, Calif.

KURZ, Stanley G.
U.S. Naval Air Station, Alameda
Oakland, Calif.

LEACH, F. H., Jr.
Rheem Manufacturing Co.
Richmond, Calif.

LEEDHAM, T. W.
Crown Zellerbach Corp.
San Francisco 19, Calif.

LEEDY, R. G.
Mare Island Naval Shipyard
Vallejo, Calif.

LEIFUR, H. K.
Stokely-Van Camp, Inc.
Oakland 21, Calif.

LEONARD, J. B.
United Air Lines
South San Francisco, Calif.

LESTER, Max
Rheem Manufacturing Co.
Newark, Calif.

LOCKE, J. E.
Hughes Aircraft Co.
Culver City, Calif.

LONG, R. H.
Twelfth Naval District
San Bruno, Calif.

LOPEZ, Michael
Lenkurt Electric Co., Inc.
San Carlos, Calif.

LORAIN, Dan
Westinghouse
Sunnyvale, Calif.

LUNDSTEDT, A. W.
Mare Island Naval Shipyard
Vallejo, Calif.

LYNESS, R. M.
Preston Construction Co.
San Francisco 5, Calif.

MAGGY, R. K.
Standard Oil Co. of Calif.
San Francisco 20, Calif.

MARINGER, L.
S. F. Naval Shipyard
San Francisco 24, Calif.

MARSHMAN, W. E.
Westvaco Mineral Prod. Div. Food Machinery & Chem. Corp.
Newark, Calif.

MARTIN, R. H.
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MARTZLOFF, T. H.
McKinsey & Co., Associate
San Francisco 4, Calif.

MATHER, F. I.
Naval Supply Center
Oakland, Calif.

MAYER, Don
Schlage Lock Co.
San Francisco, Calif.

McCONNELL, R. T.
Oliver Tire & Rubber Co.
Oakland 8, Calif.

McDONALD, Earl
Super Mold Corp.
Lodi, Calif.

McDONNELL, W. F.
Barium Products, Ltd.
Modesto, Calif.

MEHRTENS, L. H.
Pricemetal Corp.
San Francisco 3, Calif.

MELLERUP, C. W.
Mullen Manufacturing Co.
San Francisco 3, Calif.

MEYER, G. W.
Mare Island Naval Shipyard
Vallejo, Calif.

MEYERS, Dan
Standard Register Co. Pacific Div.
Oakland, Calif.

MICHELSON, Lynn
Naval Supply Center, Oakland
Oakland, Calif.

MIDDOUGH, Stan
Naval Supply Center, Oakland
Pleasant Hill, Calif.

MILLER, Wilbur
Jacuzzi Bros., Inc.
Richmond, Calif.

MONSOR, Harold A.
Dorr-Oliver, Inc.
Oakland 1, Calif.

MOORE, L. D.
Mare Island Naval Shipyard
Vallejo, Calif.

MOORE, W. L.
National Automotive Fibres, Inc.
Oakland 6, Calif.

MORAN, Jack
Dalmo-Victor Co.
San Carlos, Calif.

MORRISON, W. R.
United Air Lines
Chicago, Illinois

MORKETTER, R. S.
McClellan A.F.B.
Sacramento, Calif.

MORVAL, Oscar
McClellan A.F.B.
Oakland 10, Calif.

MOURA, J.
Hexcel Prod., Inc.
Oakland 8, Calif.

NACHBAUR, L. J.
Mare Island Naval Shipyard
Vallejo, Calif.

NELSON, Ted
Scott Co.
Oakland, Calif.

NEMETH, S. L.
Personal Prod. Corp.
Sunnyvale, Calif.

NETSELL, Ward
Hiram Walker & Sons, Inc.
San Francisco, Calif.

NORDSTRAND, B. J.
Mullen Manufacturing Co., President
San Francisco 3, Calif.

NORMAN, S. D.
United Air Lines
South San Francisco, Calif.

O'NEILL, E. J.
United States Steel Corp.
Pittsburg, Calif.

OPFELL, John
Cutter Laboratories
Berkeley 10, Calif.

ORR, W. F.
Basic Vegetable Prod., Inc.
Vacaville, Calif.

OSBORNE, J. H.
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Vallejo, Calif.

PARKER, Wendell
Cutter Laboratories
Berkeley 10, Calif.

PARKS, E. R.
Ernst & Ernst
San Francisco, Calif.

PARUN, William
Fibreboard Prod., Inc.
Antioch, Calif.

PATTERSON, D. G.
United States Steel Corp.
Pittsburg, Calif.

PATTON, L. D.
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Oakland, Calif.

PECKHAM, Harry
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Berkeley 10, Calif.

PEEK, Howard
Ernst & Ernst
San Francisco, Calif.

PENNANDEN, P.
Oliver Tire & Rubber Co.
Oakland 8, Calif.

PERKINS, D. E.
Colgate-Palmolive Co.
Berkeley 10, Calif.

PETERS, A. E.
United Air Lines
South San Francisco, Calif.

POLESE, A. M.
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POSTLETHWAITE, F. H.
Libby, McNeill & Libby
San Francisco 19, Calif.

PRAGER, Jerry R.
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PRICE, Lewis Hall
Southgate Aluminum & Mag. Co.
Southgate, Calif.

PRETTYMAN, Lambert
Maxwell House Division,
General Foods Corp.
San Leandro, Calif.

PREUSS, W. P.
Fibreboard Prod., Inc.
Antioch, Calif.

PYTEL, Leonard P.
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San Francisco 24, Calif.

QUARLES, H. C.
Tide Water Associated Oil Co.
Associated, Calif.

RANSIER, William W.
Monsanto Chemical Co.
Santa Clara, Calif.

REED, H. J.
Westvaco Mineral Prod. Division,
Food Mach. & Chem. Corp.
Newark, Calif.

REINOLD, O. S.
National Automotive Fibres, Inc.
Oakland 6, Calif.

RENSCHLER, H. R.
Rudiger Lang Co.
Berkeley, Calif.

RICHARD, Harold E.
U.S. Government
Sausalito, Calif.

RICHARDS, Lucien M.
Sacramento 14, Calif.

ROBINSON, D. I.
Hughes Aircraft
Tucson, Arizona

ROUNDS, Elwood
California Spray Chemical Corp.
Richmond 4, Calif.

RULE, E.
Hexcel Prod., Inc.
Oakland 8, Calif.

SAHAROFF, A. A.
United States Steel Corp.
Pittsburg, Calif.

SALMELA, L.
Hexcel Prod., Inc.
Oakland 8, Calif.

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SANFORD, E. T.
National Automotive Fibres, Inc.
Oakland 6, Calif.

SCATTINI, Joe
Golden State Co., Ltd.
San Francisco 3, Calif.

SCHAEFER, W. J.
Schmidt Lithograph Co.
San Francisco 7, Calif.

SCHOLAR, R. R.
Stauffer Chemical Co.
Richmond, Calif.

SCOTT, Walt C.
Rheem Manufacturing Co.
Newark, Calif.

SCOTT, W. P., Jr.
Scott Co.
Oakland, Calif.

SEHLMEYER, E. G.
United Air Lines
South San Francisco, Calif.

SEHRING, Rudy
Cutter Laboratories
Berkeley 10, Calif.

SHALVARJIAN, Haig
Sylvania Electric Prod., Inc.
Mountain View, Calif.

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Tide Water Associated Oil Co.
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Boeing Airplane Co.
Wichita 1, Kansas

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STADUM, E. Mory
Dorr Oliver, Inc.
Oakland 1, Calif.

STEWART, S.
Hexcel Prod., Inc.
Oakland 8, Calif.

STEWART, Walter R.
Shand & Jurs Co.
Berkeley 10, Calif.

STIDGER, Perry
National Motor Bearing Co., Inc.
Redwood City, Calif.

STOWERS, Robert
Basic Vegetable Prod., Inc.
Vacaville, Calif.

STRYKER, E. H.
United Air Lines
South San Francisco, Calif.

STUART, Walter B.
Kaiser Aluminum & Chem. Corp.
Walnut Creek, Calif.

SUGAR, Carl
Humphreys College
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TAYLOR, F. E.
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Oakland 6, Calif.

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TRYON, W. W.
United States Steel Corp.
Pittsburg, Calif.

UNGER, Donald J.
Calif. Att.
South San Francisco, Calif.

VAIL, F. Lee
The Diamond Match Co.
Chico, Calif.

VANCE, W. S.
Hughes Aircraft Co.
Tucson, Arizona

VAN EYK, J. G.
Naval Supply Depot
Clearfield, Utah

VAN HORN, Walter C.
John Bean Division, Food Machinery & Chem. Corp.
San Jose, Calif.

VIVIAN, Robert D.
Stokely-Van Camp, Inc.
Mount Vernon, Washington

WALKER, Robert W.
Schmidt Lithograph Co.
San Francisco 7, Calif.

WARD, J. E.
Lucerne Milk Co.
Oakland, Calif.

WEBSTER, Dale A.
Alameda Naval Air Station
Berkeley 4, Calif.

WENTWORTH, R. O.
American Pipe & Construction Co.
Hayward, Calif.

WENTZ, R. B.
United States Steel Corp.
Pittsburg, Calif.

WHITE, Clarence E.
Aerojet General Corp.
Sacramento, Calif.

WILCOX, W. W.
United Air Lines
South San Francisco, Calif.

WILDER, Beverly B.
Columbia Geneva-Pittsburg Works
Pittsburg, Calif.

WILLIAMSON, S. R.
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Vallejo, Calif.

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Ampex. Corp.
Redwood City, Calif.

WILSON, Earl
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Standard Register Co., Pacific Division
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WINTERBOURNE, W. E.
Oliver Tire & Rubber Co.
Oakland 8, Calif.

WOLFE, Robert E.
Lenkurt Electric Co., Inc.
San Carlos, Calif.

WORKS, George
Union Oil Co. of Calif.
Rodeo, Calif.

WREN, Jack
Union Oil Co. of Calif.
Rodeo, Calif.

YOAKUM, S. M.
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San Francisco 5, Calif.

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Standard Register Co.
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