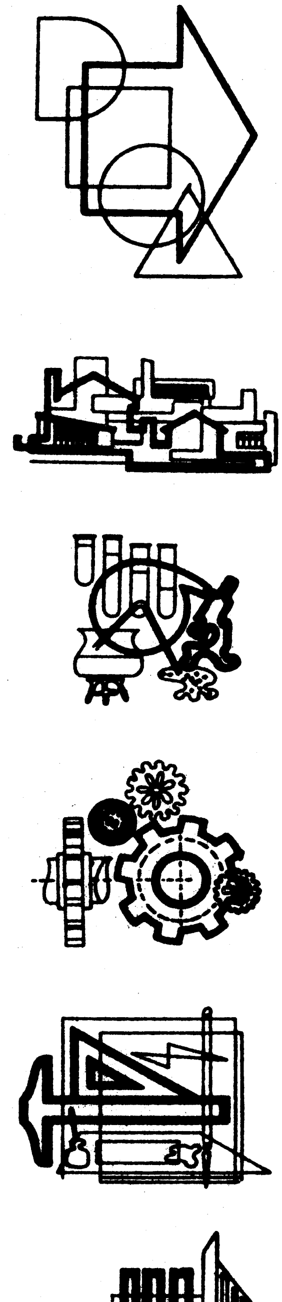
PROCEEDINGS

THIRTEENTH ANNUAL INDUSTRIAL ENGINEERING INSTITUTE



UNIVERSITY OF CALIFORNIA

BERKELEY February 3 and 4, 1961 LOS ANGELES

PROCEEDINGS

THIRTEENTH ANNUAL

INDUSTRIAL ENGINEERING INSTITUTE

Presented by

UNIVERSITY OF CALIFORNIA

THE COLLEGES OF ENGINEERING
THE SCHOOLS OF BUSINESS ADMINISTRATION
THE INSTITUTES OF INDUSTRIAL RELATIONS
UNIVERSITY EXTENSION

At Berkeley and Los Angeles
February 3 and 4, 1961

In Cooperation with:

AMERICAN INSTITUTE OF INDUSTRIAL ENGINEERS
Los Angeles, Peninsula, Sacramento, San Gabriel, Orange County and San Francisco-Oakland Chapters

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Editor: George P. Redman, Associate in Industrial Engineering
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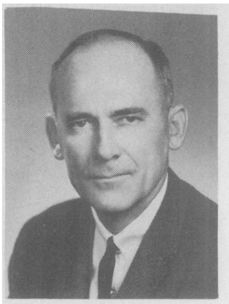
FOREWORD

George P. Redman
Editor and General Chairman
13th Industrial Engineering Institute

The thirteenth annual Industrial Engineering Institute endeavors to continue the excellent precedents which have been established by the previous twelve Institutes and to realize the highest objectives of the industrial engineering profession.

The speakers were selected after the interest questionnaires, completed by last year's participants, were summarized to determine the specific subject areas which appeared to be of current interest and prime importance. In each case an attempt was made to obtain the most outstanding individual available to share his particular wealth of knowledge and experience. The program was further tailored to anticipate the varied interest between the Berkeley and Los Angeles groups. Nine speakers appeared on both campuses as usual while the tenth speaker at both locations did not. However, the proceedings contain the papers of all eleven speakers.

It would be improper not to recognize the many people who contributed their time to the organization and presentation of this institute. Special thanks must be offered to all of the activities and session chairman, participating faculty and students on both the Berkeley and Los Angeles campuses. Needless to say, without the support of University Extension, an institute of this magnitude would be very difficult to organize. In addition, without the cooperation of the many professional engineering and management societies, a program of this nature would be futile. Finally, special gratitude must be extended to the speakers who voluntarily offered their valuable time and effort in appearing and speaking to us.



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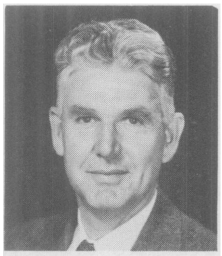

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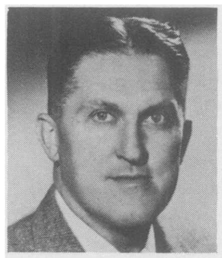

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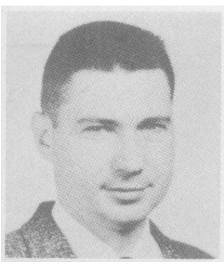

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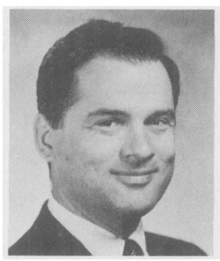

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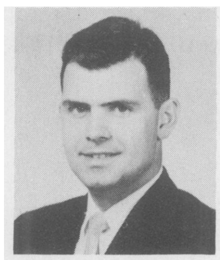

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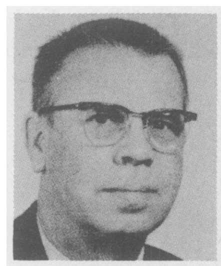

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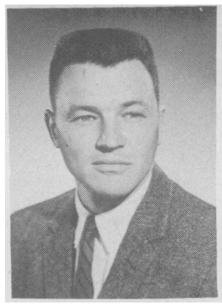

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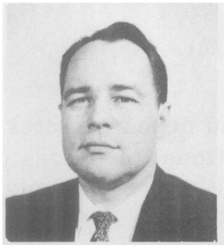

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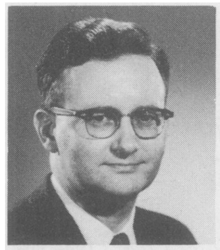

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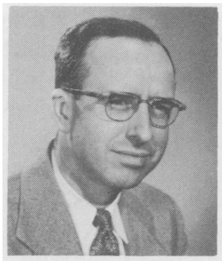

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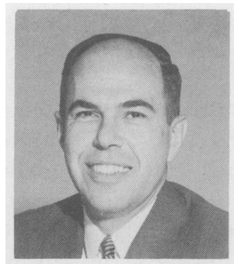

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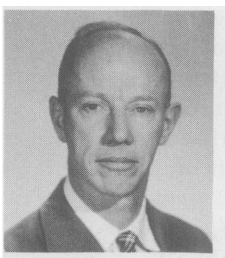

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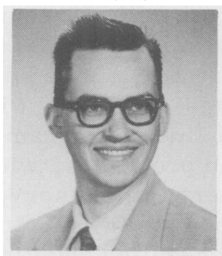

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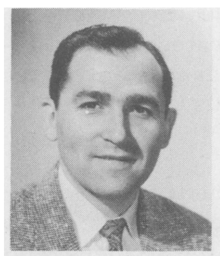

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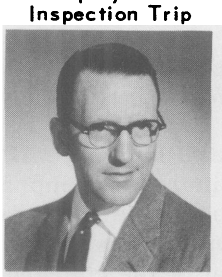
Planning Committee

E. Paul De Garmo

Displays and Inspection Trip



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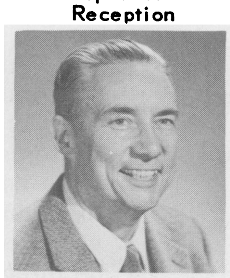

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WELCOMING REMARKS

BERKELEY

Ronald W. Shephard
Professor and Chairman,
Department of Industrial Engineering
University of California, Berkeley - 2/3/61

I am privileged and pleased to welcome you to this Berkeley session of the Thirteenth Annual Industrial Engineering Institute. The exchanges of ideas on current and future developments of Industrial Engineering, on practice and fundamental problems, provided by past meetings of the Institute has been rewarding, and I trust that this session will follow in the same tradition.

The program of the present session includes an interesting array of topics, some related to practice and new aspects of problems long faced by working industrial engineers, and others dealing with the fundamental problems arising from the human elements of our industrial economy. Still another is devoted to the future developments of Operations Research.

We at the University have had to reconsider during the last two years the significance of our past program of instruction vis-a-vis the changing technology of industry, wherein the problems related to integrated system design and operation have increased relative to those for individual components or work stations.

As spokesman for the industrial engineering department on the Berkeley campus, I have chosen to say a few words on the changes which are now taking place in our educational program, for the purpose of informing you how your University is rising to anticipate and meet the challenges and needs of our time.

Without impairment, we believe, of the immediate fitness of our graduates for practical work as industrial engineers, the four year program leading to a Bachelor of Science degree has been altered to expand the fields of study and to increase the required study in applied mathematics which is of particular significance for the problems faced in the analysis, operation and control of industrial systems. The principle used to allow the inclusion of such additional studies is that we can afford to spend less time on those things which the student can easily and perhaps better learn on the job. The conventional practices of industrial engineering will, therefore, play a lesser role in our educational program, but they will not be excluded altogether.

First, the general college requirements for study on engineering fundamentals are to be continued, but increased emphasis during the junior year will be given to the study of Probability and Statistics by requiring a one-year course on this subject. Thus our students will obtain a sound understanding of the structure of random processes, statistical estimation, analysis of data and design of experiments, sufficient to enable them to cope with these technical aspects of practical work and to prepare them for more advanced studies in industrial engineering which involve such elements.

Further, a one-year course on the model structures and methods of analysis of Operations Research will be required during the junior year of all of our students, as part of their basic training for a science of industrial engineering. Here they will learn the fundamentals of linear programming and applied stochastic processes, with emphasis on model structures which serve the practical problems of allocation of industrial resources, production scheduling, waiting lines, reliability, equipment failures, maintenance, replacement and inventories. The student will also be provided with an understanding of digital computation.

Our basic courses on Industrial Organization and Practices, Work Systems Design and Measurement, Metal Processing, Production Systems and Facilities Planning, will continue to be required, with increased emphasis on the principles involved. The material in the required course on Operations Research will be integrated with that of the courses on Production Systems and Facilities Planning.

The revised program of study will provide electives during the senior year in each of five fields: Operations Research, Metal Processing, Ergonomics, Production Systems Design and Industrial Administration. Some concentration in one or more of these fields will be permitted, especially for those students who plan to continue their studies in the graduate division for a fifth year to obtain a Master of Science degree. Perhaps you discern from this listing that we regard five years of study as worthwhile for a well trained industrial engineer--even though better than average scholarship is required to undertake graduate work. The four-year student with less aptitude can obtain, nevertheless, a sound training in engineering fundamentals.

In the field of Operations Research the courses offered have been greatly expanded, to provide the analytically inclined student with the opportunity for breadth and depth of training second to none among American universities, we believe. Advanced graduate study will be available, supplemented and supported by research of the faculty and Ph.D. candidates in an Operations Research Center newly formed. The aim of this program is to develop the scientific basis for mathematical solution of industrial planning and control, which when coupled with an advanced computer technology may very well automate most of the current management and industrial engineering functions. Indeed, this is the star to which we hitch our wagon, knowing that we cannot do less if we are to continue in those advancements of industrial rationalization by which America has led the world.

Metal processing, long neglected by university curricula but yet supporting the single largest part of the value added in manufacturing and today a critical factor in defense and space technology, is another field of study in which we are making substantial expansion, both undergraduate and graduate, with fundamental research by faculty and advanced degree candidates supported by grants from government agencies and private foundations. Oddly enough, a disproportionate amount of our advanced students today in this field are of foreign origin, but we hope to remedy this situation by encouragement of American students to undertake the obligation and challenge facing us at home.

Ergonomics, a name perhaps unfamiliar to some of you but which avoids the objectionable tone of Human Engineering, is an important area of study dealing with human factors in man-machine systems. Although, only lightly treated heretofore in our curriculum, it will henceforth be offered as a substantial field of study. The problems we encounter daily in the interactions between humans and machines are all too evident and will increase for the future as our technology is expanded and becomes more complex. I need only remind you of our recent experiences in air traffic control to rouse the sense of urgency which we feel on this matter.

We plan to carry on our former instruction in Production Systems Analysis and Design, modified by the inclusion of operations research methods and supplemented by the addition of a course on automated manufacturing.

Last and least in our responsibility for courses but not in importance necessarily, we shall continue to provide engineers with a technical background for industrial administration, the study of which may be pursued further in the School of Business Administration.

The changes in curriculum which I have outlined for you point to the unpleasant fact that education obtained by an engineer in one decade may be insufficient for the next, particularly in times of rapid change like the present. Mindful of our responsibilities in this connection, we have already initiated for this coming summer, through the facilities of the Extension Division and the Operations Research Center, an annual three week course on some topic in operations research. As a beginning, the topic selected for the summer of 1961 is "Inventory and Production Control." In subsequent years we shall provide instruction on such topics as Production Planning, Distribution and Allocation Problems, Service Systems and Queuing Problems, Traffic Analysis, Replacement and Maintenance Problems, Analysis of Storage Systems, and also treat mathematical topics like Linear Programming, Game Theory, Applied Stochastic Processes and Network Theory. As a second reason for this program, it will help us to keep in close contact with industrial problems.

With this start in the field of operations research, we plan to offer similar programs through the Extension Division in the other fields of study as rapidly as feasible.

WELCOMING REMARKS

LOS ANGELES

Franklin D. Murphy
Chancellor
University of California
Los Angeles, California

Mr. Chairman; Ladies and Gentlemen:

It is a great satisfaction to be able to welcome you on behalf of UCLA to this 13th Conference, and to have the opportunity to make your acquaintance. One constantly hopes the acquaintance may become more personal as the days, months, and years go by.

You know far better than I why you are here and what you hope to gain from this meeting. I might suggest, however, that your presence here, in fact the existence of this conference itself, is symbolic in two or three ways, and I think that it is well that we remind ourselves from time to time that the symbolism and the ultimate meaning of events are quite as important as their immediate practical value.

The nation is now celebrating the centennial of the socalled Morrill or "Land-Grant" Act, the first effective and precise statement of interest on the part of the United States government in educating the youth of America. More particularly, I think, it was the first clear statement on the part of our government in recognition of the fact that education has value beyond mere individual self-development; that education is, in fact, in the national interest. It is a fact that the only really unique contribution America has made to the theory of education lies in the "land-grant" principle. Here for the first time expanding upon the notion of Jefferson, that the national interest requires a literate population, the leadership in this country directed attention to America's number one problem: the development of an undeveloped continent, North America. "How", they asked themselves, "can we most effectively proceed to develop this underdeveloped continent--technologically, economically, and in all other respects?" The answer was clear: to open and expand the formal educational system--to meet the primary needs of the nation. Agriculture, which had been to that point solely a "trial and error" effort, was brought into the university context, and became an appropriate and proper part of university education and research. Engineering was moved from the back of the garage where apprentices worked with rudamentary tools into the laboratories and classrooms of existing universities and, much more importantly, into universities created deliberately for this purpose.

This land-grant principle was not provided as a substitute for important classical studies, but as an addition to them. How effectively and wisely we chose is manifest by our having become in a hundred years, the most powerful and productive industrial and agricultural nation in world history.

One hundred years and a revolution later, a scientific technological revolution of unprecedented proportions still in mid-stage, it is time to look about again to examine the 20th century and to define today's major national interests. This is what we have been doing although we may not realize it fully. We have certainly comprehended the fact that education is no longer a four year or a five year experience; it is a forty or fifty year experience. We understand that the only way one can maintain his creativity, drive, and relevance is through opportunities for coming together with peers, jointly pushing back the horizons. We recognize our commitment to a continuing educational process.

This then is the symbolism. Here we have highly competent and experienced people who recognize that it is useful and desirable to come together from time to time in an educational context to participate in an educational process. This is not a new concept to me, springing as I do from the field of medicine. I have understood this clearly because I suppose there is no other discipline more concerned with continuing education than medicine. Up to the time the man lays down the scalpel or the stethoscope he must continue to learn.

There is an other inescapable symbolism in the fact that this particular conference is being conducted by men from the field of management, or more precisely, the discipline of business administration, on the one hand and the various disciplines of engineering on the other. In today's industrial management, it is very difficult to determine the line on the spectrum dividing one from the other. Is not this symbolic of the rapid growth of new knowledge and of the growing complexity and shifting boundaries of the traditional disciplines? Does it not suggest then that the best education in a way, is the broadest education. I would suggest that in the 20th century we face unprecendented problems and unprecedented opportunities as well. Nothing is more important than the trained and educated mind developed, of course, within a fundamental concept of morality. But morality alone will not take us through these complex rapids of human history. If education has served us well in the past, as I believe we can prove it has, it certainly is apparent that we must look largely to education if we are to survive the present and have any trust in the future.

In this context, I welcome you. This institution, I believe, by providing the facilities, the assistance, and the resources for this conference is living up to its responsibility to its stock holders, the people of California. It does so by continuously serving our broadening and burgeoning society in ways that are germane and effective. I hope that at the end of this conference, this will be your opinion as well.

Thank you very much.

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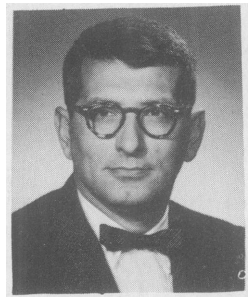
AN EXPERIMENT IN ACQUIRING AND TRANSMITTING INFORMATION



Alex Bavelas
Professor
Department of Psychology and the Graduate School of Business
Stanford University, - Stanford, California

The exercise that is described below was conceived and executed with two purposes in mind: 1) to provide an immediate experience with two kinds of communication difficulties presumed to occur frequently in management, and 2) to provoke discussion concerning the possible underlying causes of such difficulties.

What follows, therefore, is not a description of an experiment so much as a description of a didactic exercise. Many of the safe-guards and controls one would expect in a laboratory experiment were omitted entirely because they would have greatly increased the complexity of the process without adding to the value of the exercise. For this reason, the results, interesting and provocative though they are, will not be subjected to analysis. They will, in fact, be given approximately in the form in which they were presented to each group of participants when they finished their part of the exercise.

The Focus of Interest: There are many situations in which knowledge may be of little use if it cannot be effectively transmitted to others. A particular instance of this kind is a problem-solving group which must communicate its findings to others for application.

This is a common situation in industry. A large and complex organization must of necessity distribute its management over a variety of specialized functions. This formal separation of areas of activity is a convenience since many questions can be answered on largely "local" considerations. Often, however, broader questions arise for which local considerations are too narrow a base. In practice, this means that several persons, each particularly knowledgeable in his area of responsibility, try to bring their experience to bear on a common problem.

The difficulties that may beset such a group are many. The afternoon's discussion and exercise were concerned with two particular ones, both involving communication.

The first has to do with the ability of a group to make use of the information it has. Let us assume that the problem at hand is capable of being completely solved, and that the information required for its solution is available to the group. What difference will it make how the necessary information is distributed within the group?

For example, suppose there are eight men in a group, and that twenty-four items of information are required to solve the problem. Let us give each member of one group all twenty-four of the needed items, and let that group be called A-24. Then let us take another group of eight men and give each man only six items apiece: let two men have the first six items, two of them have the second six, two of them have the third six, and the last two have the last six items. Let this group be called A-6.

If each group is given thirty minutes to reach a solution, and no restriction is placed on how they work, which group will do better? In group A-24, each man has enough information to solve the problem by himself. In group A-6, no one man has enough information, and a solution will be possible only if certain members of the group share what they have. Thus, the effectiveness of the internal communication should be a more critical factor for success in group A-6 than in group A-24.

The second point of interest in the Asbury exercise has to do with the ability of a group, having finished its study of the problem, to communicate its findings to still others charged with applying them. To continue with the example cited above, let the group A-24 be required, in the thirty minutes alloted to it, not only to solve the problem but, also, to prepare a joint statement of its findings. The statement is then given to a number of individuals having no other knowledge of the problem or its solution. Let these persons be called B-24.

All this having been done, suppose that all the men--A-24s and B-24s--are individually tested for knowledge of the solution. The test scores attained by the A-24s will reflect their success in solving the problem. The test scores of the group B-24 will reflect the success of the group A-24 in communicating what they had learned in a form usable by the B-24s.

If we repeat this process with groups A-6 and B-6, how would their test scores compare with those obtained from groups A-24 and B-24?

As the participants in the exercise pointed out repeatedly, it is the A-6 and B-6 condition that more closely approaches the usual situation in industry. The members of a management group typically do not have the same information. Their particular areas of responsibility lead them naturally to the acquisition of specialized knowledge, and the solution of many of the problems that confront a management may depend on the effective sharing of that specialized knowledge.

The Exercise: The exercise followed closely the example elaborated above. The participants were separated into four groups:

Group A-24: eight members, each man to receive all the information required for solving the problem

Group A-6: eight members, each man to receive only a certain six of the twenty-four items required for solving the problem

The remainder of the participants was divided as evenly as possible into the other two groups:

Group B-24: each man to receive a copy of the statement prepared by Group A-24

Group B-6: each man to receive a copy of the statement prepared by Group A-6

Groups A-24 and A-6 met in separate conference rooms, and each was allowed thrity minutes to solve the problem and to prepare a statement of its findings. Each group was allowed complete freedom to organize and communicate as it wished.

At the end of the thirty minutes, the prepared statements were turned in by each group, and every man was then given an individual test (no further discussion or consultation allowed) on his knowledge of the solution.

The statements from the A-24 and A-6 groups were quickly duplicated. Each person designated as B-24 received a copy of the one prepared by group A-24, and each person designated as B-6 received a copy of the one prepared by group A-6. In addition, all the Bs were given an individual test identical to that administered to the two A groups. These tests, also, were taken without discussion or consultation.

The four sets of completed tests were quickly scored while the participants gathered in the main conference room. Following a discussion of the difficulties encountered, the test results were presented and compared with the results achieved by groups which had previously been through the exercise.

The Problem: The problem which was given to the groups to solve was, in effect, a one step maze. It was presented in the form of a five-by-five grid, rotated forty-five degrees so as to appear as a diamond (see Figure 1).

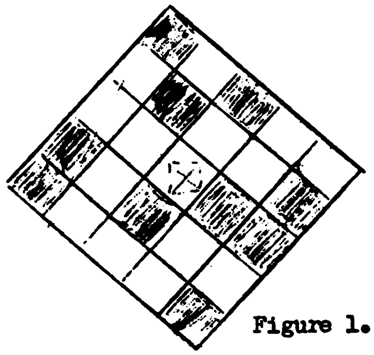


Figure 1.

Some of the squares were shaded. The center square contained arrows indicating the directions of movement allowed. The task was to start in the center square and to make a step into one of the adjoining squares--the correct one. The solvers were told that the shaded squares were not to be entered. They were not told the significance of shaded squares not adjoining the center square.

Note: The form of the problem used in this exercise was suggested and analyzed by Belver Griffiths. Mr. Griffiths also assisted in the preliminary testing which was done through the generous cooperation of Mr. D. F. Deedman and the New York Telephone Company.

Each grid was arranged so that if the solver remembered the instructions concerning allowable directions of movement and remembered that shaded squares were not to be entered, he would be left with a choice of one of two possible squares to go to.

The information which was distributed at the start of the exercise in groups A-24 and A-6 consisted of twenty-four such grids on which the correct step had been plainly marked. By studying these correct instances it was possible to deduce the underlying principle which made them correct.

The test which was taken by all the participants consisted of a booklet of twenty-four such grids without the correct steps indicated. The test grids were not the same as those which had been marked for instructional purposes, but they could be answered correctly by following the same principle.

The Test Results: The test scores will be given in approximately the form in which they were presented to the participants: individual scores and group averages. The conditions under which the exercise was done do not warrant further analysis.

In considering the test scores it should be kept in mind that the twenty-four questions used required a choice of one of two possibilities. Thus, without any knowledge of the underlying principle--by guessing alone--the most likely score to be attained would be 12. The maximum score would be 24.

TABLE 1

GROUP MEAN SCORE

	Groups A-24 N-64	Groups B-24 N-51	Groups A-6 N-64	Goups B-6 N-51
Group #1	21.9	15.0	11.9	14.0
Group #2	18.4	15.6	14.0	12.4
Group #3	21.2	14.6	12.0	13.3
Group #4	15.9	15.7	12.5	12.3
Group #5	18.8	17.4	14.6	16.5
Group #6	17.6	15.5	21.7	17.6
Group #7	18.6	12.8	14.1	14.6
Group #8	22.9	20.4	18.0	17.4
	Mean- 19.4	Mean- 15.9	Mean-14.9	Mean- 14.8

The exercise was done eight times, once in each of eight Asbury sessions. These are the average test scores for each of the four sets A-24, B-24, A-6, and B-6. At the bottom of each column is the mean score all groups in that set.

Table I shows the mean score attained by each of the groups. The mean score of all the A-24 groups taken together is 19.4, and this very probably indicates that on the average these groups learned a good deal about the underlying principle. The mean score of all the B-24 groups is 15.9. This score is barely acceptable as evidence that the A-24 groups succeeded in communicating what they had learned.

In comparison, the mean scores for all A-6 and B-6 groups leave considerable doubt as to whether anything was learned or communicated.

Table II and III show the individual scores for all groups. The participants were particularly struck with the variance within groups.

For instance, in one of the A-24 groups, two of the men scored perfectly with 24 points apiece, while two others scored 11 and 9 respectively. This is interesting when one remembers that the members of this group spent thirty minutes in free discussion about the solution of the problem, and that they jointly composed a statement of what they had learned. It was clearly understood that the task was a group effort. Competition in the sense of striving for a higher personal score was not in evidence. There seemed to be no motive for withholding insights or hypotheses. Clearly, not everyone who speaks is heard.

TABLE II

INDIVIDUAL SCORES

Groups A-24

Member	1	2	3	4	5	6	7	8
Group #1	24	23	23	22	22	21	20	20
Group #2	24	21	21	21	18	16	13	13
Group #3	24	24	24	23	22	20	18	16
Group #4	20	18	16	16	16	15	14	12
Group #5	24	24	23	22	20	18	11	9
Group #6	23	21	20	20	16	14	14	10
Group #7	22	20	19	19	18	18	18	15
Group #8	24	24	24	24	23	23	21	20

Groups A-6

Member	1	2	3	4	5	6	7	8
Group #1	18	14	13	11	11	10	9	9
Group #2	18	14	14	14	14	13	13	12
Group #3	21	13	13	12	11	9	9	8
Group #4	17	16	16	15	13	10	9	4
Group #5	18	17	16	16	16	14	11	9
Group #6	24	24	24	24	22	20	18	18
Group #7	16	16	16	15	15	14	12	9
Group #8	21	19	18	18	18	17	17	16

The variance in the B groups is also very great. Some of this may be attributed to the fact that the statements received generally lacked clarity and interpretations had to be made. In one discussion following the exercise, the point was made that one should expect lower extreme scores to occur in the B-24 groups than in the B-6 groups - the reason given was that since the communication from the A-6 groups usually had no information in it, the B-6 scores should group closely around the chance score of 12 - and that the communications from the A-24 groups were usually more specific, although often ambiguous, and, therefore, if misinterpreted, should lead to systematic errors. The data lend a certain amount of support to this hypothesis. Table III shows that in the B-6 groups the lowest score was 10, and this score was achieved by five persons. In the B-24 groups, five scores below 10 were turned in: 5, 6, 9, 9, 9. The moral may be, "If you don't know what you're talking about, don't make your instructions specific".

TABLE III

INDIVIDUAL SCORES

Groups B-24

	Member 1	2	3	4	5	6	7	8	9
Group #1	23	19	18	18	16	14	12	9	6
Group #2	21	18	16	13	10				
Group #3	21	18	17	14	14	13	11	9	
Group #4	19	17	17	16	14	14	13		
Group #5	20	20	19	18	10				
Group #6	18	18	17	16	13	11			
Group #7	17	15	12	10	8	5			
Group #8	24	23	22	18	15				

Groups B-6

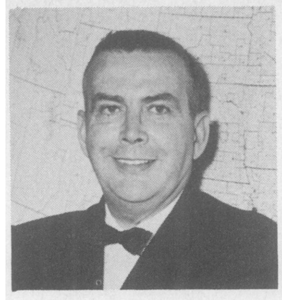
	Member 1	2	3	4	5	6	7	8	9
Group #1	18	16	15	14	14	13	13	14	10
Group #2	14	13	13	12	10				
Group #3	19	16	14	13	12	12	10	10	
Group #4	14	13	13	12	12	10			
Group #5	19	18	17	17	16	12			
Group #6	21	19	18	15	15				
Group #7	18	17	15	15	12	11			
Group #8	20	19	17	17	14				

Concluding Remarks: The exercise described above had two main purposes: 1) to provide an immediate experience with two kinds of communication difficulties presumed to occur frequently in management, and 2) to provoke discussion concerning the possible underlying causes of such difficulties.

The exercise succeeded on both counts, and it appears to have much to recommend it as a method. Along with other well known departures from the traditional lecture method, it shares the virtue of requiring active participation. It has the further strength that the discussion is about one's own experiences rather than someone else's, such as in the case method. And that experience is both recent and shared with the others, a circumstance which makes it difficult to avoid or dismiss the implications of the facts which emerge. The exercise is not merely a demonstration. The results are not rigged. The participants are fully aware that the results could have come out differently. Thus, when the data produced show systematic trends, the discussion is more vigorous and searching than is often the case with hypothetical examples or debates of "correct principles".

The usefulness of such exercises as an educational technique should be tested further. They have certain limitations when they must be used in traditional settings. What these limitations would be under radically different instructional arrangements is an intriguing question that deserves serious study.

As to the data themselves, although it was not considered appropriate to analyze them in detail, it should be said that they have led to considerable speculation, which will, very probably, lead to further laboratory experiments. Some of the most interesting leads to such experiments came out of the discussions of the participants following the exercise. From the point of view of research this was one of the major values of the Asbury Project.



HUMANICS OF INDUSTRIAL ENGINEERING

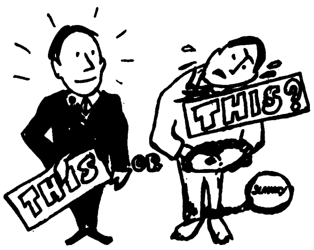
Jerome Barnum
Director and President
Jerome Barnum Associates
Scarsdale, New York

The great need in the free world today is "research and invention in the realm of ideas in respect to the way men can work and think and dream together in a private enterprise society dedicated to the utilization of the resources of nature, and of human nature, for the betterment of the lot of man here on earth."

There can be no sharp distinction between research and invention. However, invention is the word we attach to the specific result. Research, on the other hand, deals with the delving into the thousands of curious factors and avenues of inquiry that may lead to that result. To-day, let us be researchers.

The basic fact of today is the staggering rate of change surrounding every facet of human life. Change presents challenge and opportunity.

The basic concern of this conference should be, I believe, the survival of free man of this earth. That question is by no means settled as of to-day. "Countdown Berlin" is but one manifestation of a polyglot problem of awesome proportions.



In the long look of history, the success or failure of the Industrial Engineering profession may be decided as of today. We have the capacity to tip the balance in the verdict, "Has 20th Century America something vital and precious to be preserved, or is it simply a crude imitation of Athens or Rome? Is America on the threshold of a final and tragic decline?"

In the process of working in various parts of the world, I have not been able to escape forming some impressions. What Nehru called "The Tragic Paradox of Our Age" is not an American invention:

but it might be subject to the melancholy judgment of being an American lack of invention in the realm of ideas.

More specifically, those of us who are Industrial Engineers, social psychologists, and management analysts must stand indicted for at least interim failure. We are like the German about whom the philosopher said "he performed each minute step with infinite accuracy as he swept on to the grand fallacy."

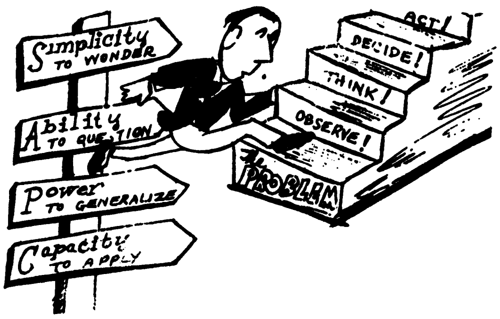
Industrial Engineers have many technical problems to face. But even a surface consideration of these matters leads inevitably to a wider and deeper range of thought. Unless we are wise, unless we develop sensitivity to the total picture, unless we discover clarity of vision (or at least are clear about the questions being posed to us), unless we tune in that clear small voice that forever whispers "quo vadis"--whither goest thou, then all may be lost in the confusion that muddles the world today.

I do not pretend to have the answers to these greatest of questions that have been presented to mankind. I can only say in sincerity and humility that I have dedicated my life to researching them and I am constantly thinking about these questions. That is what I am going to ask you to do...for if you will do this... think...then these problems will be solved and free man will survive.

If we are true inventors and researchers, let us not be dismayed in this undertaking if we frequently fail. An inventor is constantly failing. He may try, and fail, a thousands times; but if he succeeds once, he has it made. (Do we recognize this in our management and methods research?)

Let us also learn that we cannot look for the answers to the great problem of our age in the books. No matter what we are trying to do, if it is new we can find some book that will say it can't be done. We have only one inflexible rule in Jerome Barnum Associates: If we are truly working on a new approach or a new problem, stay away from bookshelves and committees in the beginning, as both will tell you we were nuts to start the project in the first place.

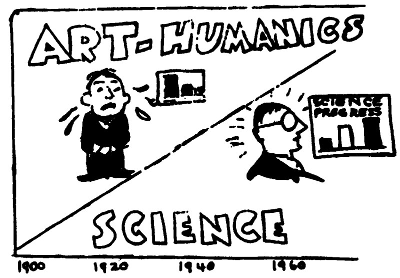
The first step is always to define the problem. After that you can study it and come up with some ideas as to how to proceed. Then you can tap your reference sources, your books and committees. If you have plenty of time-- and find out what others thought about it. Basically you are demonstrating the simplicity to wonder, the ability to question, the power to generalize, and the capacity to apply.



The problem needs more definition, but let us take a stab at it to-day; because even in taking a very long journey, the Chinese proverb tell us, it is necessary to take the first step first.

THE PROBLEM

In our lifetime amazing changes have occurred, and each of us who knows the world of the laboratory realizes that we are now on the preliminary threshold of the technological age. Man needs no longer to be the helpless victim of external forces. We approach a time when life can be good for all men. Yet, while man forges the conquest of his external circumstances, we witness the weird spectacle of the disintegration of the value system which could make it all worth while, the decay of the moral and spiritual fabric of man's existence, and the apathetic violin solo being rendered as the forces that would enslave man shove, and shoulder, and sneak, and squirm, and snake their way ever nearer, ever clearer, on the path of certain exhaustion of civilization itself.



Specifically

1. The Western World can survive only if we achieve a constantly rising productivity rate, on a lot healthier platform than we have witnessed these past ten years. This is specifically our joint responsibility and our job. It is the task of management, engineers, scientists, and workers.

2. Productivity is the only key to plenty, so it is the sole source of the more abundant life we claim we want.

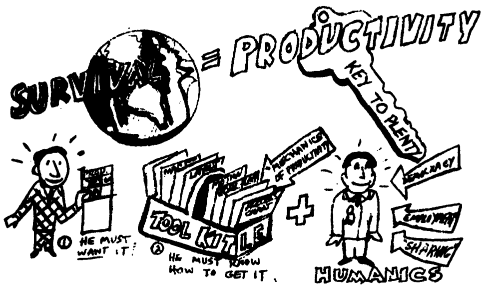
3. The essential, dramatic increases in productivity required in the free world cannot, and will not, come about until people really want them. Each of you know that the employee group that truly thirsts for higher productivity in America today is the rare, if not non-existant, exception rather than the rule.

4. The Industrial Engineering profession has developed a tool kit--a set of analytical techniques--that can be used to increase the productivity of almost any operation, yet these basic hammers and pliers of the management trade are almost completely unknown to at least ninety per cent of the members of management--foremen, supervisors, middle and top management--and unused by ninety-nine per cent of our individual contributors, the non-supervisory employees.

5. Considering the foregoing four points, we must conclude there is much room for improvement in the "mechanics" of management, but that is only a small part of the job. The next series of conditions deal with the "humanics" of making it all worth while. It will not profit us to conquer the physical world

if we in turn fail to conquer ourselves. Herein is Nehru's tragic paradox of the mental conflicts in this age of transition. The physical changes in the future will make all the material progress that has gone on up to now appear to be but a stumbling, bungling beginning. This, of course, presupposes that man will not allow science, which he has created, to turn around and destroy its creator, by being overwhelmed and annihilated in a nuclear war bursting the balloons of civilizations with the sudden pinpricks of ICBM's. Again, science advancing beyond our comprehension, and posing problems we have been incapable of understanding, much less solving, forces us to ask "quo vadis"--whither goes thou, and What is the meaning of life? We must also ask, "Productivity--to what end?"

6. Here in America we are a people dedicated to concepts of freedom and something we loosely call "democracy." Man spends most of his life, the largest number of hours each day by far in



connection with his work. How much freedom and democracy do your workers have? Is this whole American value system good only after 5:30 p.m.? Can we expect man to live as a free, effectively-functioning, participating, democratic member of the human race between 5:30 p.m. and whatever time he goes to bed, and then become part of an authoritarian states (our businesses) all day long? I doubt it. This question faces us as humanity goes to the test. The old days of non-thinking acceptance or apathy do not appear to be adequate in this changing world. Living that has meaning and vitality is a continuous adjustment to changes and happenings. So is management. If things would only not change we wouldn't need managers! It is the lack of adjustment that creates conflicts as well as bankruptcies. Let us plan against spiritual, as well as financial, bankruptcy!

7. Unemployment, whether it is temporary, transitional, or "permanent" cannot be tolerated in an enlightened society. It is no good to tell the unemployed father of five or six children that employment "on the whole" is on the increase. It is a very personal thing. It is also a big, unsolved problem of our way of life. I fear I may infuriate many by mentioning one or two personal views on this subject:

   (a) From 1850 to 1950 productivity increased five-fold while hours worked per week dropped from 70 to 40. Have we now come to think there is something holy about the 40-hour week? I am sure it will be down to around 24 hours while some of us are still alive.

   (b) I believe that no company will ever achieve its true productivity potential without giving guarantees in writing that no one will ever lose employment as a result of thinking up new and better ways of doing the work.

   (c) I believe this problem is the most vulnerable point in the capitalist society and its early solution is essential to counter the talk in Communist circles of the contradictions of private enterprise. Unless it is solved, I am afraid the wake of disillusionment that could follow a major recession might become a vacuum into which the false faith of Communism and the disciplines of an authoritarian state might rush.

8. Man was not born to run your machine, or add your columns of cost figures, but to live. We are not only building products or rendering services, but more particularly we are building a world. Therefore, the people in our companies, where most of their lives are lived, have to encounter "l'ambiance" for personal fulfillment. Here is where energy and spirit overlap. Human beings need a minimum sense, at least, of being in charge of their own lives. Part of your job is to reconcile the forces of human destiny with the forces of efficiency. Rationalism, and the Foundations for "Economic Education" too often skid along the polished surface of this problem without ever becoming aware of its inner core. It is clear that in the final analysis it is the quality of humanics that counts. People

are our most important asset; and we must subordinate every other consideration to the needs of man and how to meet them. Can this be done in a private enterprise economy, a private capitalism? I think it can. In fact, I believe it can be done in no other way.

Since we started talking from a viewpoint of research and invention in the realm of ideas, what can we do next? I said the problem needs further definition, so one thing we can do is go on defining it. In the meantime you might also shoot the next politician you hear uttering that glib bit about American "knowing how to sell soap but not knowing how to sell themselves." We must remember that marketing involves product-analysis as well as sales promotion techniques. When a soap doesn't sell we look at the soap itself, as well as the advertising.

Since none of us is ever smart enough to arrive directly at the final "right" answer to anything, we must think very hard, and we must study, and we must create. We have to work our way laboriously from experiment to experiment, and from test to test, until we finally come up with something that works. A lot of people are unwilling to do this. They would like to shortcut this tedious "nonsense." Unfortunately, the only people who have ever produced in the laboratory are the ones who never thought their education and their native intelligence were so great as to avoid the need for trying things out to see if they would work.

I want to devote most of my remaining time to relating to you some of the things that seem to be working for us. If the yardsticks for measuring success are to be increased productivity and enhanced human satisfaction, we would have to say these things do work.

INVENTING AN IDEA

Now we come to the stage of analyzing the problem. Eventually our group found one method that works. I am sure there must be other methods. Improving our method will be a lifetime job. It is a matter of tedious and sometimes painful trial, test, and experiment; but we know of no other way. The answers are not in the books.

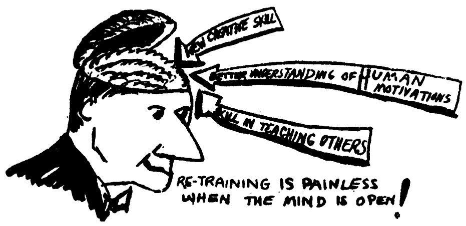
The answers we find seem extremely simple once they are worked out, but remember that "nothing is complete until everything possible has been taken away from it." We call this method "Directed Energy."

We couldn't have calculated these things. No one we know is smart enough to make such calculations, although we think up the things to try in our heads. Then we go through the primitive process of trying something out, learning as much as we can about its strengths and weaknesses, and trying something else. The "Directed Energy" approach is constantly changing although its basic philosophy has remained constant.

Our first step consisted of a reorientation of the management consultant and the staff Industrial Engineer. We rewrote our job descriptions and our company objectives. Now we have placed at the top of our responsibility list "the study of industrial life to discover ways of advancing the aims of society, without transcending the aims of the individual human beings composing it."

THE INDUSTRIAL ENGINEER'S CHANGING ROLE

In order to equip ourselves for this task we set out to reeducate ourselves: to improve our inventive skills and attitudes, to learn more about man and his basic motivations, to even understand the questions posed by our times, and to learn to teach and to stimulate others into thinking about these great challenges.



We said to ourselves: "Productivity is the only benefactor our workers have in terms of reaching the higher standard of living everyone claims he wants. Therefore, when the Industrial Engineer appears on the scene with a new method there can be only one logical reaction: "Oh, goody, here comes the productivity man. His work will result in a higher standard of living and a more secure Western World for my children and their children's children. What lucky people we are to have him around." And we asked by a show of hands how many of our people are customarily greeted that way. Ask yourselves this same question, Mr. President; Mr. Industrial

Engineer.

The conclusion had to be that people either were kidding themselves about wanting the better way of life, or else they really didn't believe that productivity was a good thing for them.

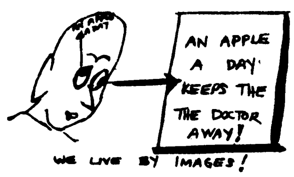
But weren't the "facts" clear, you may ask. We learned that no one, not even you engineers and scientists, live by "facts"-- not one of us does. Rather, we live by images--stored up beliefs--and we act and behave as though these images, rather than the things they represent, are "truth." Let us try a little experiment to illustrate how it works.

Read this statement aloud:

AN APPLE
A DAY
KEEPS THE
THE DOCTOR
AWAY!

Editor's note: 95% of all engineers and executives tested have read the statement incorrectly. Mr. Barnum has used this experiment, and ones similar to it, in over 100 management training programs he has conducted in fifteen different countries.

The reason you read this simple statement incorrectly is that you have stored in your mind a statement that reads "An apple a day keeps the doctor away!"--and so compelling is this "Image" that you have "read" it, instead of the statement you are looking at with your eyes.



We realized that if we wanted to change human behavior in an industrial environment, or anywhere else for that matter, we had to first change the image upon which it was based. Images are the result of our perception of experiences, knowledge, and sensations. We realized we would have to add new experiences, knowledge, and sensations to produce new images. Then if we were lucky, we might get different reactions.

In order to carry out this project we had to undertake a study of contemporary images, at all levels of industrial society, of "productivity." This study would fill a book, so I will concentrate on two aspects of this image tonight:

1. At the foreman and worker level the relationship management claims between personal advancement and increased productivity is regarded as a trick or gimmick. The factory worker, for example, may be able to see that his income has gone up 25% as productivity has increased a more or less comparable amount; but this same worker also knows a milkman, or plumber, or carpenter (whose productivity hasn't changed a single bit) whose income has gone up 25% or maybe even more, during the same period.

2. At all levels, including middle and upper management, there is fear of unemployment. Many will tell you, "Sure, productivity could be doubled next year--but half of us would be out of work. For the ones who remained there would be no real desire to share, on any fair basis the fruits of the increased productivity. Productivity may be fine, in the long run; but we have to live in the short run."

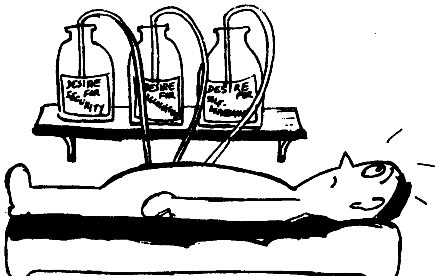
We believe this problem will only be solved when some modern counterpart of Henry Ford I duplicates his dramatic decision on the $5.00 day with a similar move in the realm of working hours; sharing the fruits of increased productivity, and protecting employment-continuity' among the people who are affected by technological advancement.

It is a complex problem, and I don't pretend to have all the answers. I feel that some concerted broad-scale action is necessary; but until that comes along, we have found it is wise to give the necessary assurances, project by project. Because we are sincere about it we are believed. When you are believed you see the alchemy of new attitudes going to work and people start to say, "Now, maybe this isn't such a bad idea after all."

Now, let us go to the next point. When someone comes to believe that increased productivity is a good thing for him, in his own perception of what's good for him (as opposed to yours), do you automatically get acceptance and support? Of course not. The way a thing is done is just as important as what is done.

We studied fundamental motivations, and after clearing away all of the confusing semantics of the "head shrinkers", we talked a lot with people working in all kinds of jobs and came to the conclusion that we do the things we do to satisfy some rather simple hungers that all of us experience. They are like chemicals in our system, and we do things to satisfy them, and we do things to avoid having them taken away from us.

Some people call this "augmentation of need satisfaction", or the "diminution of need satisfaction". These hungers are for security, recognition, and self-expression. You can give them fancier terms, but this is what they boil down to.



INDUSTRIAL ENGINEERING MUST DISCOVER HOW TO MEET THESE BASIC NEEDS

Picture three bottles containing these ingredients on a shelf with tubes connecting them to your system. The "mix" you have may differ from mine, or from the fellow's sitting next to you, or from the little lady's at home; but the ingredients are universal and unchanging. The way you act and react depends on your "mix". The best way to have trouble is to ignore this basic chemistry of man. I am afraid that is what we do most of the time in Industrial Engineering. It is, likewise, the tragedy of top management thinking in the free world.

The law of intelligent action says you accept conditions as you find them, and then proceed to make them work out for the general advantage. One thing we have to learn to accept is basic human nature itself. Its been that way a long time and its going to be that way long after we're all dead and gone. St. Thomas Aquinas put it this way: "God grant us the serenity to accept the things we cannot change; courage to change the things we can; and wisdom to know the difference."

Since the basic nature of man is not going to change, our job in business becomes one of understanding it, and designing a way of working with it. In other words, the thing that can change is business: the way we deal with man in the industrial climate.

Our main job as Industrial Engineers is to find a way of doing our work in a manner that will meet the requirements of man's fundamental needs for security, recognition and self-expression. Unless we succeed in doing this, we may "perform each minute detail of our work with infinite accuracy as we sweep on to the grand fallacy". Let us now have a look at the approach we have been using that has met with quite a bit of success.

THE DIRECTED ENERGY APPROACH

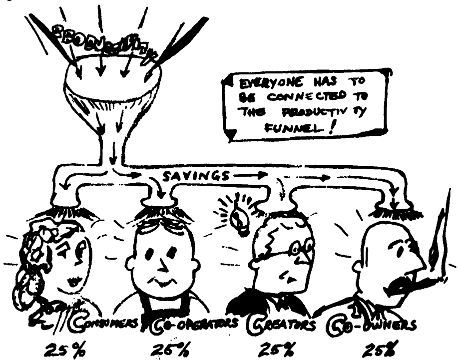
1. We sit down with the client and work out a set of policies everyone can live with to cover the basic questions of employment, unemployment and sharing the benefits of increased productivity. We limit our work to client companies who are willing to do this. Generally speaking, the sharing formula works out like this:

> 25% of the benefits to "Consumers" (the people who buy the product or service). This is done through price reduction, quality improvement, product upgrading, better services, and the like.
>
> 25% of the benefits to "Cooperators". (That's the term we use to descirbe everyone who works in the enterprise from the janitor to the president). Usually this money is put aside as a kitty out of which the wage increases can be paid.
>
> 25% of the benefits to "Creators". (That's what we call the people like yourselves who think up the good ideas that reduce the costs in the first place). Frequently, this is done through something like a suggestion plan, performance appraisal, plus research budgets

to "keep up the good work".

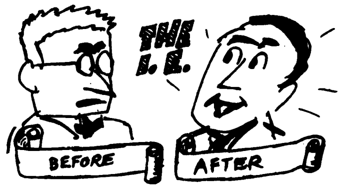
25% of the benefits to the "Co-owners" (shareholders). They deserve something, too--but not all! Of course from their standpoint, sharing works out to be good business as well as good morals, since profits invariably go up.

This formula benefits everyone--and doesn't cost anyone a cent.



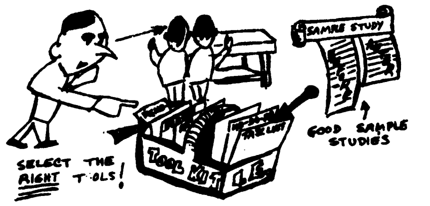
2. After we have checked into the economic soundness of the company's program for dealing with rising productivity, we endeavor to take a picture of the corporate image from the viewpoint of the people who work there. We, then, are in a position to get specific about the things that have to be done if the proper "climate" for the total program is to exist. We call this step the "basis diagnosis" and it includes an audit of the company's performance of meeting the human needs for security, recognition, and self-expression. We always follow a policy of protecting employment as productivity rises. This is not as difficult as it first appears to be if there is sound advance planning .

3. Next we retrain our Industrial Engineers, systems men, organizational specialists, quality control, and personnel people: everyone who is expected to "service" a productivity program. Basically, this is a plan of training that is aimed at allowing the Industrial Engineer to "stop doing Industrial Engineering work and to start doing humanity's work." He learns how to re-orient himself into the kind of role occupied by a beloved teacher you once knew, instead of "the needle" on methods.

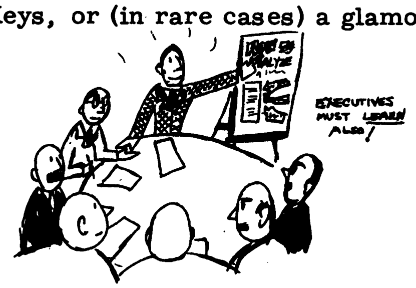


4. At this point we decide which tools of Industrial Engineering have the greatest "pay-out" prospects in each division of this company. This is done by evaluating the type of work each does, selecting the tools we ourselves, as management consultants, would use to improve their operations. As a result of this step, we can "prescribe" tools much as a doctor prescribes medicine. We work out some "sample" case applications.

5. Now we are ready for top management. We get the chief executives together. It may either be all of the officers and division heads, or this group plus the board of directors. We give them an appreciation session and have



them take part in enough productivity demonstrations and problems to make sure they know what it is all about. Usually we take them away to some retreat atmosphere such as you will find in a hotel in the mountains, a spot in the Florida Keys, or (in rare cases) a glamour



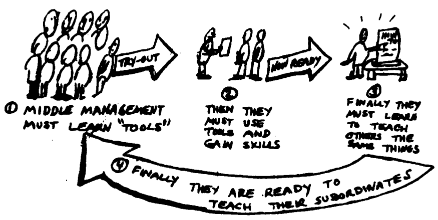
setting such as the Prado do las Americas in Acapulco, the Virgin Isle in St. Thomas, Sjusjoens in Norway, or the Hougenpot Castle on the Rhine. (We'll go to the French or Italian Riviera if necessary, and stop twisting my arm.) The point is: whatever is required to get the executive group away from the day-to-day realities of turning out work and into an atmosphere of inventive curiosity, we will do. This usually involves 24 hours of "sessions" spread over a three-day period.

6. Next we "train trainers". This involves taking the members of middle management, superintendents, office managers, and other supervisors of supervisors, and teaching them how to use the specific tools of Industrial Engineering that were previously selected. Then come the assignments and "homework".

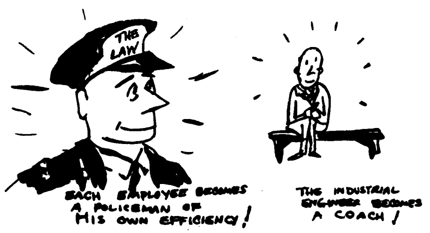
The training phase lasts one week--usually from 1:00 P.M. to 6:30 P.M. daily. After that, they go back to their regular jobs; look at the work through new eyes; and study some specific aspects of it just as though they were Industrial Engineers. While they are doing this they are competing with their fellow members of middle management for some rather exciting citations and prizes.

7. After the "spring try-out" period, usually from a month to three months, we bring our conferees back together for one additional week of intensive training; this time from 9:00 A.M. until 5:00 P.M. daily. During this time master teachers show them how to train their subordinates the same way they were taught during the first round-table. At the same time their "case problems" are reviewed and individual counseling is given. By this time the conferee knows how to increase productivity himself and how to teach it to others.

8. He goes back to his own division of the company and selects his first round table group: between 7 and 12 men. He starts out with several two-hour training sessions aimed specifically at attitude-formation in respect to productivity. He explains that in the future "each man will become a policeman of his own efficiency" and that the job of management and methods improvement will become the responsibility of the fellow who does, or controls, the work.

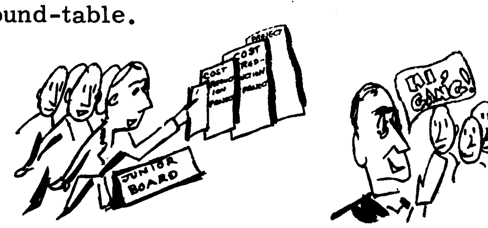


The Industrial Engineers then proceed to quietly move off the playing field over onto the bench where they coach, but let the line supervisors carry the ball.



To put them in a position to do this ball-carrying, they receive stimulating training in the basic tools and techniques. For this job, he is aided by a series of visual aids for each "tool". They provide the instructional core for teaching foremen and supervisors how to make process charts, work distribution analysis, chronocyclographs, and so on. Generally, we devote two hours to "how to make" on each tool and then give our conferees specific assignments. Then they go out to their work areas and use the tool. Generally, two weeks later they return to the round-table to learn how to analyze and improve the operations they have documented.

9. After the training phase, which usually lasts about three months, the round-tables carry on in the "junior board of directors" tradition. The "instructor" moves out of the picture and becomes available only as requested as a counsellor. The round-tables or boards submit projects through the usual channels covering work they wish to study. Each conferee, in turn, concentrates on his own projects in his department, either independently or with a team of cooperators selected through the round-table.



10. Having had a demonstration of results, each conferee in turn has an opportunity of establishing his own round-table for subordinates in his own department or section. Most participants are eager to carry the message to all possible ears and hearts.

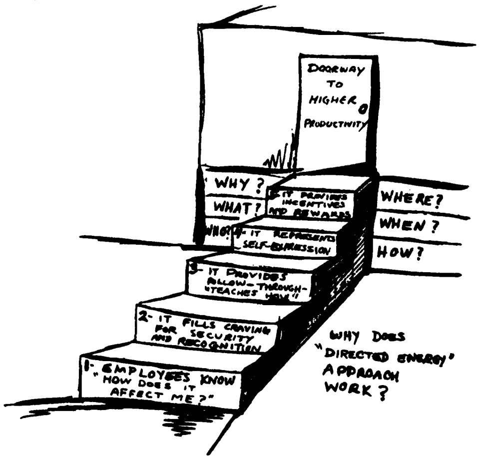
If you ask me today why this method works I am not sure I could answer you, although I am sure I could have given you an articulate explanation ten years ago. Basically, I think it works for some very simple reasons:

First: The company's policy about technological advancement is well known in advance. Everyone can see clearly that he will get a break as productivity improves, and he knows exactly how it will be done, and how it will affect him.

Second: A feeling-of-belonging is derived from being selected to become a member of a round-table. It satisfies the need for security and recognition.

Third: Once a man is "tapped" for participation he is not forgotten. Management provides training so he learns how to use the tools. What is it to be in favor of higher productivity if you don't know how to go about the task of bringing it about?

Fourth: The round-table provides the needed avenue for Self-Expression. Every type of "resistor" eventually yields to the opportunity of waiting until the other fellow shuts up so he can tell you the right way to do it. (Footnote: Frequently he can).



Fifth: The substantial rewards and commendations that go with successful performance in the idea-invention arena stimulate everyone to "get in the act". When everyone gets to thinking about everything he does, and asking "why", you can't help but get results.

To date the results have been most encouraging. To put them in terms you and your presidents will readily understand:

> During the last five years the average return on these programs has been 630% per annum. In other words, the company that invested $10,000 in an installation is getting $63,000 per annum in savings.
>
> Morale has shot up by leaps and bounds. People are happier and healthier. And they are wealthier.
>
> A poll conducted in January 1959 revealed that 87% of company employees participating in Directed Energy Round Tables rated their jobs "the most interesting occupation I can think of" while only 17% of non-participating supervisors and workers rated it this way.

Here is one product of the laboratory that is working. The approach of tolerance would teach us there are other methods, and that others have some share of the truth also. I have tried to faithfully report on the one method we know works.

I started out by endeavoring to discuss some of the issues in the challenging world of which we are a part, and suggesting to you that the ultimate verdict as to the kind of world we leave behind rests not with politicians, or statesmen, or "great" men (because as Lincoln said "there are no 'great' men"), but with you. This is something you can do.

I heard on a "do it yourself" radio program the other day that "to avoid hitting the thumb with a hammer, grasp the handle with both hands". I suggest a different approach. It involves the total proper use of our tools, plus an understanding of the end-use accomplishment. That will automatically preclude their use by the I.E. only. When he is the only one to use the tools it is something like the definition I once heard of adultery: "The wrong people doing the right thing."

We live in a world of bewildering technological change, and conflicting political philosophies as to how to live with that change. This challenge need not rob life of all meaning. On the contrary, it can move us mysteriously to the brink of understanding--the infinitely beautiful flash of understanding of the unknown: the perception and comprehension that proves that God has worked in subtle and compassionate ways.

Research is for the curious of all ages. Invention is for the young--the young of all ages. The young know you cannot change man to fit the needs of business, but you can change business to fit the needs of man. How old are we?

Problems of Selection and Utilization of Information Processing Equipment

George W. Brown
Professor of Engineering and Business Administration
Western Data Processing Center
University of California - Los Angeles, California

This is one talk that has not required much preparation on my part. Sometime last year I was asked to talk to another group on standards for selection and utilization of equipment in the data processing field, and in preparing for that appearance, I discovered, of course, what I already knew, which was that there weren't any standards and indeed the state of fuzziness of the art was such that it didn't look like the time was quite right for talking about standards for selection and utilization of such equipment. The situation has not changed a great deal since the time last year at which I spoke on the same subject. We will talk about some of the obstacles in the way of standardization and something about the reasons for them and perhaps a bit about the hopes for progress towards a happier state of the world in these respects.

It's not just a matter of equipment capacity and cost. We have to examine the objectives, the organizational restraints, personnel, operating methods, procedures, and various other policies; - all these enter into the questions of selecting equipment and its utilization.

Now it's relatively easy to handle small changes, that is, any company or installation that's considering the addition or subtraction or substitution of a relatively small proportion of its equipment has a fairly easy time evaluating this change. In this field there are many opportunities to consider large changes, mostly involving new types of equipment, equipment that obsolesces rapidly. There are a number of uncertainties and dangers involved, as in any situation in which we have to estimate in advance the effect of making a very major change. One major reason for considering such changes is the familiar fact that data processing equipment in general tends to vary in capacity very nearly proportionally to the square of its cost. Thus, when something new comes out from which you can expect to get four times the output with twice the expenditure, you can see that you've got a major decision to make, determining whether or not to make the change that's indicated.

Let us now examine the typical process of deciding to make such a change in the data processing ways of some enterprise. They always have a preliminary feasibility study, and it's almost always called that, "feasibility study." The purpose of this study is to determine the areas of potential application, to determine the general types of equipment which will be considered, to anticipate probable organizational structure to go with it, and to estimate costs and time to achieve the change.

The next step is generally called an application study, or the application study phase. This is after the feasibility study has been successfully concluded, and successfully concluded always means that they have decided they will do something and not stay where they are. So now we get into the requirement to study more deeply the particular application. It generally turns out that during the application study, it's not possible to formulate all of the applications that you would probably put on the nice new device you are hoping to get, so what generally happens is that a so-called typical application gets formulated. It's intended to be typical of the things that you will hope to do; this typical application may also be used as a basis for requesting bids from equipment manufacturers.

The next step is the equipment selection stage. At this point everybody takes a trip to Poughkeepsie or Endicott or Philadelphia and perhaps a few other places. This is the period of the wooing by the manufacturers, and one way or another at the end of this period (sometimes it's an Alice-in-Wonderland process) a set of equipment is ordered.

The next stage is planning for the installation. Something we do very well is the planning for the physical installation. We do that very well. People aren't yet planning very well in other respects. But let's suppose in this period that we go on with the application studies; we go on with making firmer plans for the things that will be done first and we thinkwwe see how to set things up organizationally etc., then the next stage is called installation and conversion. This means the conversion is twofold., There is a conversion of data, often called for. You are familiar with the fact that one system may have things on a manual filing basis and another system expects that the data will wind up on magnetic tape. In addition to the data conversion process there is, at some stage, a systems conversion to be done. When there is a major change in the information processing procedures you can't close up shop one day on one system and open up the next on another system. A common solution of the system conversion problem is to run side by side in duplicate two different kinds of operations, both to achieve the same thing, and usually when the new one is doing about as well as the old one, we can cut over.

The next stage really goes on all the time. It's review of what's happened and changes of plans and feedback in general.

At each of these stages people are re-estimating the costs. In fact they are about as busy estimating costs of these processes as they are doing anything else. As you would expect, the costs, as estimated, get higher and higher and higher as you get closer to the day of change-over and they continue to climb after that day. This seems to be standard and is typical of the field, simply because the oversights, the misconceptions and various other changes that you hadn't thought about all begin to catch up with you, and so almost uniformly the operational results of this whole process come out below expectations. You don't really know what you've got until you've got it. Of course, in passing it's easy to note that this field isn't the only one that suffers from that difficulty. But the basic reason for it is that the analysis required to tell what to do is proceeding over a period of time that's very long compared to the period of time in which the problems are changing. That is, problems and boundary conditions change day-to-day and the analysis is normally inadequate to deal with the changing situation.

There is a celebrated example of an installation which acquired the very cheapest machine possible, in terms of performance per dollar. Now, the fact is that the machine outperformed anything else the people were considering. It also outranked all the other machinery in cost, but the ratio -- performance per unit cost -- was more favorable for this device than for any other. It just so happened in the particular example I have in mind that the group later ran up against an almost irremovable bottleneck. They were unable to program enough applications ever to use more than a fraction of the capacity. You see they bought more capacity for more money, per dollar they bought it very cheap; they expected to program up to capacity, but they just couldn't cope with the problem of providing operating programs to use the machine and still keep up with changes in problem formulation. This is the kind of difficulty people often get into. It's certainly not the only one.

Let's now list the costs associated with this process. On the top of the list we have the equipment and maintenance -- that's easy, everybody expects to have equipment and maintenance and along with it comes the physical installation. This is again fairly easy to estimate, mostly air conditioning and wiring. The next cost that people think about is the cost of doing the systems analysis which is required, and that cost is of course not what is required to keep up to date, and you'll see why in a little bit. All through the process one has analytical costs. There is the cost of data conversion mentioned earlier, this cost itself is a non-trivial part of the cost of many of these jobs; it may involve many thousands of hours of key-punching and other manual translations of information in order to get from one system to another, but this is, in itself, often not too difficult to estimate.

Next are programming costs. This one is hard to estimate for the same reason that the systems analysis is hard to estimate, and indeed it's hard to tell where one ends and the other begins. And I'll come back to this in a moment. The programming costs are the largest "rat hole" in this whole process. They mount up during the period in which you think you are done or should be done, but you aren't.

Finally, the systems conversion period. Well, that's pretty obvious. Until it's pretty well debugged you don't convert, but the cost has to be charged in because you are operating in parallel for a period of some time. The real variable in the systems conversion cost depends on how long the debugging process goes on; that is, the debugging costs you something, but it costs you twice. It costs in the services of the people who are debugging and it costs in the fact that there may be two systems running side by side during the whole debugging period.

Next on the list are the operating personnel. This estimate never comes out quite right, but in terms of actual operations, we generally don't miss this as badly as we miss some of the other costs. I should add to these the costs of making further changes. Again, because no system remains or can remain static and frozen, laws change, various environmental factors change, the nature of the business changes, and as the parameters of the system change one has to expect to make changes in the information processing system that goes along with it. And these changes, future changes, are a part of the cost of making a change now. It may be hard to estimate them but if you put yourself into a position from which it's more difficult to make changes in the future than it is now, then you ought to be charging yourself something for this; that's just common sense economics.

Let's talk about equipment for a while. I'm not going to talk about specific sets of hardware but about the attributes that give us such a bewildering choice with respect to equipment, either available now or to be available before long. There is an infinite richness of options available for tape configurations, random access files, interrogation stations, on-line input-output equipment, various kinds of peripheral equipment for conversions between cards and tapes, off-line satellite computers, and so on. These things are all either around or about to be around so soon that they must be taken into account, particularly by those who must consider large systems. Of course the price range is fabulous. The system can be fairly ambitious at a cost of a few hundred thousand dollars, or it can go on from there into many, many millions of dollars. That's the price range that people have to chose from in deciding what they are going to do in major installations. Of course if you are talking about something relatively small, the price range gets extended downward; perhaps to as little as $25,000.

The development cycle for this equipment is very rapid and that's the basis of 90 per cent of our problem. There's the always imminent chance that the equipment you just bought will be replaced by something to be announced very shortly. This happens to most everybody; in some respect it has happened to everybody, and in fact, there hasn't been a computer that wasn't obsolete by the time it was delivered. This is the nature of the field.

As a corollary to this rapid development cycle you discover that there's a built-in kind of incompatibility. As we get to a very ambitious system it gets to be incompatible with another set of equipment that's going to be the next one down stream; this incompatibility results from changes in logic and structure in the system. We don't have to go into any great detail, but you can see that the work of getting started on one of these systems involves a great deal of effort and somehow once it's done people hate to have to do twice as much all over again in order to do something different. But this rapid development cycle somehow generates an incompatibility with what you've been doing.

Then there's a tremendous amount of variation in what the manufacturers will offer in the way of services to people who are thinking about getting their equipment. There is not only variability in the kind of maintenance that's available, but in application to systems and the development of operating and programming techniques and in other back-up services. These things vary a great deal from manufacturer to manufacturer, and they happen to be a fairly important part of the intangible value of dealing at one place versus another, depending on what you are planning to do.

Related to this is the relationship to other users. One manufacturer may have a relatively large number of obsolete equipments out in the field, a lot of people have them and they have solved problems like yours. Another manufacturer has something which looks much better but you are going to get No. 1 or maybe No. 2. You don't have the benefit of anybody else's experience. You can't borrow either programs or experience. It's the kind of trade people have to make. It isn't just like selecting which of the big three or I guess big 4 or 5 now; it's not that simple. Coupled with this, of course, there are the biases of people and other considerations. By the biases of people I mean the familiar fact that anybody who's dealt with computers finds right away, the fact that forever after the man loves the machine he first got exposed to and all future machines should be like that one. Again he hates to put in the same kind of investment ever again, but somehow people get very emotional about this. There are people who just won't deal with manufacturer A under any circumstances, even if he offered a million blue chip stamps, there's just no way that he will deal with manufacturer A, he is persuaded he shouldn't deal with that manufacturer. There are others who feel just as strongly in the same negative way about manufacturer B or C, and then there are others who feel very affirmatively about such manufacturers. These things are highly emotional, highly irrational, yet we find them very commonly.

Now I want to talk about some of the organizational aspects of the problem; for example, centralize vs. decentralize. Computers get to be a battleground for which empire will get developed; should it be a separate empire; should it report to the general manager or the president or to whom. One possibility that hasn't been much thought of so far, but which I think will become more important pretty soon, is having centralized service with centralized equipment, but having actually decentralized functions manage their own use of that equipment. This is something that hasn't really been practical so far but there are signs that it will become more practical; perhaps someday we will be able to share computer and information processing services within any company the way we now share switchboard facilities. We don't stop and ask whether the chief operator ought to report to the general manager or to the president because everybody in the company has a telephone. Yet the corresponding kind of question is commonplace in data processing.

Closely related to the organizational problems are data flow problems, for example, the question of whether one consolidates files for economy because they have information in common or whether one permits the duplication of files in much the same way they are duplicated now for different uses. Argument rages incessantly on this point. It is natural to feel that one ought to be able to economize and put files together, but then you have to face the fact that you've built in some rigidity. Thus, if for one operation sharing this file you want to make some changes, you may upset everybody else and you may be essentially unable to make the changes. These are traditionally the reasons people organize separate files in the first place, and you can remove all those differences and consolidate as you will, and some of these reasons will show up again, so that you can't adopt an ironclad organizational principle in this respect any more than anywhere else.

Obviously decisions regarding organization and who's going to run it are key decisions. Who to run it is nontrivial to settle. We are all familiar in this area with certain companies in which there is a constant struggle between engineering and the controller; the people in engineering know more about this field somehow, but they don't know much about other parts of the business. People in the controller's activity know a great deal about the business but not so much about this field. Will we build the empire in one place or the other, or, as an alternative, are we going to have to yield to pressure and create some kind of supermanager who talks only to God in order to get on with the job. Clearly this can become ridiculous, and often is.

I want to talk now about some of the programming and operating problems which enter. Some of the earliest major applications involving data processing involved the order of several hundreds of thousands of handwritten instructions. That's what it took to get a program just to do file maintenance on life insurance policies. It sounds strange but that's indeed what it took. We are now quite a distance from there but we haven't gone all the way. People are no longer writing those instructions by hand, in the idiot language of the machine. They now use methods that seem rather more sophisticated, involving the use of compilers which will operate on the program material which programmers submit to produce by machine the idiot language of the machine. That's one step away from the idiot language. Progress has occurred in other ways, as well. There exist now "generative" programs for such things as sorting, outputting printed reports, file maintenance, statistical procedures, and so on. These generative programs have the property that every time you want a new application, it is not necessary to write a new program. You simply specify some parameters for that application and the program generator writes the appropriate program for you, but it obviously involves analyzing the class of applications in order to do once the kind of work that people have been doing over and over again. Of course, there are other languages that people use to write programs in, languages which are so-called "problem-oriented." A typical example is Fortran language, an algebraic language for doing more or less scientific and engineering calculations on IBM's equipment. Algebraic-type languages exist for other equipments. Then there's Flowmatic, which is a Remington-Rand's Univac language oriented towards the business area. People are now able to write programs using notations that are closer to the problem area than what they might have in the past. Currently a great deal is going on along these lines.

I promised to say something more about the relationship of the programming system to the systems analysis. The real difficulty is that tools and languages for doing systems analysis on information systems are not sufficiently precise to permit us to get a complete and unambiguous analysis short of having a debugged computer program. That is, to say it in somewhat fewer words, we are not sure that any systems analysis is completed in this field until the final program is debugged and running, and not before that have we completed the systems analysis. You can't tell in this process of debugging how much of it is due to simple programming oversights and how much of it is due to logical oversights that go back to the original conception of the system. Our formulation of the system, short of the computer program, is not sufficiently detailed to put the formulation to a test so indeed the only precise formulation of the problem as a problem in information flow that we are likely to have is the finished and running program for a specific machine.

Now you can see where the incompatibility problems come from. If somebody says, we'd like to import another set of equipment to do this job, what you find is that you don't have an analysis of the system; you have a program which, unless it will run on the new machinery, is not terribly helpful to you when it comes to considering new machinery as a way of doing things. This is clearly one source of problems.

Along with the difficulties inherent in our language defects, there are some difficulties inherent in the way people approach programming and systems analysis. Somehow or other, the profession at large hasn't learned about documenting what they have done. But it's a natural enough difficulty. You have a job, you are under pressure to do it anyway, you know you can't possibly meet the deadlines you've got, how can you, under those circumstances, invest 10 per cent of your effort into documenting what you are doing. If it's even 10 per cent you can't do it. That's the nature of the beast. But if you don't document what you've done, the man who's done the major job of analysis gets a promotion or leaves the company or six months later, when a change has to be made, even if he is still with you he doesn't remember what was going on in his mind when he did this job. How, then, do you recover the benefit of the original effort? Again, it's a matter of the language deficiency. We don't have the ways to write it down, and it's the natural tendency of people to do as little documentation of their analytical efforts as it's possible to get away with. This is why it is difficult to make changes. This indeed is why it's difficult when somebody's written a dandy program that's one machine pass doing four jobs on consolidated files and suddenly somebody else changes a withholding rate or something else trivial and then the whole mess may require reanalysis. Perhaps somebody didn't leave space for one more character in a record and this fact is essential to the whole system. It's like kingdoms and horseshoe nails, the kind of thing we are into every day in this field. Well, I could go on with this, it just goes on and on. There are plenty of misconceptions about this on the part of those closest to the field. These people, using the computers themselves, hate to feel that automatic operator programs (for example) are somehow better than having people mess with the system, but they are. The very people who are in a sense revolutionizing the activities of a company by pleading for automating those activities through data processing, are often the most conservative, in fact reactionary when it comes to applying the same notions to their own activities. They are the people who stand in the way of modern programming systems, who stand in the way of sensible operating procedures in large installations, because they once learned how to do it and that's the way they want to do it forever. They suffer from all of the blindnesses that they accuse the managements around them of having with respect to the mechanizing of procedures that are required for the business.

I've said that there were some things happening that are going to make the situation improve. I'll run down it very quickly in the remaining time.

There are more efforts going on in the so-called "problem-oriented" languages. There was a conference on data systems languages called Codasyl. It was put together by a group at the request of the Defense Department. It involves the major manufacturers and the product of that activity is to be called Cobol, which means "common business-oriented language." This is supposedly to combine the best parts of the business languages of the various manufacturers as they exist now. If this ever goes through, we'll find all major machines able to cope with a language which is pretty much standard for all of them. On the algebraic side there has been a international effort going on for some time on a language called Algol. Also I believe the American Standards Association is in this act trying to standardize on such things as characters, codes, conventions and the like. These sound like pretty trivial things, but it's about as bad in our field as trying to work in the mechanical field with nonstandard threads.

There's a modular trend in equipment. This is really going to help solve all these problems. Instead of viewing a major installation as some monolithic large machine, all one single device, we're really going back in a way to the philosophies of the oldtime installations, with individual boxes that do different things and with the sharing of tasks of somewhat different kinds in parallel amongst such things working together, with the mixes of equipment being very flexible. Of course, the difference between this and the old-fashioned tab installation is that there won't be so much carrying of cards around from one place to another, and these new machines will share access to common files, memory etc. But with this trend toward modularity, we're going to have to face some of these programming problems as well. Some of them we've put off, that we've tried to sweep under the rug, will no longer stay swept under the rug. The only way we can deal with this system is by developing the right kind of formula for describing and scheduling parallel operations. In fact it begins to resemble the machine shop, the job shop, for scheduling. This may not sound like a blessing, but I believe it is. Someday we may even standardize what these basic operations will be, at least for a while, as they were standard for many years in the tabulating field. Someday the organizational level at which the physical hardware sits will be irrelevant, just as irrelevant as the organizational level of the plant maintenance people.

Meantime, while there may not be any right way to do things, it's worth noting that there are organizations that seem to be able to support flourishing activities in electronic data processing and seem to feel that they can accept them. There are also a number of them that have great trouble and it's curious that there seems to be somewhat of a critical threshold for the environmental circumstances. Under some circumstances people make an attempt and it all dies. Under circumstances which seem not terribly different in another place it all takes hold and within two years everybody is happy as a lark. I think that we are learning something. I think that some of the things I've mentioned plus a possible stabilization for a little while of the hardware, to come pretty soon, may make quite a difference. But meantime, unfortunately, we can't really talk about standards for selecting and utilizing data processing equipment.

COMPUTER SIMULATION OF MANUFACTURING OPERATIONS IN THE GENERAL ELECTRIC COMPANY

Richard S. Clement
Business Planning Specialist
Distribution Transformer Department
General Electric Company
Pittsfield, Massachusetts

INTRODUCTION

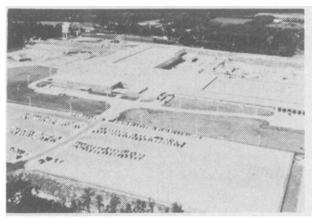
Computer simulation is really an exciting experience. And, I might add, an expensive experience. Do I wish to discourage you from trying simulation? Not at all. The opposite, in fact. I wish you could share the visions we in the General Electric Company have of the-not-too-distant future: visions of managers of Production Control testing a variety of alternative production schedules for "fit" before releasing to the factory floor; images of managers of Industrial Engineering accumulating 10 or 20 years of "experience" with new factories before hiring the architect! These things have already been done in several Departments of the General Electric Company. In a few years, at the rate it has been growing, computer simulation will be common practice.

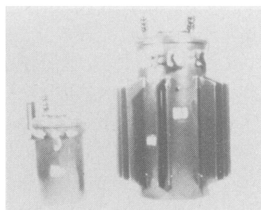
But, as I indicated earlier, computer simulation is expensive. Frankly, we have made some costly mistakes. However, during the past three years simulation effort within our Company has expanded smoothly in an ever widening circle, growing both in numbers of applications and in sophistication of the simulation models used. This progress is the result of a carefully thought out program developed and implemented by our Company-wide manufacturing staff (i.e., Manufacturing Services Division).

In this paper I will describe the basic elements of simulation model development. The easiest way to do this, I believe, is to tell the story of how we developed our first model. That story will embody all of the basic points I wish to cover. Later I will summarize these main points and will tell of subsequent simulation work within our Company.

THE HICKORY MODEL

In early 1957 a study of the Tank Shop of the General Electric Company's Distribution Transformer Plant at Hickory, North Carolina was undertaken for the purpose of defining the capabilities of that shop. It was felt that the Tank Shop was inadequately understood and represented a potential trouble spot due to its highly erratic down-time behavior. Also, a few months of operation at the Hickory Plant had revealed unexpected improvements over productivity at the older plants of the department, presenting an opportunity for substantial increased capacity of the Hickory Plant. The Tank Shop represented a possible roadblock standing in the way of a general increase in plant output. Slides #1 & 2.

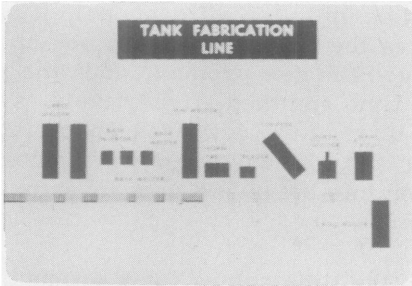




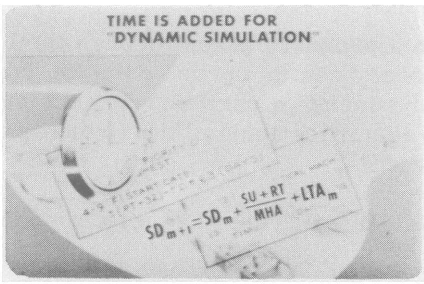
The Hickory Tank Shop is a series line with a fairly high degree of mechanization. The sequence of operations in tank fabrication is as follows:

1. Roll casing into cylinder.
2. Flash weld seam.
3. Strip scale from seam.
4. Bead top.
5. Punch bushing holes.
6. Weld fins (approximately 40% transformers having cooling fins).
7. Insert base into cylinder.
8. Weld base.
9. Weld hanger bracket, lifting lug, etc.
10. Weld remainder of parts.

Slide #3.



A study team of Industrial Engineers at the Hickory Plant spent five months collecting and analyzing data. The data consisted of time studies, production schedules, tank characteristics, history of breakdowns, etc. After a long, serious attempt at manually manipulating this data into a meaningful description of Tank Shop behavior, it became obvious that an electronic computer would have to be brought to bear on the problem. Slide #4



Accordingly, the Manufacturing Services Division (i.e., the Company's central manufacturing staff) engaged a team from the Computer Department to design a model of the Hickory Tank Line, and to program it for a 2000 word memory computer. The modeling team, composed of a mathematician and two programmers, spent three months performing the job.

The resultant "model" is a six inch deck of punched cards. This deck can be reproduced to make more models for use on other computers. Furthermore, any desired combinations of machines and any sequence or combinations of products can be simulated without reprogramming the computer. Thus the Hickory model is not a model of the Hickory Tank Shop. It is a a model of a typical "flow" shop, of which the Hickory Tank Shop is an example. Without reprogramming, the same model can be used to simulate a motor frame fabrication line or any other manufacturing line which falls within the capacity limits of the model, as follows:

1. Up to 25 machines (in series)
2. Up to 25 inventories.
3. Up to 20 different product varieties per run.
4. Up to 10 product physical characteristics (i.e., for set-ups).
5. Up to 250 jobs can be processing at one time.
6. Up to 300 jobs can be in inventory at one time.

In order to understand the potential of this model, and its limitations, it is best to skip ahead now to what the model gives us, then come back to how it does it. Appendix No. 1 is the "output" of an abbreviated computer simulation run of the Hickory Tank Shop. The computer gave us this information in accordance with the instructions of the model (i.e., the six inch deck of punched cards). These instructions were for the computer to produce a given quantity of a given variety of tanks in a given sequence and to tell us what happened while doing this, specifically:

1. How many tanks were in process in the Tank Shop, and where were they, at five minute intervals? This information is listed under "History of Queues" (still referring to Appendix No. 1). This tabulation reads from the right, starting with Station No. 16, to left.

2. When was each tank finished? See column titled, "Tank Production."

3. How much set-up time was incurred by each machine? How much process time? How much idle time due to log jams downstream (called queue delay)? And how much idle time due to lack of material (called starve delay)?

4. Finally, the computer was told to tell us what its exact state was when the run ended (i.e., How many tanks were still in process, none in this case; and what were the machines set up to produce at the time the run ended).

Without describing the details of the computer program we can get a feel for the logic of the computer (or, more correctly, for the men who designed the model) if we think of the model in terms of three simple building blocks.

1. Products
2. Processes
3. Inventories

Products - Each product type is characterized in the computer by an identification number and up to ten physical characteristics. Each physical characteristic can have up to ten classes. For instance, we found that all tanks at Hickory could be adequately identified by ten characteristics, as follows:

Physical Characteristic Number	Description
1	Number of fins
2	Diameter of tank
3	Length of tank
4	Length of fins
5 etc.	

As an example, physical characteristic No. 2 had four classes of tank diameter:

Class	Description
1	14" diameter tanks
2	16" diameter tanks
3	19" diameter tanks
4	21" diameter tanks

The only other piece of information associated with a product during a computer simulation run is the "time" identity given each product as it enters the system.

Processes - Each "process center" (i.e. machine) is characterized in the computer by the amount of time it takes to process the various product types, the amount of time it takes to set up from one physical characteristic class to another, and the number of units it can process at any one time.

Inventories - Each "inventory center" (storage area or conveyor between machines) is characterized in the computer by its capacity and the elapsed time required for a product to pass through it (i.e. This has meaning in the case of a paced conveyor.)

The thinking process of the computer during a simulation run goes something like this:

1. The first product enters at the start of the run (the time in tenths of minutes is 0000.0) and presents itself to the first process center for processing.

2. The process center first compares the physical characteristics of the new product with the physical characteristics of the last product that passed through to detect any differences. If any (there could be up to ten differences), it calculates the time required to set-up to produce the new product, adds the process time and then, figuartively, sets the alarm of the new product to ring when it is to move out of the process center into the subsequent inventory center.

3. When the time comes for a product to leave a process center it moves into the succeeding inventory center providing, of course, that the inventory center is not already full to capacity. If the inventory center is full, the unit cannot move out of the process center, and the process center begins to log idle time due to "queue delay." When a unit does enter the inventory center, the alarm of the product is set to ring when the "transit time" through the inventory center has elapsed.

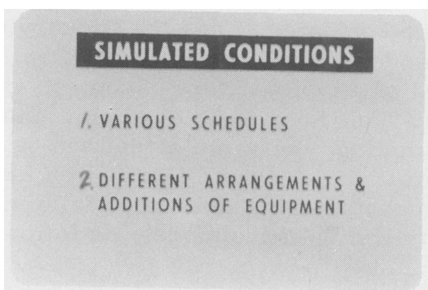
4. When a product passes through the last inventory center in the shop, the computer punches a card showing the product identification and the time it was finished.

If the reader will refer again to Appendix No. 1:

1. Note that the "History of Queues" is no more than an inventory of work-in-process taken at regular intervals. Inasmuch as each process center and each inventory center in the computer knows at all times how many units it holds, it is a simple thing for the computer to print this information out whenever it is requested to do so.

2. Note that the totals of process time, queue delay, etc., for each center are merely a print-out, at the end of the simulation run, of the totals which the individual centers have accumulated during the run.

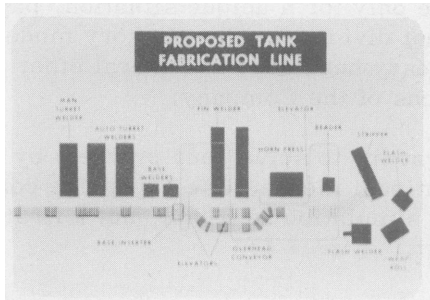
Slide #5



We first made a series of "relative" simulation runs which compared the effect of scheduling all tank varieties (10 - 100 Kva inclusive) once each week, three times per week and daily. The model showed us, much to our surprise, that set-up was not nearly so important a factor as we had thought it. After thoroughly investigating the "relative" effect of various scheduling frequencies on Tank Shop output, we turned to the question of what was the "absolute" capacity of the Tank Shop at the optimum scheduling frequency.

Our decision was to add 10% to all process times in order to compensate for miscellaneous delays, including machine breakdowns up to 3/10 hours. This was a purely arbitrary decision on our part. Secondly, we decided to end argument regarding the accuracy of our set-up data (some felt it was too low) by making a second "absolute" run using doubled set-up values. The results ended the argument -- there was not enough difference in the answers to argue about. We next took the simulated "absolute" capacity answer (units/week) from the computer and plotted it as a straight line over a sixty working day period. From that "absolute" capacity figure we manually subtracted machine breakdowns, taken from actual shop records.

We made a variety of "absolute" simulation runs on the computer using various quantities and varieties of Tank Shop machines. If we wanted to know what would happen if we had two flash seam welders instead of one we would change the input data to the computer (i.e. change the punched card which defined the capacity of that machine to two) and make another simulation run. If we wanted to know what would happen if we improved the efficiency of the horn press 25%, we merely had to change the input card to the computer which described the process times of the various tank types at the horn press (i.e. reduce those time values by 20%). In this way we accumulated a wealth of experience with the Tank Shop. We learned some things and, perhaps as important, we unlearned some foolish ideas we had held regarding Tank Shop behavior. However, it should be stressed that the computer did only the simple data manipulation and left the creative work to us. We got back from the computer only what we put into it. Slide #6



By being able to test various machine and loading patterns we came to feel at home with our future Tank Shop. In the end we concluded that the desired capacity could be obtained from the Tank Shop in its existing form (one series line) with the addition of handling aids and more equipment. Also, we discovered that we could get more output from two fin welders and an overhead storage conveyor, permitting constant use of the two fin welders, than we could get from four or more fin welders used intermittently. Finally, we were able to prove that the Tank Shop could operate economically on the higher frequency scheduling pattern required by customer demand and the needs of the rest of the shop.

BASIC POINTS

The Hickory Tank Shop Model was our first successful manufacturing simulator. We learned the following from this experience:

I. Three kinds of skills are required to do successful simulation work:

  A. Practical knowledge of the industrial situation to be simulated... represented in the person of an Industrial Engineer.

  B. An ability to translate the practical situation into abstract concepts... best done by high caliber Mathematicians trained in computer use.

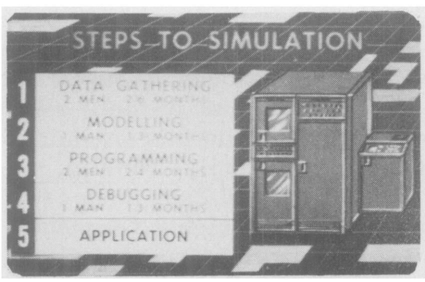
  C. Intimate knowledge of computer programming (i.e. trained Computer Programmers).

II. The additional time and cost required to design a "universal" simulation model (i.e. applicable wherever the same conditions exist), rather than a model suitable only for a unique situation, pays great dividends. The Hickory model has already been used in several other locations of the Company.

III. First try to solve your problem by conventional means. Use expensive computer simulation as a last, not a first, resort.

IV. Be wary of broad-brush treatment of the conditions to be simulated. A carefully detailed ground-up approach will yield more gains than will highly generalized models.

V. Start with a simple simulation model. Do not undertake more difficult models until after successfully designing and testing simpler models. Slide #7.



SUBSEQUENT WORK

Since the Hickory model was completed, a number of other simulation models have been designed and used in the General Electric Company. Several are outgrowths of the Hickory model, making it bigger and more comprehensive (e.g. it can now simulate machine breakdowns).

Other models have been designed for use in simulating job shops. The most powerful of these is the GEMS Program (i.e. General Electric Manufacturing Simulator). In the words of its originators:

"GEMS is a series of computer sub-routines instead of one large all-inclusive computer program. Thus, many different versions of GEMS can be created simply by selecting and piecing together the appropriate sub-routines from the GEMS library."

A partial list of the GEMS capabilities includes:

A. Alternate routing.
B. Overtime.
C. Assembly of any numbers of levels of sub-assemblies and parts.
D. Use of outside vendors.
E. Lot splitting.
F. Expediting.
G. Rescheduling.
H. Random machine breakdowns.
J. Floating manpower.
K. Labor stealing.
L. Job grouping (i.e. to save set-ups).

CONCLUSION

In conclusion, computer simulation is here, today! It holds out to us an opportunity to eliminate a great deal of the intuition in our decision making. However, unless it is approached realistically, simulation can become an expensive toy. Our job...our opportunity...is to make it a practical Industrial Engineering tool.

SIMULATION PRINTOUT

AN EXPERIMENT IN DYNAMIC SIMULATION APPLIED TO SCHEDULING
FLOW SHOP MANUFACTURING OPERATIONS

DYNAMIC SIMULATION MODEL OF THE HICKORY TANK SHOP

DISTRIBUTION TRANSFORMER DEPARTMENT   GENERAL ELECTRIC CO

RUN NUMBER	DATE	ACTUAL RUN START	ACTUAL RUN STOP	TOTAL ELAPSED TIME
108	4-21-59	1000	1008	8 MINUTES

SHOP TIME -- 70 9/10 MINUTES SIMULATION TIME -- 8 MINUTES
RATIO OF SHOP TIME TO SIMULATION TIME -------- 9 TO 1

HISTORY OF QUEUE AT 5 MINUTE PRINT OUT INTERVALS

STATIONS ARE IDENTIFIED AS FOLLOWS -- FL - FLASH WELDER ST - STRIPPER
BD - BEADER HP - HORN PRESS   BI - BASE INSERTER   BW - BASE WELDER
TW - TURRET WELDER   IN - INVENTORY CENTER

TANKS MOVE FROM RIGHT TO LEFT -- STATION 16 - FIRST STATION
STATION 00 - LAST STATION

```
SHOP TW    TW IN BW IN BI IN    IN HP IN BD IN ST    FL
TIME 00    02 03 04 05 06 07    09 10 11 12 13 14    16   STATION NUMBERS

10005000 00 00 00 00 0      1 00 00 01 00 01 00 01 00 01 00 00 00 00 0*
```

AFTER 5 MINUTES OF SHOP TIME TANKS ARE STILL FILLING UP THE LINE --
THE FIRST TANK HAS PROCEEDED DOWN TO THE INVENTORY STATION BEFORE THE
BASE INSERTER -- TOTAL OF FIVE TANKS IN PROCESS

```
10010000 00 02 02 02 00 00 01 00 01 00 00 01 00 00 00 01 00 00 00 00 0
```

AFTER 10 MINUTES THE LINE IS FILLED - ONE TANK WAS ACTUALLY PRODUCED
AT 9 8/10 MIN- TOTAL OF TEN TANKS IN PROCESS

```
10015001 00 02 00 00 00 00 00 0            1 03 01 00 01 00 00 00 00 00
10020000 00 00 0  00                       1 09 00 00 01 00 00 00 00 00
```

AT 20 MINUTES TANKS ARE QUEUING IN FRONT OF THE BEADER THIS IS
CAUSED BY CHANGE OF DIAMETER SET/UP ON THIS MACHINE   NOTE STARVATION

```
10025000 00 00 01 02 00 01 00 00 01 01 02 01 07 01 00 01 00 00 00 00 00
```

AT 25 MINUTES LINE IS BEING FILLED WITH TANKS OF NEXT DIAMETER SIZE

```
10030001 00 02 02 01 00 01 00 00 00 00 00 01 09 01 00 01 00 00 00 00 00
10035001 00 01 00 00 00 00 00 0            1 10 01 00 01 00 00 00 00 00
10040000 00 00 00 02 00 01 00 00 01 01 00 01 10 01 00 01 00 00 00 00 00
10045001 00 02 01 02 01 01 00 00 00 00 00 01 09 00 00 00 00 00
```

AT 45 MINUTES THE LAST TANK HAS ENTERED THE LINE

```
10050000 00 02 00 00 00 00 00 0            1 09 00 00 00 00 00
10055000 00 00 00 00 0            1 01 00 01 07 00 00 00 00 00 0
10060000 00 01 01 02 01 00 01 00 00 01 00 01 02 00 00 00 00 00 -
10065001 00 02 01 02 00 00 00 00 0*
10070001 00 00 00 00 00 *
```

LAST TANK PRODUCED AT 70 9/10 MINUTES -- NO 75 MINUTE PRINTOUT

TANK PRODUCTION

RUN	TIME OUT TANK TYPE	
108	0000980002	AT 9 8/10 MINUTES THE FIRST TANK TYPE 02 CAME OFF LINE
108	0001050002	
108	0001130002	
108	0001200002	
108	0001280002	
108	0001350002	
108	0001430002	
108	0001500002	
108	0001580002	
108	0001650002	
108	0002780006	
108	0002880006	
108	0002980006	
108	0003080006	
108	0003180006	
108	0003280006	
108	0003380006	
108	0003480006	
108	0003580006	
108	0003680006	
108	0004370010	
108	0004440010	
108	0004540010	
108	0004610010	
108	0004710010	
108	0004780010	
108	0004880010	
108	0004950010	
108	0005050010	
108	0005120010	
108	0006190015	
108	0006290015	
108	0006390015	
108	0006490015	
108	0006590015	
108	0006690015	
108	0006790015	
108	0006890015	
108	0006990015	
108	0007090015	AT 70 9/10 MINUTES THE LAST TANK CAME OFF THE LINE

STATION SUMMARY INFORMATION

NOTE - STARVE DELAY FOR ANY PROCESS STATION EVEN NUMBERS EQUALS TOTAL SHOP TIME LESS SUM OF S/U PROCESS AND QUEUE DELAY TIMES

ST	TOTAL S/U	PROC TIME	QUEUE DELAY
16	00080	00280	00056
15	00000	00000	00000
14	00030	00240	00065
13	00000	00000	03766
12	00297	00280	00000
11	00000	00000	00090
10	00030	00270	C0000
9	00000	00200	00000
8	00000	00000	00000
7	00000	00200	00000
6	00110	00200	00000
5	00000	00000	00040
4	00070	00600	00000
3	00000	00400	00118
2	00015	00650	00057
1	00000	00000	00000
	70	00290	00000

STATION SET-UP STATUS AT END OF RUN TIME

ST RUN	TANK SET/UP CHARACTERISTICS
7160108	0191010228
7140108	0191010228
7120108	0191010228
7100108	0191010228
7080108	0000000000
7060108	0191010228
7040108	0191010228
7020108	0191010228
7000108	0191010228

SET/UP AT END OF RUN FOR STATION 16-- CHARACTERISTICS 1 2 3 4 5 6 7 8 9 10
SET/UP CLASS 0 1 9 1 0 1 0 2 2 8
THIS MEANS ST 16 FLASH WELDER IS SET/UP FOR 21 INCH DIAM TANK 42-1/4 INCHES LONG ETC AT END OF RUN

FUTURE DEVELOPMENT OF OPERATIONS RESEARCH

George B. Dantzig
Professor of Engineering Science
Director of Operations Research Center
University of California - Berkeley, California

As a result of the growth of industrial and government complexes, and the wartime progress in information handling, computation, and analysis, the post-war period has been marked by advances in the use of the scientific method for the planning and control of operational systems. This effort has been characterized by an increasing flow of information through operational and statistical reporting systems, and by the increasing use of planning tools (such as balanced programs and budgets). Although many of these techniques are not especially sophisticated, they must be appreciated as part of a movement toward simulation of large scale systems in order to better evaluate alternative decision possibilities and to effect better control of operations.

Out of this effort is emerging a new science, concerned with the problems of rapidly selecting optimal courses of action from many alternatives. This development, in conjunction with the mechanization of many simple, human, control tasks, foreshadows for the future the automation of many higher level, mental processes. In the not-too-distant future, machines will undertake many complex control tasks.

The broad group of studies dealing with decision theory and its applications, popularly referred to as Operations Research, includes investigations which have led to the development and generalization of new mathematical disciplines, such as linear programming, game theory, dynamic programming, and extensions to older disciplines, such as mathematical statistics. The products of this research have found successful application to decision problems of man-machine systems involving production, allocation, and distribution under stochastic, deterministic, and competitive conditions. This, in turn, has opened to consideration a host of new questions, calling for an expanded research program and additional trained personnel capable of doing research and of selecting and applying the available techniques to appropriate subject matter fields.

In contrast, the central function of engineering in society is the creation of predictable systems of facilities and processes for the performance of required tasks within specified time limits and budgets. Some essential aspects of this creative process are (1) planning and design (involving conception, analysis, and prediction of performance and cost); (2) direction and control of fabrication, construction, and processing (as governed by time and cost constraints); and (3) in all these aspects, the exercise of skill and judgment in the synthesis of requirements and the compromise of conflicts. While engineers, as individuals, may at any one time perform many specialized functions over the range of engineering effort, this philosophy of feasible design permeates and gives drive and meaning both to engineering education and to practice in all the separate specialties which comprise the spectrum of engineering activity.

Contrary to the focus of an earlier day upon design of isolated elements and processes, recent socio-economic and technological developments have created an urgent need for analysis of complete systems and for design of increasingly complex systems of facilities and processes. Thus, increasing emphasis is devolving upon research as an indispensable component of engineering science and academic procedure.

In this connection modifications of engineering education are already taking place at the University of California. Some of these changes are (1) strengthening of the scientific base in engineering education and in curtailment of over-specialization in undergraduate curricula (together with increased emphasis on socio-humanistic studies); (2) growing recognition of graduate study as an all but indispensable preparation for engineering practice in its most professional and creative aspects; (3) incorporation of high-level professional programs with design orientation, and programs emphasizing research as a preparation for teaching and developmental work.

It is with these developments in mind that the Operations Research Center of the Institute of Engineering Research was set up last

September at the University of California at Berkeley. Its purpose is to engage in research into methods for the analysis, effective design, and control of man-machine systems.

The activities of the Center are designed to contribute to the evolution of this field of Engineering Science. The Center will complement existing formal academic courses by providing a much needed "laboratory-type environment" where decision problems can be subjected to mathematical and experimental analysis, and where, moreover, students and faculty alike can obtain "field" experience.

THE GENERAL NATURE OF THE RESEARCH

In the years preceding World War II, mathematics had received powerful stimulation from problems arising in the pure sciences (notably in physics and chemistry). By contrast, the post-war years have seen the emergence of a mathematics rooted largely in the applied sciences.

Concurrently, far-reaching advances in computer engineering have taken place and, as a consequence, mathematics is now playing a major role, not only in the sciences themselves, but also in application to the complex management and design problems of government and industry. Thus, hand in hand with great advances in the engineering arts have come mathematical procedures specifically designed to exploit the potentialities of the enormous computational power these arts have made available.

The problem of effective control of a system is closely related to the question of what decisions to make in order to improve its over-all operation. If a decision is characterized as a choice of actions to be taken, then the problem is one of picking (rather than creating) some course of action out of the many existing alternatives in such a way as to maximize some objective function which measures performance of the system as a whole. Once a problem is formulated as a mathematical model, a mathematical problem arises -- that of finding an analytic or numerical solution which satisfies the conditions of the model and maximizes the objective function.

One important class of decision processes is program planning. Industrial production, the directed flow of resources in an economy, the exertion of defense effort -- all are complexes of interrelated activities which require program planning. The term 'programming', as used here, means scheduling the selection, timing and extent of activities to be performed so that a system may move from some fixed status toward a desired objective. When interrelations between the levels of various activities throughout the program are abstracted in mathematical terms, the resulting representation is referred to as a mathematical programming model. If, in addition, the mathematical description satisfies assumptions of proportionality, additivity and nonnegativity, it is called a linear-programming model.

With all the Accomplishments to date, there is a Need More than Ever for a Sustained Program of Basic and Applied Research

From 1947 on, rapid progress in the use of mathematical decision models can be attributed largely to the fortuitous development of techniques -- such as the simplex method for solving linear programs -- independently of actual applications and well in advance of them. Yet it is doubtful if any of those who were ultimately to benefit by these applications could have foreseen their importance with enough clarity to support the basic research required to bring them about.

Rather, it has been the other way around -- the tool inspired the application.

A survey of the present situation shows that such industries as those processing petroleum, food, and lumber products would now be willing to undertake full, mathematical scheduling of their systems if research could produce a practical method for solution of sufficiently large programs. Yet it is doubtful if any company can at present undertake to support the basic research necessary to bring this about.

To date, research in the mathematical programming field has received the major part of its support from the military and, therefore, has frequently been oriented toward military ends. Benefits to the general economy, through great, have been in the nature of byproducts.

The growth of applications has been so rapid that development of supporting mathematical theory has fallen behind and is becoming a bottleneck to further progress.

If the trend toward increasing use of mathematics in planning and control is to continue, there is an immediate need for a greatly increased base of direct support for fundamental research into mathematics bearing on the processes of operational decision.

In order to make concrete the discussion of future developments in Operations Research, and to elaborate further upon the needs for sustained programs of research, I have selected two topics in the Theory of Planning and Control that may be of special interest to engineers. The first of these is:

I. Integrated Planning-Execution Theory

We believe that it is important to develop theory and techniques for integrating, in a precise way, the planning and execution functions of large scale systems. At present, those echelons responsible for day-to-day control as well as those engaged in long-range planning within a system, usually have access to a plethora of information which, more or less, mirrors the real world. Broadly speaking, this information is combined with simplifying plans to form a base for developing operational decisions. The resulting programs are generally used to effect over-all policy with, however, no precise means of translation into detailed particular decisions. Conversely, there is usually a corresponding lack of precise means for re-evaluating a plan in the light of new developments. In spite of this, it generally is believed that great economies can result from the use of scientific planning methods, but the gap between the paper plan and the day-to-day actions which it purports to control is so great that this has been substantiated. It is hoped that the research contemplated for integrated planning-execution models may in time provide industry with a way to make analytical planning both effective and practical.

The general approach which we have been considering at the O.R. Center will be to study some system (such as a supply, a communication, or an air-traffic system) with the object of providing a "brain" to control it. Like an organic brain, it will need a precise way to couple its activities to those of the system; moreover, this is to be done in such a way that long range objectives and day-to-day decisions are coordinated. This interconnection will be made at first, not with the real world (which could hardly afford us the luxury of such an experiment), but with a detailed "descriptive model" of the system's operation which previously will have been developed.

The first step to the approach just sketched consists in developing a mathematical (or logical) description of the detailed operating characteristics of typical systems encountered in applied fields.

Since a completely detailed decision model for the system as a whole could be too complicated, the second step will be to develop a solvable mathematical model for determing some optimal policy for the system as a whole, based upon simplified assumptions and suppression of detail. For example, based on certain simplifying assumptions with regard to the uncertainties in the flow patterns through a communication or traffic system, a mathematical model might be developed which (when solved) would yield an optimal routing decision which could take account of both long- and short-term considerations.

The third step will be the development of an interconnecting set of submodels which will yield precise procedures for translating broad planning decisions into effective action, and for reviewing decisions in the light of new information. This integrated planning-execution system will be tested on the detailed "descriptive model." The detailed description may take the form of a "Monte Carlo" simulation on an electronic computer or may involve both men and machines in a "gaming laboratory." However, because such detailed simulations can be expensive and because their elaborate structure makes them inflexible, great stress will be laid on developing a system of analytic submodels which will be used to express the action of micromechanisms wherever possible. Special attention will be given to seeing how well the mathematical model controls the descriptive model under extreme operating conditions or under conditions intentionally designed to violate one or more of the simplifying assumptions upon which the model is based.

Two important advantages should result from this approach: (1) It is expected that it will furnish the originators of the mathematical model with a more or less realistic "field test" of their model and that it will stimulate them into further work to patch up its weaknesses. (2) It also is expected that the set of submodels, techniques, and procedures used to interconnect the mathematical model to the descriptive one will be ready for use as a fully integrated planning-execution system in its real world counterpart.

The second topic in the Theory of Planning and Control is:

II. Decentralized Decision-Making

Industrial planners have long speculated about the possibilities of issuing an internal currency to managers of various parts of a system to make local decisions which are optimal for the system as a whole. If these prices could easily be determined, this scheme might be an excellent way of integrating planning with execution. The practical difficulty, however, in applying this approach is that the determination of these internal prices depends upon constructing the "production function" which, according to theory, relates all the inputs of a system to its outputs.

Historically, however, economists have considered the actual construction of such a function as something outside their domain. Indeed, since this problem was more technological than economic, they deemed it a clear responsibility of the engineer. But the engineer possessed no method for translating his knowledge of machines into such economic figments as production functions, so there the matter has rested. The underlying difficulty is that the production function is really too complicated to be determined explicity, although it can now be obtained implicitly as the by-product of a mathematical programming model.

Nonetheless, special computational methods, recently developed for solving certain large scale linear-programming models, called the decomposition principle can be viewed as an efficient decentralized decision-making process which derives its own set of internal values called "objective prices" because the prices reflect the objectives of the system. These can be used to guide parts of the system to make a sequence of actions that converge toward an optimal solution for the system as a whole. This approach might well be developed into a workable method for organizations by trials on suitable "guinea pig" problems.

The central theme of my paper has been Future Developments of Operations Research. I first reviewed with you the rapid progress in methods for handling, computation and analysis of information for operational systems. We have seen that out of this effort is emerging a new science, concerned with the problems of rapidly selecting optimal courses of action from many alternatives. This development, in conjunction with the mechanization of simple, human, control tasks, foreshadows the automation of many higher level, mental processes. In the not-too-distant future, machines will undertake many complex control tasks.

We next discussed the role of engineering in society. We have seen that contrary to the focus of an earlier day when engineering concentrated upon the design of isolated elements and processes, recent socio-economic and technological developments have created an urgent need for analysis of complete systems and for the design of increasingly complex systems of facilities and processes.

We next saw that in the years preceding World War II, mathematics had received powerful stimulation from problems arising in pure sciences. By contrast the post-war years have seen the emergence of a mathematics rooted in the applied sciences concerned with developing mathematical procedures specifically designed to exploit the potentialities of the enormous computational power of modern day electronics. This trend will continue.

We then turned to two topics in the Theory of Planning and Execution. We first discussed the great gap that exists between planning and execution. We pointed out our belief that great economies can result from the development of integrated planning-execution models and our anticipation that they will in time provide industry with a way to make planning both effective and practical. We sketched an approach to this type of model.

Finally we outlined an approach to decentralized decision making that could iteratively tend toward an optimal program for the system as a whole. It has the merit that the planning staff does not require detailed operating knowledge of each part and each part has a set of objective-prices to guide its day-to-day decisions. Thus we have at hand at last a theoretical foundation for a rigorous, well understood, decentralized decision-making cycle capable of development into a practical procedure in government and industry.

TECHNICAL MANAGERS AND HUMAN RELATIONS

Keith Davis
Professor and Chairman
Department of Management
Arizona State University
Tempe, Arizona

This afternoon I face somewhat of a personal dilemma. Being a typical person, I want to be liked and accepted by this group. On the other hand, as an academician I like to say what I believe, to speak the truth as I see it. Thus we have a dilemma: If I soft-pedal my thoughts, I won't like it; but if I follow through forcefully with my ideas about technical managers and human relations, some of you won't like it because you will say I am going too far. It's heads or tails, I lose, but I think you will be the better winner if I present my thoughts without reservation. That is the approach we will take.

Probably most of you are technical managers or technical staff specialists, that is, the central interest of your work is science, technology, or engineering. This afternoon I want to discuss with you some of the human effects of the technical manager's work. My purpose is constructive--to help us as managers apply the type of analytical thinking which will see these effects and correct any problems that result. Admittedly, I may exaggerate some ideas, but this is merely for added emphasis. My basic thesis is that technical management generally should be more human relations than technical. Of course, you already knew this, but let us explore it further to see why and how. For purposes of illustration we will take a typical industrial engineering manager and his men, who are concerned with plant layout, motion study, time study, incentive rates, and related activities. What we say about him can be transferred to other managers as the case applies. Naturally the industrial engineering manager has to apply some human relations in supervising his people, but what about the work he is managing? It can be argued that this work concerns only technical facts and has nothing to do with human relations. But is this only technical work?

1. Much of their work concerns the motions and activities of people.

2. When the work concerns only machines and layouts, these are to be operated by people. Any changes which are made will affect people.

3. The technical facts are gathered and interpreted by people, namely industrial engineers.

4. These facts are processed and interpreted for the use of other people in other departments, usually involving a staff line relationship.

Indeed, human relations is much involved because layouts and time studies are made by people and invariably affect other people.

Here is an example to illustrate this idea. A technical manager needed to make down-time studies of a certain department, and he set up machine records to be kept by every machine operator to report the length, time of day, and cause of all machine down-time. The foreman was to see that his men kept these records for thirty days. The foreman and his men fussed and complained and finally kept such inadequate records that they were not useable. The technical manager wondered why and concluded that they were all obstructionists who did not have the company's interest at heart. But look at the human side:

1. This analysis further pried into the activities of the men.

2. Keeping the records was more work for the men. Several did not like paper work.

3. Enforcing the record keeping was a chore for the foreman, especially since his men resented it.

4. The foreman saw no personal, direct benefit coming to him from the study.

5. The men saw no direct benefit of the study. In fact, they feared it would bring changes which would reduce their incentive earnings.

6. The unhappy men complained to the foreman who complained to the industrial engineers and soon everyone was obstructing rather than cooperating.

7. Meanwhile, the technical manager in his office wondered why there was so much commotion about "this little piece of paper work." He was sure that a company with so many obstructionists would never be efficient or make a profit. Yet--and here is a key point--one of the main reasons the company has so many obstructionists is that it has technical managers who do not understand human relations. They are a cause of the problem, rather than victim of it.

There is in my portrayal a trace of exaggeration, but these kinds of problems do exist, not in isolated situations, but frequently. If this is the case, then we had better do some thinking about human relations. There are three areas which especially merit our attention.

1. The technical manager's background experience as a non-manager.

2. Supervising his own people.

3. Working in a staff relationship with people in other departments.

First, what about the technical man's background experience as a non-manager? We shall assume that he is in all respects qualified for the technical aspects of his work. However, people often forget that at an advanced level such as most technical work is, it takes sound knowledge of human relations even to be an effective employee, that is, to understand one's role in a group, to relate authority and responsibility, to sell ideas, and so on. Thus it is difficult even to be an effective employee unless one understands organizational dynamics. If you cannot succeed as an employee, it is unlikely that you would ever get the chance to become a manager. For example, a Factory Management survey of industrial engineering managers regarding why they discharged or transferred time study men who had failed, reported that 72 per cent mentioned human relations deficiencies compared with only 28 per cent technical deficiencies.[1]

Business is a complicated social system, and the bigger the business the more complicated it is. You have to have a minimum understanding of this system if you are to succeed in it. The fact that you have lived and worked in this social system for ten adult years does not mean you understand it anymore than your neighbor understands the weather because he lives in it. As a matter of fact, when you reach the stage where you think you know all about organizational human relations just because you have experience, you are simply admitting that you are looking at this subject so shallowly that you don't see much in it. The only way 98 per cent of us can learn about it is to approach it seriously and studiously. Here many technical people are mentally handicapped because their academic training lacked even one course in human relations, psychology, sociology, and related areas. They are also emotionally handicapped because their scientific heritage has led them to honor only unchangeable facts, but human relations deals with values, attitudes, and intangibles also. The result is that many capable technical men never achieve managerial status for which they are richly qualified in terms of basic intelligence and creativity. (For this reason the combination of a technical degree and a master's degree in business management has become quite popular.)

Let us turn now to my second point, the technical manager's human relations in supervising his own people. The job of managing is quite different from that of working in one's technical specialty. The manager gets things done through others rather than doing the work himself. He must be able to motivate others and communicate with them, yet there is very little in mechanics or chemistry that will help a manager motivate others. So a whole new subject must be learned at considerable sacrifice of time and energy. Often this time is not available and the manager must operate in a makeshift way. Sometimes he misses the boat.

One supervisory idea will serve as an example. There is considerable research evidence that an employee-centered manager has both more productive and more satisfied employees than a production-centered supervisor. When research first disclosed this relationship, I talked with one technical manager who insisted that a horrible research error had been made. The research conclusion was not logical, he claimed. How could a manager primarily oriented toward people get better production than a man who devoted his whole energies to production? Surely a production oriented man would get better production.

In a few weeks, however, he reached a deeper understanding, reasoning along the following lines: Managers get results only through people. In the sequence of this situation, the people precede the production. They come first. Until they are prepared and motivated to produce, it is useless to emphasize production.

And so it goes--each human relations idea must, like this one, be learned through study and/or hard thinking.

Let us turn to my third area for discussion, the technical manager's staff relationship with people in other departments. My use of the term "staff" refers to working with others outside your chain of command in a service, control, coordinative, or advisory capacity. This is one of the most difficult and misunderstood business relationships, and it immensely complicates human relations. Since the staff man generally does not have command authority over people in other chains of command, he can succeed in many of his tasks only by selling his ideas to others and developing good relationships with them. One of the case problems in my book concerns a young industrial engineer who developed an improved assembly sequence requiring new combinations of job duties and rearrangement of an assembly team. The new set-up would not work and cost the company a large sum of money because the engineer ignored the human implications of his change and thereby failed to sell it to the foreman and his men. The engineering manager likewise failed to see the human side and, therefore, was not able to provide competent leadership when his engineers faced problems of this type.[2] Failure of the project was attributed to the stubborn obstructionists on the production line; yet, remember the statement which I made earlier: The reason the company had so many obstructionists was that it had too many technical people who ignored human relations.

Let us take another example, that of an industrial engineer we shall call George who is revising the machine layout and work sequence in a department. This is essentially an engineering problem. I wonder how many engineers like George and their technical managers realize all the possible human effects of their work. Some of these effects are as follows:

1. To the shop social system George and his manager are outsiders. They are not a part of the primary group.
2. To the men George is an instrument of change and a threat to their security. George's revised set-up may require new job classifications or new work notions. George does not realize that his changes are a source of pressure on the men. They do not like to see him enter the shop.
3. The foreman, an older man with a grammar school education, resents having a young college man like George with little shop experience tell him what to do. This is a problem of status which George does not perceive.
4. George takes some of the foreman's valuable time which could otherwise be devoted to production.
5. George's work will require new patterns of supervision and communication by the foreman. By establishing location and sequence of work, George is determining who contacts whom and for what purpose.
6. George was unaware of the shop informal organization and its effect on his plans; so he ignored it. (Or else he was aware, but still ignored it).
7. George's viewpoint was narrowly confined to his own specialty, whereas the foreman had to look at the whole department. As a result, George (with his manager's support) pushed his needs too far which caused the foreman to resist.
8. George used a pack of high-powered, ten dollar words which made him feel good but which some of the men could not understand. George made reference to "what management wants," as if he and his manager were in regular contact with top management and spoke with their authority.
9. The revised layout changed certain "initiations of action"; that is, who would pass work on to whom. The receiver of a procedural initiation of action is psychologically secondary. Problems may occur especially when the initiation puts pressures on the receiver, affects his incentive earnings, and is a low-status person initiating to a high-status person. As a matter of fact,

George's new work layout gave the unskilled day laborer who set work at the machines a significant influence over the incentive earnings of the skilled machine tenders. This was equivalent to having a budget clerk tell the sales manger he cannot buy an item, or having a record clerk tell the superintendent to correct a form.[3]

10. With all these trouble areas, and with George and his manager being partially blind to them, conflict increased. Soon George was subconsciously trying to catch the foreman in some indiscretion to show his inefficiency, and the foreman was trying to delay and confuse George's work in order "to show him up." The result is: What is success to George becomes failure to the foreman, and vice versa; so the original staff-line service relationship has disappeared.

Again, my story is exaggerated for purposes of emphasis, but it does show how many chances there are for conflict and misunderstanding in this simple line-staff relationship which is primarily an engineering problem. In a more complicated situation the chance for human problems would be even greater. Most of us do not realize how tremendously difficult these human problems of technical management are; hence we are not prepared to meet them.

My discussion of these problems should under no circumstances be considered a criticism of scientists, engineers, or other technical persons. As a matter of fact, their high intelligence, professional attitude, and practical common sense has enabled them often to apply acceptable human relations in spite of their poor preparation. What I am suggesting is that we need more preparation, more study, more emphasis.

In summary, I wish to offer the following conclusions:

1. Human relations in technical management is very fundamental--perhaps more so than most of us now realize.

2. Any technical man who aspires to be a technical manager should have background preparation in organizational human relations.

3. A technical manager who has extensive staff contacts outside his department must have thorough training, academic or otherwise, in organizational human relations.

4. Technical managers poorly prepared in human relations are often the cause of obstructionism in their firm, rather than the innocent victim of it.

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2. Davis, Keith, Human Relations in Business, McGraw-Hill Book Company, New York City, 1957, Case 7, "The Dekker Company," pp. 506-512.

3. For another example, see Whyte's classic study of the restaurant industry where one point of conflict was a young order runner who was "telling" the chef what food to prepare. Whyte, William H., Human Relations in the Restaurant Industry, McGraw-Hill Book Company, New York City, 1948, pp. 49-63.

The Development and Use of Performance Standards for Managerial Personnel

John B. Joynt
Vice President-Management Planning
New York Central Railroad
New York, New York

I INTRODUCTION

"Newsweek" reports that:

a. 66 2/3% of all college men change jobs within five years after graduation--some more than once.
b. 15% of all junior executives change jobs annually,
c. 100,000 key men move annually to bigger jobs with greater challenges and rewards.

The losses in dollars for recruiting and replacing an executive can easily run as high as $50,000 a man. But how can you put a dollar value on the real loss of top-notch men with imagination and drive? And, why do people in key spots change jobs? An article "Why Managers Change Jobs? gave three reasons:

a. We don't build jobs around people's abilities. We are too technical in designing organization structure. We are reluctant to delegate, and we lack faith in people.
b. People are looking for greater challenges, greater opportunities, greater freedom to manage.
c. We don't have a regular and fair system of appraising managerial performance. We are lacking standards of performance for management personnel. People don't know where they stand.

Crawford H. Greenewalt, President of E. I. DuPont, in his book "The Uncommon Man" points out that we all draw from the same work force. It's what happens to our people after they are hired that makes the difference in the strength of a corporation. The limiting factor in corporate growth, therefore, is the ability to keep and develop competent managerial and technical personnel.

II NEED FOR PERFORMANCE STANDARDS

People want to know where they stand--they want to know how to do things better--they want to improve and progress. If you don't think so, just look at the number of "best sellers" that have titles like "How to be a Better Manager"--"How to -------", etc.

Everyone in this room would like to know where he stands with his superior in regard to his performance. He may have a pretty good idea. Most of us are aware of our strengths and weaknesses, but I wonder how many of us really know where we stand in the eyes of our management and our associates.

Don't we need a sound, constructive, down-to-earth appraisal plan for managers -- one that takes us deeply into performance and results expected? How often do we appraise our people and how well is it done? Is the man being appraised and his superior really on the same wave length in facing up to the areas needing improvement? Do they lay out a specific plan of action?

Saturday is a big day at my country club. All the caddies are out. Before teeing off, one caddy dialed a number to get a job mowing a lawn. It was apparent from half the conversation that somebody had the job--and was doing very well. When he hung up, the other caddies gave him the "ha-ha." They said, "Ha, ha, you didn't get the job did you?" He answered, "I already have the job--I just wanted to know how I was doing."

It's important to know how we're doing. As we go up the organization ladder it becomes more important. Experience of Four Companies - The president of a large insurance company in Texas said this about the need for performance standards: "When I sat down with my vice presidents one-by-one to establish standards of performance, we couldn't even agree on the most important thing in the job, much less a standard.

The president of a large utility company analyzed unsatisfactorily completed assignments and concluded that in nine out of ten cases when the end product didn't measure up to expectations, the superior had not made clear what he expected at the outset. The assignments were too vague. They didn't pinpoint the problem nor the results expected. This company now is applying the concept of performance standards to special project-type assignments, as well as to regularly assigned responsibilities.

The president of a very large construction firm decided to develop performance standards first for his general foremen because they control large expenditures.

A new president of another company decided to start with himself and his vice presidents. It took a few months to fully develop standards of performance at this level as it uncovered many problem areas that had been neglected--need for defining objectives, organization improvements and forward planning. It led to a rather comprehensive management improvement program requiring several years to complete.

What are We Seeking? - What are we looking for in management--all of us? A better approach, greater managerability--a sound basis for measuring effectiveness. We want a regular, fair system of appraisal based on a sound standard of performance, a standard that is just, reasonable and attainable. We should reach an understanding on performance expected with our subordinates well in advance of appraisal time, preferably at the beginning of each year. Standards developed jointly between a man and his superior--mutually agreed to standards--provide a solid foundation for accomplishment.

III RELATING PERFORMANCE STANDARDS TO THE KEY ELEMENTS OF A MANAGER'S JOB

Meaning of Management - We define management as "getting results through people." Mr. Lawrence Appley, President of the American Management Association, says that managing people is the entire job of a manager.

Good management and management improvement are synonymous and every manager is expected to improve performance. This is accomplished by raising the level of performance of his work group. At one time we defined a performance standard as a statement of conditions which will exist when a good job is being done. But what do we mean by "good?" Experience with performance standards, therefore, highlighted a need to go more deeply into results expected.

What is a Performance Standard? - Rather than define the term "performance standard," it seems more appropriate to regard a standard as a management process by which we determine specific objectives or tasks to be accomplished for each management job--line and staff--the results expected and the basis for measuring performance. (Illustration No. 1)

Standard or Guide - On the New York Central System we have used the term "performance guides" rather than "performance standard" because of the high degree of judgment required in setting the so-called standards and in using them in the appraisal of managerial personnel.

Although the use of performance standards represents a real advance in management, they must be introduced the right way and at the right time. The timing can best be determined by each company or by each manager himself.

The Attitude of the Manager - Since it's the manager's job to make things happen, he must think in positive terms--see the whole picture--also think in human terms. He must have an intellectual respect for the function of management and an appreciation for measurement as a management tool.

The way we approach the job of developing standards--our attitude--the process--may be much more important than the written standard we come up with. It's the thinking through process that brings about understanding, acceptance and motivates a group to improve results.

If a group having the same responsibilities, such as sales managers, production managers,

ILLUSTRATION NO. 1

STEPS IN DEVELOPING A PERFORMANCE STANDARD

STEP 1 -- IDENTIFY THE KEY RESULT AREAS FOR EACH JOB

Key result areas reflect the things that are important, the purpose for which the job exists today and how it is expected to contribute to the objectives of the company.

STEP 2 -- IDENTIFY MEASUREMENT FACTORS FOR EACH KEY RESULT AREA

The basis for measuring performance.

STEP 3 -- ESTABLISH A STANDARD FOR EACH MEASUREMENT FACTOR

For many tasks, measurement factors may be expressed in rather specific terms. For example: production output, both quantity, quality and cost; sales volume by territory, product, etc. For other managerial tasks it is difficult to develop precise measurement data.

For example: the extent to which a manager delegates effectively, his ability to develop people, effectiveness in communication, public relations, human relations, etc. Both are important in measuring performance.

STEP 4 -- CLASSIFY MEASUREMENT FACTORS

Sometimes we classify the measurement factors in two categories:

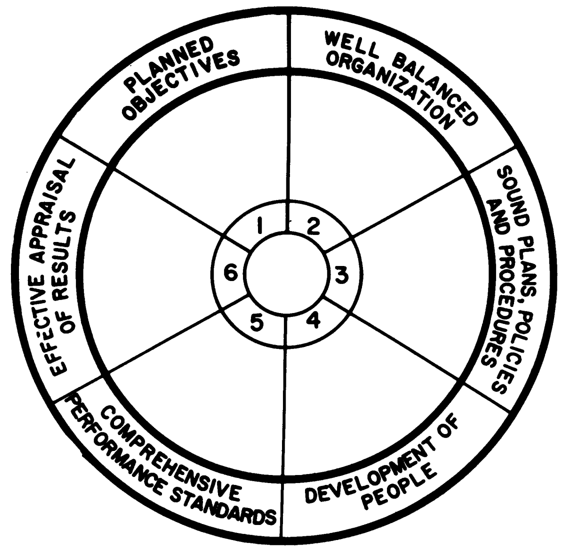
(1) Factual -- where we have facts, figures, percentages, ratios to measure performance.

(2) Judgment -- where the appraisal of performance is based largely on judgment. Here we attempt to sharpen our judgment through the use of performance standards.

etc. will sit down with their superior--and take enough time to thoroughly think through the results they expect to obtain and how to get them--one thing is bound to happen. A higher level of performance is bound to result.

The Elements of Every Manager's Job - The elements of management (as reflected in Illustration No. 2) apply to all jobs, whether line or staff. Performance standards can link all of them together and the process of developing this can be the key to management improvement. Key elements are:

ILLUSTRATION NO. 2



a. Planned Objectives -- the establishment of goals and objectives for the business as a whole and every function provides the foundation for performance standards. As managers we must have personal goals and objectives. Frequently the development of standards causes us to take a good, hard look at the purpose of the business, and each major function.

b. Well-Balanced Organization -- to realize our objectives we must have good organization--organizational structure, therefore, should be geared to accomplishment of objectives and the results expected. Accountability for results should be fixed as well as authority and responsibility. Accountability becomes more specific with performance standards.

c. Qualified Personnel -- until we have people qualified to man the organization, our objectives or standards will not be attained. For that reason, the development of personnel is a key responsibility of every manager. Performance standards and managerial appraisals are essential to good management development for both the manager and the individual being appraised.

d. Sound Plans, Policies and Procedures -- with major areas of authority and responsibilities determined, we can proceed with development of necessary plans, policies, and procedures. These are essential for the organization to function smoothly. They are closely related to organization planning and decision-making.

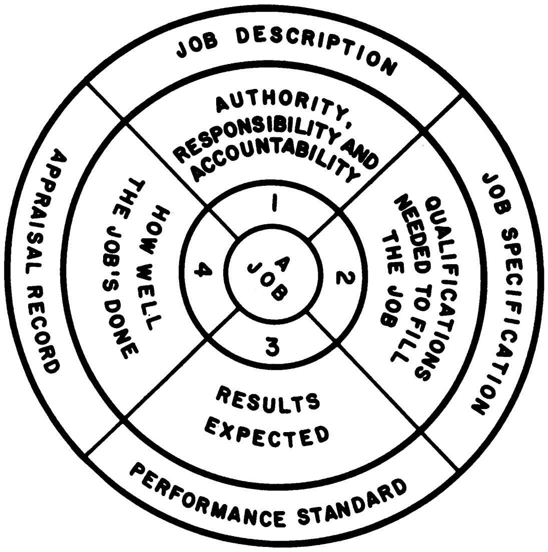
e. Comprehensive Performance Standards -- when we design organization structure we must not only determine the results expected, but we should have some acceptable standard of performance in mind. Performance standards for managerial personnel and organization are so closely related that some companies consider both at the same time.

f. Appraisal of Results -- when we have developed performance standards we then have a sound basis for appraising results. Also, we are in a better position to identify promotable personnel,.determine their developmental needs and accelerate their development.

Performance standards are closely related to all the elements of every manager's job. They seem to always summarize and pull together the basic purposes of every manager's job.

Relationship Between Performance Standards and the Other Management Tools -- although we do not want a triump of technique over purpose, the techniques or tools of management are important to facilitate the entire managerial process. There are four tools that are so closely related to the elements of management they are described below: (See Illustration No. 3)

ILLUSTRATION NO. 3



a. The Job Description consists of a statement of authority, responsibility and reporting relationships and is used in organization planning.

b. The Job Specification describes the necessary qualifications needed for and individual to fill a certain job. Generally it is used in connection with recruitment of personnel outside, but is being used more for internal development.

c. The Performance Standard is a statement of the results expected, identifying the key result areas and the basis for measuring effectiveness. (See Illustration No. 4)

d. The Management Appraisal reflects an individual's performance, how well he's doing his job and what steps may be taken to improve his performance or otherwise assist in his development.

IV HOW COMPANIES APPROACH THE JOB OF DEVELOPING PERFORMANCE STANDARDS

The Ideal Approach - The ideal approach is for performance standards to be developed as part of a company-wide management improvement program, with the president and the key management personnel assuming a key role. As a group they first would determine:

ILLUSTRATION NO. 4

PERFORMANCE GUIDE FOR A TRAINMASTER

KEY RESULT AREA	MEASUREMENT FACTORS	PERFORMANCE STANDARD	FACTUAL OR JUDGMENT
Crew Efficiency	Avg. Tons Per Train	5% Above Last Year	F
	Locomotive Utilization	No Less Than 85%	F
	Maintenance of Schedule	95% On Time	F
	% Performance Against Time Standard	95%	F
	Cars Handled Per Engine Hour	4.0%	F
Car Utilization	Late Deliveries	None	F
Customer Services	Number of Complaints	No Bonafide Complaints	J/F
Operating Expense	$ Clerical Expense vs. $ Train and Eng. Payroll	15% or Less	F

a. What the management improvement program should consist of.

b. The timing and proper sequence of each major phase of the program.

Management improvement must be tailored and timed to meet the needs of the corporation. The six-step approach referred to in Illustration No. 2 has served as a guide for many companies.in this respect.

New York Central's Approach - After Mr. A. E. Perlman assumed the presidency of the New York Central System, he called about 75 of his top management people together for a three-day meeting to discuss organization and management and to lay out a plan to further improve the management of the Central. He had one major objective--a management second to none. Organization and management meetings were held twice a year for a few years, and are now held annually. At the first meeting the approach to management improvement on the Central was discussed and a long-range program agreed to. The timetable which evolved is as follows:

1955 -- Organization review and job clarification.

1956 -- A new company plan of organization introduced, coupled with a review and clarification of corporate objectives.

1957 -- Management Appraisal Plan introduced.

1958 -- Management Succession Planning added to supplement the Management Appraisal Plan.

1958 -- Performance Standards introduced in major departments.

1960 -- Management Appraisal Plan revised to use performance standards in the appraisal process.

1961 -- Long-range manpower planning, and extension of training and development, recognizing that good railroading is a life-long learning process.

Other Company Approaches - General Foods, Sun Chemical and other companies also have regular organization and management meetings. These meetings serve several purposes:

a. They give an organization direction.

b. They provide an excellent means for communicating plans.

c. Problems are resolved and decisions reached.

The New York Trap Rock Corporation, under its president, Wilson P. Foss III, started with a three-day meeting of the 35 key personnel to plan an improvement program best suited to their company of 1200 employees. At this meeting they developed a three-step approach:

STEP 1 - Job clarification and organization review.
STEP 2 - Management Appraisal Plan
STEP 3 - Performance Standards.

The American Enka Corporation (with 6000 employees) under the leadership of the late John E. Bassill, President, established a similar pattern many years earlier. When the performance standards were introduced at Enka, a pilot approach was used, starting with key finance jobs, and then extending standards to engineering, research, etc. Many companies use the pilot approach to gain experience.

Doing Research - At the outset most companies do some research in the field even though experience with performance standards is somewhat limited. The American Management Association has published research report No. 42 "Setting Standards for Executive Performance" which is available. Both A. M. A. and the Society for Advancement of Management hold seminars covering performance standards for managerial personnel.

Importance of Line Participation - In New York Central we worked directly with line management rather than using staff. In 1959, the year we introduced performance standards, for example, we held a series of one-day meetings throughout the system with approximately 3500 management personnel attending. It took about six weeks to complete these meetings, which we hold each year.

In the 1959 meetings we actually developed performance standards in practice sessions. We then discussed the standards we developed so that the entire group of 3500 management people learned how to develop a standard. Following these meetings, managers throughout the System developed standards in cooperation with their subordinates. An illustration of a standard developed by a group of Trainmasters is set forth as Illustration No. 4.

V USE OF PERFORMANCE STANDARDS

Performance standards are used in many ways. They may be used on a daily basis to check on performance and to improve effectiveness and for long-range development of personnel. In talking to one of our young Trainmasters on the New York Central, I asked him how he used his performance standard. Much to my surprise he pulled his performance standard out of his pocket. He told me he used it to learn more about his job; also that everyone who reported to him as familiar with his standard because he had discussed it with his people at some length in a group meeting. By getting his people involved in this way they became familiar with what was expected of them, which further motivated them to raise the level of performance for the group.

In the New York Central we also use performance standards to assist in determining training needs and accelerating development. Our Management Appraisal Plan is now centered around performance standards. A copy of our Performance Appraisal Report is attached as Illustration No. 5.

VI CONCLUSION

Approach - Many companies have had job clarification programs for years. A lesser number have management appraisal programs. A comparatively smaller number have introduced performance standards. It would seem logical to introduce these three programs in the following order:

a. Job Clarification

b. Performance Standards

c. Management Appraisals.

Most companies, however, have introduced standards of performance in the following sequence:

a. Job Clarification

b. Management Appraisals

c. Performance Standards.

The reason for this sequence is as follows:

a. We cannot appraise performance or develop a standard unless we know what the individual is responsible for. So job clarification comes first.

b. Management appraisals are frequently introduced next because they are urgently needed and not too difficult nor time-consuming to do. Furthermore, appraisals emphasize the need for standards.

c. The development of performance standards if done the right way may consume two-man days of concentrated management effort--either a two-day meeting or a series of shorter meetings. They take us into the very heart of every manage-job.

For these reasons many companies tackle standards last.

Need for Re-Appraisal of Appraisals - We have reached a point in management appraisals in many companies where we must shift emphasis from personality to performance--not because the personality is not as important as before, but to bring about an appropriate balance between personality and performance. Appraisal programs which lack this balance will probably fall by the wayside because they do not adequately compensate busy line executives for the time consumed. Consequently, the re-appraisal of appraisals is timely for many companies.

Benefits from Performance Standards - With the use of performance standards we add much to our effectiveness as managers. Things that may have been lacking are:

a. A much more careful examination of the critical factors affecting performance.

b. An understanding between an individual and his superior as to the results expected--the kind of understanding which may never exist without standards.

c. A much better set of yardsticks as to job requirements, enlarging and clarifying accountability.

d. A fair, sound and realistic basis for appraisal of managerial performance.

e. A sounder basis for identifying promotable personnel and accelerating their training and development.

f. But most important of all--improved performance.

VII QUESTIONS AND ANSWERS

Some of the most frequently asked questions on performance standards are as follows:

QUESTION: Who prepares the performance standard--the man himself, his superior, or a staff man?

ANSWER: Performance standards should be prepared by the individuals responsible for results--line personnel. Staff can be helpful. It is desirable for a group having the same job (such as several sales managers reporting to a sales vice president) to develop the standard in a group meeting. The discussion, exchange of ideas and understanding which result through this process is most important. I recommend (1) that every manager assume the responsibility for developing standards; and, (2) that they be developed with a group of individuals having the same job working with their superior.

QUESTION: If an individual has a key part in developing his own standard, will the standard be too low?

ANSWER: Our experience indicates that individuals setting standards for themselves set them too high rather than too low. This is because they are over-optimistic in terms of their own ability to accomplish the things they are to do.

QUESTION: Do you prepare a standard for the job or for the man?

ANSWER: It can be done either way, but for practical purposes I recommend strongly that you prepare standards for the job even though there are several individuals with different experience and capabilities performing that job. Even though the results on the job will vary because of the experience of the individuals, this variation can be dealt with effectively during the appraisal.

QUESTION: Are standards flexible or stable?

ANSWER: The key result areas and measurement factors are fairly stable, but the standards of performance will vary depending on the existence of different conditions. For example: costs will vary between an old plant vs. a new plant; sales volume between a good territory vs. a poor territory. Furthermore, standards may change with time--last year's success might be this year's failure. For that reason we must use good judgment at all times in applying standards.

QUESTION: Can you develop a performance standard for any job?

ANSWER: The answer is yes, provided you know the job well. The ability to develop an effective performance standard is a true test of managerial competency.

QUESTION: Which is most important--the written standard of performance or the process we go through in developing a standard?

ANSWER: The thinking process we go through in developing the standard is the most important--the understanding and communications values which result.

QUESTION: Is it desirable to use staff in introducing performance standards and in reviewing performance?

ANSWER: Competent staff can be very helpful, particularly at the outset, but the objective should be for every manager to develop his own performance standards and appraise his personnel.

QUESTION: How do you convince a manager that it is worthwhile to develop a good standard?

ANSWER: My experience provides a simple answer: Before one goes through the experience of developing a standard he has grave doubts as to the value he gets for the time consumed. After he has developed a standard with his people, he is thoroughly convinced. At one time I was a "doubting Thomas" myself.

QUESTION: How do you prevent a standard program from collapsing?

ANSWER: Any management program will collapse unless it gives line management a good return for the time they invest. This applies to standards and appraisals. I feel very strongly that standards of performance, if properly prepared, are well worth the effort. With good standards there is less danger that appraisal plans will collapse.

QUESTION: Can you develop accurate and realistic standards?

ANSWER: As indicated above, certain standards are based on facts and others are purely judgmental in character. Even where we have facts we must use good judgment in determining the standards which we use. We should be specific where we can. Where we cannot, the analytical process we go through will sharpen our judgment.

QUESTION: How do you overcome the vague and general terms which are in effect a restatement of the job description, and not too meaningful in appraising performance.

ANSWER: At one time we defined a performance standard as a statement of conditions which will exist when a good job is being done. Now we identify the key result areas, the measurement factors and standards for each measurement factor where this is practicable. Through this approach we become much more specific in terms of result expected. The job description is quite different. It should be a broad, general statement--one that if followed will cause an individual to grow and develop.

ILLUSTRATION NO. 5

NEW YORK CENTRAL SYSTEM

Form NYCS G-90 (Revised 1960)

PERFORMANCE APPRAISAL REPORT

Title of position__________ Name of employee__________

Dept.__________ Location__________

KEY STEPS IN THE PERFORMANCE APPRAISAL PLAN

STEP 1. Preparation for the appraisal—determining the key result areas and measurement factors upon which the appraisal will be based and reaching an understanding between the man and the boss well in advance of the appraisal.

STEP 2. Periodic appraisal of performance through the Appraisal Meeting.

STEP 3. The Development Meeting at which a plan of action is agreed upon.

STEP 4. The Management Review Meeting at which an individual reports to his superior the results of the appraisal of his subordinates.

STEP 5. The continuous process of Training and Development and Job Improvement which follows the annual appraisal.

Complete information about the Appraisal Plan is covered in the Guide for the Administration of the New York Central's Management Appraisal Plan. (Revised April, 1960)

USE OF THE PERFORMANCE APPRAISAL REPORT

The two inside pages provide space for:

1. Listing key result areas and selected measurement factors applicable to this job.
2. Appraising the man's performance against these factors.
3. Determining actions for improvement where indicated, including training and development needs.

The back page provides space for your summary of this man's qualifications.

The appraiser (boss) should retain this Performance Appraisal Report in a confidential file. A year hence, when again appraising this employee's performance, refer to the recommendations on page 3 to check upon what has been accomplished.

REPORT ON TRAINING AND DEVELOPMENT NEEDS

Following the appraisal, fill out in duplicate the sheet headed Report on Training and Development Needs, according to the instructions shown thereon. Send one copy, through channels, to the General Manager or department head. He will, in turn, transmit the form to the District Personnel Assistant or Training Administrator of the department, who will compile an inventory of departmental training needs. He will use it also to maintain a record of appraisals held.

At the development meeting between the employee and the boss only, the two will discuss the findings and recommendations resulting from a review of performance.

DETERMINATION OF KEY RESULT AREAS AND MEASUREMENT FACTORS

Well in advance of appraisal, the employee and his boss should jointly agree as to the key result areas and measurement factors on which an appraisal of job performance should be based. These should be listed in columns (1) and (2) below.

Typical key result areas are effectiveness in communications, development of subordinates, quality of service, utilization of property, maintenance of equipment, meeting cost standards, developing new methods, etc. There are scores of others. Select those that apply to this job.

If Performance Guides have been prepared, they will prove helpful in selecting key result areas; use the Common Responsibilities page from the Company Organization Manual. Sometimes, important special assignments become key result areas.

Significant measurement factors should preferably be quantitative, such as keeping costs, ratios or percentages within acceptable standards. But there may also be important judgment factors, such as the effectiveness of public contacts, adequate delegation of authority or acceptance of responsibility.

Indicate how well each key result area is being performed by placing a check mark in one of the five columns at the right.

KEY RESULT AREAS	SELECTED SIGNIFICANT MEASUREMENT FACTORS	APPRAISAL: Inadequately done	Needs some improvement	Usual or acceptable	Above average perform.	Very well done

2

ACTION TO IMPROVE PERFORMANCE AND ACCELERATE DEVELOPMENT

Whether a key result area is appraised high or low, if any improvement action is desirable, state it below; indicate who is responsible and when it should be completed. Where an appraisal at the left is below "acceptable," state why below, as well as the action desired. Following are some suggested typical actions, but you should make them as specific as possible for each key result area and each employee appraised.

ACTIONS BY EMPLOYEE

JOB KNOWLEDGE—Acquire more specific knowledge to improve job performance.

ATTITUDES—Improve attitudes toward job, boss, company, fellow workers, public, new ideas, methods change, care of company property, etc.

SELF-DEVELOPMENT—Improve quality or quantity of work, speech, tact, housekeeping, etc. Take vocational guidance tests; participate in civic or professional activities, courses of study and outside reading.

ACTIONS BY BOSS

PERIODIC CHECK—Determine frequency of employee work progress; acquisition of knowledge or skill; changes of attitude.

JOB ROTATION—Decide the job progression needed; new understanding; development by challenging assignments.

STANDARDS—Establish and enforce standards of production, cost, quality or service; jointly between man and boss.

TRAINING—Individual coaching and help on the job.

ACTIONS BY COMPANY

(Do not promise some company action until you are certain it will be done)

TRAINING—Inside or outside company; state kind needed.

	WHO IS RESPONSIBLE? EMPLOYEE	BOSS	COMPANY	WHEN SHOULD IT BE COMPLETED?

3

SUMMARY OF QUALIFICATIONS

Identify strongest single qualification for greater potential usefulness to the company__________

Identify area having greatest possibility for improvement__________

Is this man promotable? Yes____ No____.

If so, to what and when:__________

Is he best suited for line or staff work? Give your reasons for this conclusion:__________

Other pertinent observations:__________

MANAGEMENT SUCCESSION PLANNING

If this individual should leave his job tomorrow, could you identify immediately a capable successor?__________

Who?__________

If "No" indicate the reason and action you plan to take to develop a successor:__________

APPRAISAL MADE BY

Name (Chairman)__________ Title__________

Name (Helper)__________ Title__________

Name (Helper)__________ Title__________

Name (Helper)__________ Title__________

USE OF FORM—CONFIDENTIAL

This form, when completed and signed, is confidential. It is to serve only as a discussion outline during the DEVELOPMENT and MANAGEMENT REVIEW meetings. This form should be retained in the personal and confidential file of the chairman. Its contents may, however, be discussed at any time with anyone having a legitimate management interest in them.

Additional copies of this form may be obtained from the General Stationery Storekeeper, Collinwood, Ohio, on regular monthly requisitions.

4

WORK SAMPLING IN ENGINEERING

William R. Leighty
Chief Industrial Engineer
Factory Operations Unit
Boeing Airplane Company
Wichita, Kansas

INTRODUCTION

The chart you see before you (Figure 1) represents a few of the items associated with the technique of work sampling. I would like to discuss the mathematical principles of this tool and derive for you, from basic probability theory, the fundamental formula which, precisely and accurately, defines the results of the work sampling process.

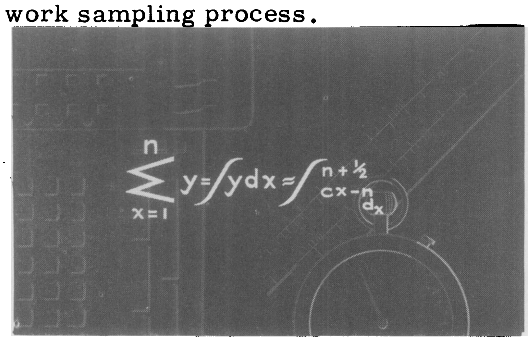


Figure 1

I would like to, but, with the misgiving that I would only be commiting the same error that this profession of ours often commits. We are too often like the watch maker who becomes so involved with the watch mechanism, with the precision and balance of a delicate instrument, that he forgets his purpose. As a result we often find ourselves with excellent theories and techniques but find it difficult to put them to use. So, lets leave the mechanics and theory of sampling to many fine textbooks that cover the subject. We wish to discuss a "down to earth" proposition of applying this powerful statistical tool in a management situation.

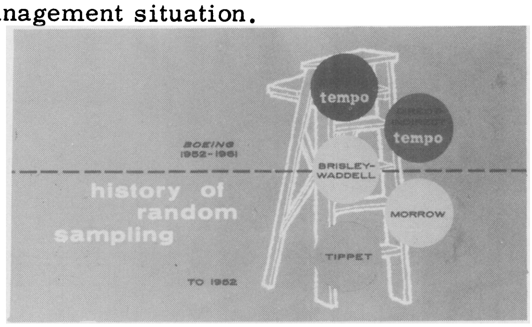


Figure 2

Of course, we owe a great deal to many people for what we know today of performance sampling. As early as 1927, L. H. C. Tippett, a statistician, used a sampling technique in the British weaving mills to measure delays and called this method "Snap-Reading". Prof. Morrow helped gain recognition for this method in about 1940 in this country. Because of its use to measure operator and machine delays, it became known as "Ratio Delay Time-Study". In 1952, C. L. Brisley collaborated with H. L. Waddell of a popular trade magazine and popularized Ratio Delay Observation with the name "Work Sampling". This type of sampling had great potential application, especially for non-repetitive or long cycle operations. In the fall of 1952, the Industrial Engineering Section of Boeing-Wichita decided to try work sampling on "for size". In the middle of 1953, a "Run for the Record" was made on the RB47 in final assembly. From that date on, sampling has been an important tool in our work measurement kit.

Of course, - sampling told us how often our direct labor people were working, but not how hard. Very early we detected a need to rate or level the skill and effort of the direct labor employee. We learned, through correspondence with Dr. Barnes, that he was conducting studies where the productive elements were rated. As a result of the research, we decided to rate what we termed productive work. This technique is called "performance sampling" the results of which we call TEMPO. Since the first study of October 1953, we have conducted a total of 738 sampling studies. Approximately 26,700 employees have been studied and a total of 4.5 million observations have been recorded.

But, enough of history, we promised to discuss performance sampling as applied to a particular company's problems. And believe me, we had, and still have some points of concern.

RECOGNIZING THE PROBLEM

First of all, let me assure you that we have no crystal ball or any other such device that automatically warns us of impending adverse conditions. Admittedly, there have even been a few occasions when we have been caught with our trousers in the "half mast" position. Perhaps some of you have also had that experience. All I'm trying to say is that, in all probability, we operate our business in much the same fashion you operate yours. We try to keep an eye on the factors that are good indicators of the way the trends are developing and react accordingly. This "over-all surveillance" attitude is probably what caused our initial discomfort.

WARNING SIGNS

We began to see some warning signs. For example, there was a note of warning in the indirect to direct manpower reports; not too apparent, but it was there. A look at the want-ads indicated that there was a good demand for technical type personnel while the direct labor market was diminishing.

Figure 3

Some objective searching confirmed our growing suspicions that this was not a localized condition. Review of reports, published by the Bureau of Labor Statistics, indicated that there was a definite trend toward inversion of the direct to indirect labor ratio on a national scope.

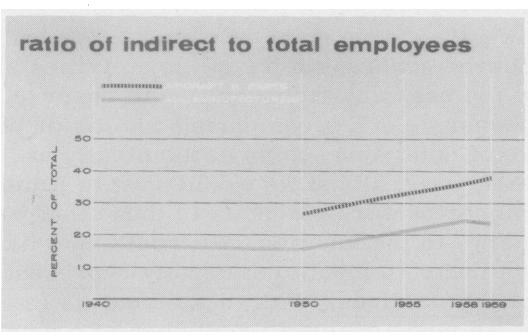


Figure 4

UPWARD TREND OF INDIRECT LABOR

For example the ratio of production workers to all other employees, for all manufacturing concerns, was 82.3% production workers with 17.7% employed in other areas in 1950. In 1959 there were 76% production workers with 24% in other areas. In our business of aircraft and parts manufacturing the relationship in 1950 was 73% production workers, with 27% employed in other functions. By 1959 there were 62.5% production workers with 37.5% in other areas. We recognized that this information was not absolute, but it was an indication of a trend. After our initial awakening, we realized that the growth of this condition had been very subtle and inconspicuous. We hadn't seen anything because we weren't looking for anything.

CAUSES

We could see some of the causes for this trend. For example:

a. Mechanization - We have a number of numerical controlled machines, which we feel have contributed a great deal to our production output and flexibility. This is the obvious part; you can watch these machines produce parts which you can see, touch, and even count if you like.

However, what isn't so obvious is the sizeable staff of people behind these machines that are so necessary to their function. The tape programmers, data processing personnel, and related clerical support all contribute to indirect costs. And behind these is the engineer, who is designing a higher performance product which requires more sophisticated manufacturing techniques.

THE NEED FOR CONTROL

In the past, major attention had been focused on the direct labor component of operating costs. As a result, many indirect and technical operations had grown like Topsy. What had been for us an initial point of concern now began to develop into a major consideration. We began to realize that we had significant resources in the form of scarce, expensive, technical skills. We needed assurance of the best utilization of these skills for a reasonable re-return on the investment. Eventually, this whole thought process we had gone through consolidated itself into one plain and simple fact. You have to adequately control all costs if you expect to maintain a competitive position in the industry.

PRELIMINARY PLANNING

We have found that our Engineering managers are striving for better controls in their areas, and I might add, have done a commendable job at Boeing. The Director of Engineering realized, however, that something was missing, an adequate management tool would enable him to cut costs. Since he was aware of our activities in other indirect areas, he came to us with his problem. Knowing that this project would not only be interesting but would be a challenge, we went to work immediately. We began to develop alternatives that might help resolve the situation:

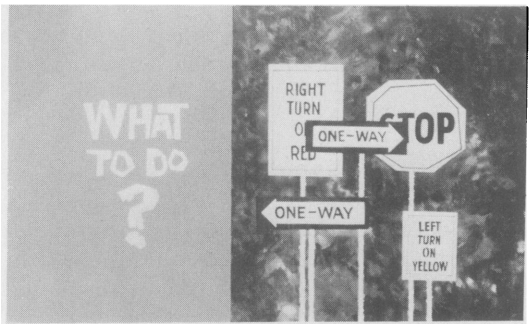


Figure 5

Considering the variety of ways we could analyze this problem, we came to the conclusion that we first had to decide what we expected to accomplish. This isn't always easy as you probably know. I think the necessity for economy finally forced our decision. We decided that what was needed was a means of:

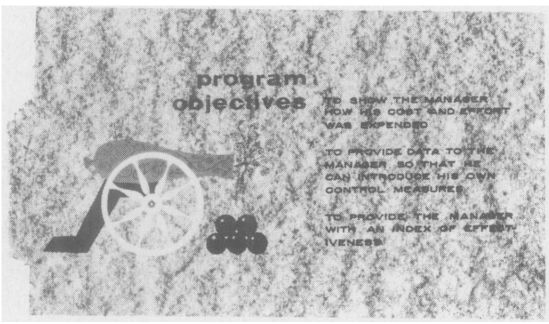


Figure 6

a. Showing the manager how his time and effort was expended.
b. Providing data to the manager so that he could introduce his own control measures.
c. Providing the manager with an "index of effectiveness".

It was only incidental that, during the process, we hoped to establish the ground work for further Industrial Engineering activity.

WHY PERFORMANCE SAMPLING

Perhaps we were a bit biased by our previous favorable experiences, but it looked to us like performance sampling would provide the basis to meet our initial requirements. We believed a sampling approach would be the most satisfactory for our purpose because:

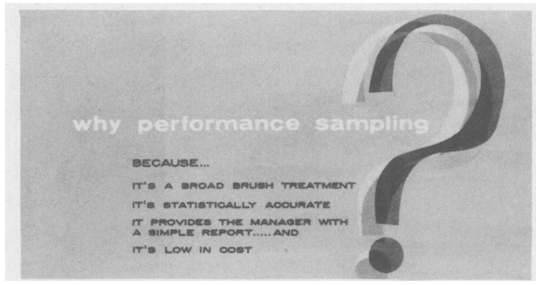


Figure 7

a. It would be a "broad brush" treatment yet definitive by work category.
b. It is statistically accurate.
c. The cost of development and maintenance would be lower for us than the other methods considered.
d. There would be no special training costs because experience had already been acquired in other areas.
e. It would provide the basis for an easily "digested" report which would:

   1. Show the per cent distribution of time for the prime activities of the area.
   2. Be a means of showing the trend of the principal productive factors.
   3. Be a direction indicator for the concentration of improvement effort.
   4. Be an impersonal and flexible management tool.

THE APPROACH

Having decided that performance sampling would give us essentially what we wanted, another obvious problem presented itself - exactly what were we going to sample? We had to find out the general nature of the activities and one of the best ways to do this is to observe. So that's what we did. Considering our major objective of doing this job as economically as possible, we realized we would have to limit the number of work elements to those that were "primary" to the function. We would also like to have these elements reasonably representative of all functions. With these thoughts in mind, we made observation studies of a number of different work areas and derived elements which seemed to satisfy our purpose.

I don't intend to imply that we arrived at these elements the "first crack out of the box". We didn't; we made some initial mistakes and, of course, had to rectify them. To further satisfy ourselves that the elements would meet the requirements, we tested them for a period in a pilot area. The results indicated they would suit our purpose.

By limiting the elements to what we considered to "prime functions"; we not only saved "data collection" money but also kept the scope of the activity confined to terms readily understood by the area manager. We felt the latter point was important for these two reasons. Understanding leads to acceptance and support, and with understanding, the area manager could develop "targets" or goals for his own operation. It is our opinion that the development of "targets" by the area manager for his own operation is an essential factor for the success of this type of program. Our reasoning behind this philosophy is:

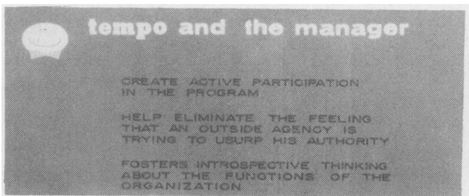


Figure 8

a. It creates active management participation in the program.
b. It helps eliminate the feeling that some outside agency is trying to usurp his authority.
c. It causes the manager and his subordinates to do some "introspective thinking" about the function of the organization.

CONCEPT SUMMARY

After further consideration, we felt that an index of effectiveness would provide additional utility to the manager so we decided to "rate" what we termed the "productive" work elements. To arrive at an "effectiveness index" we simply multiply the average rating times the total productive per cent. The result we call "TEMPO". In summary, our concept developed into:

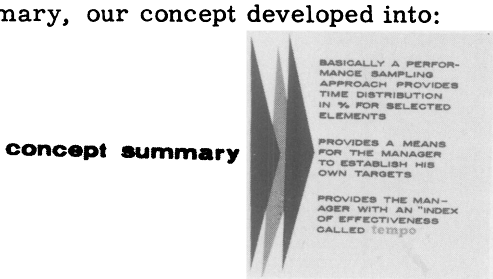


Figure 9

a. Basically a performance sampling approach which would give us time distribution in per cent for selected elements.
b. A provision for the area manager to establish his own targets at periodic intervals.
c. An "effectiveness index" which we call **TEMPO** derived from rating the productive elements.

Many of the results from this type of program cannot have a precise value placed upon them because of their intangible nature. However, considering both tangible and intangible items, we believe we have derived the following "yield" from this program.

a. The manager's are more aware that excessive costs are not limited to the direct labor activities.
b. The managers now have something quantitative they can "put their finger on" resulting in active and objective participation in cost reduction.
c. They now have a device to assist them in better administering their respective areas.
d. There is at least a relative index of how they are doing with respect to similar operations.

PROGRAM IMPLEMENTATION

Most people have to be "sold" on new ideas, a typical and not necessarily unhealthy condition. I doubt if you are any different in this respect. Certainly Engineering managers aren't.

You don't attempt to "sell" something of this nature unless you're reasonably certain your guns are loaded and your powder is dry. All this means is that you've got to have faith in your own product before you can sell it to someone else. The matter of "selling the product" cannot be over emphasized. In this case, it's both a marketing problem and a human relations problem intermixed. It's a composite problem which must be handled in such a manner so as to eliminate doubt, prejudice, and misunderstanding. This is a "must" in order to establish the cooperative atmosphere absolutely necessary to the success of the program. In short, the program has to be bought by all parties concerned. Probably some of your own experiences emphasize this as a pretty stiff requirement in itself. This could easily be the toughest part of the whole project. With these thoughts in mind, the following points were stressed in the presentation to Engineering Managers and their employees.

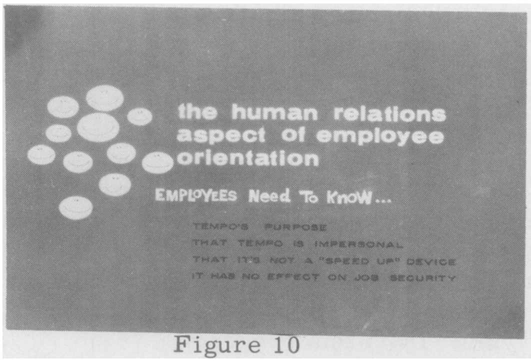


Figure 10

1. The overall purpose of TEMPO
2. That TEMPO was not a speed-up device
3. That TEMPO was impersonal, any individual identification used during the course of collecting data would be destroyed.
4. TEMPO would not affect their job security; and reduction in personnel would take place through normal attrition and turn-over, transfer, voluntary resignation, or promotion

Of course, all questions were answered in a straight-forward manner. Judging from subsequent reactions, we feel we did a reasonably good job of informing those concerned.

INSTALLATION OF THE STUDY

From this point, our procedure was fairly simple.

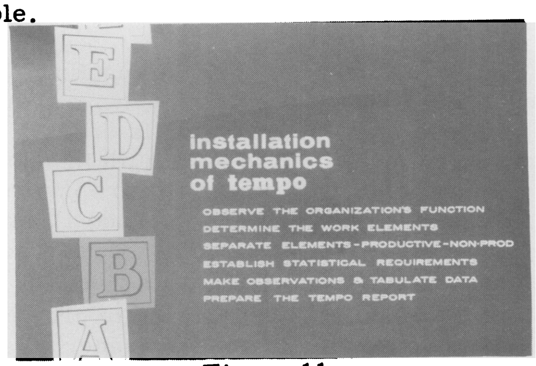
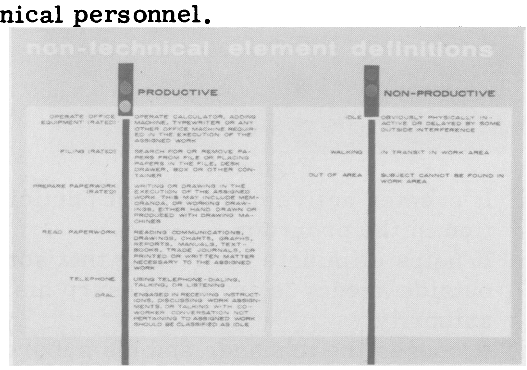


Figure 11

1. We observed the functions of the organization to be sampled.
2. We determined the elements that most aptly described the functions.
3. We separated the derived elements into productive and non-productive categories as desired. "Productive" for this purpose is defined as "those elements which contribute objectively to the accomplishment of the organization's designed function". "Non-productive" elements are those elements inherent to most functions but which do not obviously contribute directly to the organization's end item objective.
4. We established the statistical requirements, the standard error, co-efficient of variation, required number of observations, sample routes and schedules. We developed our routes from layouts of the area being studied; this, of course, is for the purpose of establishing the preferred observation points and, also, random routes wherever the floor layout permitted.
5. We made the observations and tabulated the data.
6. We prepared the TEMPO report.

We found in our studies that we actually needed two sets of elements. One designed for "Non-technical and clerical" and the other for technical personnel.



Non-Technical Elements

1. Operate Office Equipment
2. Filing
3. Prepare paperwork
4. Read paperwork
5. Telephone
6. Oral
7. Idle
8. Walking
9. Out-of-area

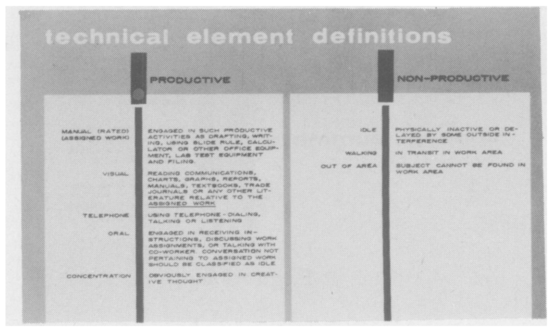


Figure 13

TECHNICAL AND ENGINEERING ELEMENTS

Productive Elements

Manual - (Rated) Subject is actively engaged in such productive activities as drafting, writing, using slide rule, calculator or other office equipment, lab test equipment and filing.

Visual - Subject is reading communication, charts, graphs, reports, manuals, textbooks, trade journals or any other literature relative to the assigned work.

Telephone - Subject is using telephone (dialing, talking or listening).

Oral - Subject is actively engaged in receiving instructions, discussing work assignments, or talking. Conversation not pertaining to assigned work is classified as idle.

Concentration - Subject is obviously engaged in creative thought.

Non-Productive Elements

Idle - Subject is obviously physically inactive or delayed by some outside interference.

Walking - Subject is in transit in work area.

Out-of-area - Subject cannot be found in work area. If subject is out of area for three successive trips he is dropped from the sample and another subject studied.

UTILIZING THE RESULTS

No doubt, there are any number of ways that the administration of the program could be handled. We preferred one which had the element of "personal touch". It is for this reason that an Industrial Engineering representative personally discusses the periodic report with each area manager on an individual basis. During the discussion, the representative helps the manager interpret his report and offers suggestions as to potential areas for improvement. Particular attention is paid to the "non-productive" elements. Incidentally, this is the place where it is necessary to inject a little more "Sales" psychology. Our basic report shows time distribution by category in per cent.

To insure that the significance of the per cent figure is understood, the respective percentages are converted to their equivalent in time and manpower. At least one of these factors strikes home.

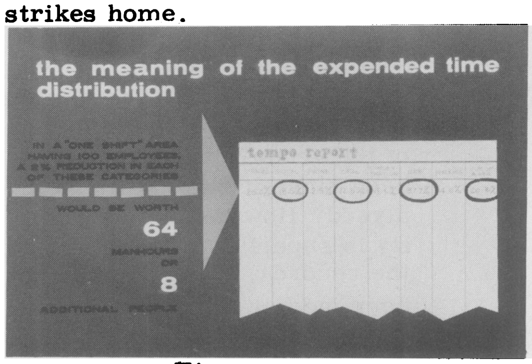


Figure 14

We specifically cover those items which are potentially costly and, more particularly, if they have an adverse trend. For example:

Idle - Does it exceed a reasonable per cent of the normal work day? If it does, it may be a warning of:

- Low workload
- Excessive manpower
- Work improperly scheduled
- Inadequate or insufficient supervision
- Output uncontrolled
- Inequitable workload distribution

Oral -

- Social or business
- Low workload
- Is this a warning that additional job training is needed
- Is there adequate effort to objectively control this item
- Do employees know what performance is expected from them
- Excessive manpower

Out-of-Area

- Is it really necessary to the function of the organization
- Could the situation have been handled by telephone
- Is there an organizational control for this activity
- Could this be an index of low workload - or excessive manpower

You may have noted that there are several factors common to all of these elements which could readily cause adverse percentage values; the two dangerous ones, of course, are "low workload" and "excessive manpower".

"Productive" elements need surveillance too. Peculiar distribution here may be an indication that some functional realignment is needed.

- Manual - Is the "paper mill" process the most suitable for the functions of the group? How long has it been since it was critically analyzed? How much of the activity is superfluous? Can some of the records, reports, etc. be combined or eliminated? Are distribution lists current? Do the recipients actually use the information?
- Visual - Should you be in the pipeline for some of the information you are receiving? Are you guilty of failing to cancel a report requirement after its usefulness ended?
- Telephone - Is this a reasonable percentage for your function?
- Walking - Is office area layout adequately planned?

SUMMARY

Where to from sampling - We do not feel, as yet, that we have wrung out the total value of performance sampling in our Engineering Department. There are some additional refinements we can make to the basic TEMPO program. However, we don't intend to be lulled to sleep by our own self-satisfaction. We are doing some planning toward the use of sampling to set standard times in the areas that are compatible to this type of control. We also feel that many of the Industrial Engineering tools such as process charts, systems analysis, flow diagrams, etc. which served so well in direct and indirect labor areas will have equal application in Engineering. All are "old hat" Industrial Engineering media, proven through years of use. (Figure 15) We think this same "old hat" will fit Engineering functions if you can just gather the courage to try it on.

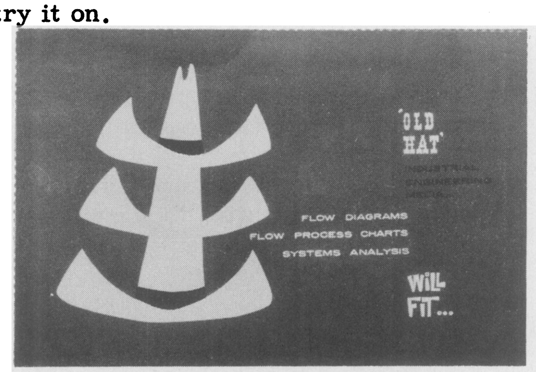


Figure 15

THE KEY TO EMPLOYEE-MANAGEMENT COOPERATION

Fred G. Lesieur
Lecturer
Industrial Relations Section
Department of Economics and Social Science
Massachusetts Institute of Technology

With world conditions as they are today, this industrial society of ours is already facing more complex problems with respect to survival than possibly any other time in our history. American industry is not only facing competition from the industrial society of the free world and that of the communist-dominated part of the world. Certainly I need not stress the motivating force behind the industrial society of the free world. Its goals are set; it wants to get where we are, to have the things we have. Please believe me, this is real incentive for them. So far as the communist-dominated part of the world is concerned, we know all too well what its aims are.

For us to maintain or possibly enhance our position will take the best from both management and labor in the days to come. I don't think we can any longer afford industrial warfare. Somewhere, somehow, we are going to have to learn to live and work together. The stakes are too high, the consequences too great to have us go any other way.

This brings me to the subject that I want to discuss with you today: The Scanlon Plan.

The two strongest beliefs that Joseph Scanlon had were first that most people want to work, and second that there is an area in which a union and a company can meet that does not involve conflict, this area being how the job can best be done. The problem with the former today is that in many companies the average worker finds it very difficult to do his best because of what I will call "restraining influences." The problem with the latter is the fear on the part of many companies of working with a union in areas other than negotiation, grievances, etc.

I would like to discuss these restraining influences with you, using my own experience as a machinist along with over ten years of work in industry with union-management cooperation. I want to take you on a trip through the eyes of a worker.

Work forces today are generally divided into two groups: the direct and the indirect, or if you come from New England you would be more familiar with productive and non-productive. The direct worker is generally the person whose work the company thinks it can measure with some degree of accuracy. With respect to this worker, the feeling is that the way to get him to work is to appeal to his selfish nature. In many plants this fellow is the aristocrat of the work force. He is the one the company sets up in business for himself. He is on individual incentive. He gets paid for what he does. I would like to discuss for a minute or so with you the reactions of this fellow who is in business for himself. It doesn't take him too long to react like a business man, to learn to control his market, to sell his product for the best possible price, and along this route, to become a pretty selfish individual. He soon learns that to help his fellow worker costs him money, so he doesn't.

Now this is where team work enters into the picture at the plant level. If this fellow happens to be an older worker in seniority and works the day shift, he will quite often operate in the following manner. When new tools are delivered to the tool crib, he will take them off for his job. At the end of his shift, instead of bringing the new tools back, he will return the old set that he had in his box and lock up the good ones. Let the night shift use the dull tools. He also knows that it is very important to know who the inspector is on the floor that day. Despite the fact that the engineering department has set rigid standards for the quality of the product, he knows that inspectors are still human beings. Some are easier than others. We used to call them constructive and destructive inspectors. To us a constructive inspector was a fellow who knew where the part went and knew what dimensions should be held as opposed to other dimensions that were not as fussy. The destructive inspector was the one who made us follow the print. There was no sense in putting extra time on the job if we had what we called the constructive inspector on that particular shift. Quite often it makes little difference to the worker that maybe three or four of his fellow brothers in the union who have to put this piece of equipment together af ter he finishes with it spend five days trying to do the job because the parts don't seem to fit together rather than one day if the proper job had been done in the first place. You see, after it leaves his machine, it's their problem, not his. He gets his; it's up to them to get theirs.

Now, coming into direct contact with this businessman in the plant is the industrial engineer. He is the man who supposedly sets the rate scientifically on the job the worker is doing. Despite the fact that they both are working for the same company, they are pitted against one another with respect to the wages that this worker wants to take home to support his family. To most workers, no matter how nice this fellow might be, he is the enemy. I am not trying to say that industrial engineering does not have a place in the plant. In fact, under proper conditions, the contribution that an industrial engineer can make to better and more efficient production is unbelievable. I sincerely believe that industry has gone a long way towards destroying the real value of the industrial engineer by having him set a monetary rate for the production worker on the job.

The real problem you run into here is that you are asking the industrial engineer to deal with the experts. The engineer probably has hundreds and in some cases thousands of rates to set and police. The worker on that machine has just that job to do. If this worker is proficient at all, he can become quite an expert. He becomes a bit of an engineer himself, and in many cases will find a better way of doing the job. So in many instances the industrial engineer may return to one of his previous masterpieces of rate setting and discover that instead of the worker making a 20 per cent bonus, as he was supposed to on that job, he is making 60, 80 or 100 per cent. The engineer discovers that possibly the worker has bastardized his creation. He has re-engineered the job to his own liking and in a way which enables him to make more money--very often much more than the company wants him to make. So the next step the industrial engineer has to take is the re-engineering of the job, to take care of this black eye on his masterpiece.

You gentlemen know how companies like having their prices cut for the product they make. Well, just imagine how this fellow back in the plant likes having his prices cut. He soon learns what the trade will bear, how much it is safe to turn in before you as a company start to impose an excess profit tax on him. He has to become a bit of a banker. He saves on the good jobs so that he can apply the excess to the poor jobs, and he hopes to come home with the same salary week after week. This whole atmosphere makes for excellent team work, you see, between the industrial engineer and the worker. It shouldn't be too difficult for you people here to realize the contribution that industrial engineering can make in a situation if somehow it didn't have to control the worker's take-home pay.

Just visualize, if you will, a foreman trying to run a department in this particular plant that I am talking about. The department is made up of maybe 60 per cent aristocrats, direct workers, and 40 per cent indirect. I think that in the past twenty-five years industry has done more to usurp the foreman's job than probably any other in the company. It is no wonder that foremen, in many cases, don't know whether they are fish or fowl. There was a time in American industry when a foreman had to know his people and his job. When he needed more help in his department, he interviewed people for the job. Today, in many companies we have experts doing this, and very often all the foreman does is requisition one, two, or five men that he might need. Formerly he was called upon to know what a day's work was. Now all too often all he can go by is a piece of paper telling him that John Jones is doing 200 Z hours or whatever type of measurement the expert has set. I would venture to say, and this experience has happened to me in a number of plants, that upon going to a foreman and asking him how Henry So-and-So is doing in his department, he would have to refer to a piece of paper telling him what Henry was doing. The fact that Henry was doing what the paper said was a day's work but yet was spending one third of the day away from his machine wouldn't mean a thing.

I've seen cases where foremen have tried to get some of these incentive workers back on their jobs and found themselves quite helpless when promptly told by the particular worker, "I'm meeting the day's work standard that you have set, so it is my money that I am playing with and not yours. You've got every right to tell me to get back to my job when I'm not meeting that standard. But until such time, you take care of your job, and I'll take care of mine." This really promotes team work in a department.

Now industry has tried to combat this problem at the foreman's level by instituting training programs. Some of these programs have been very good; however, in many cases I have found that the training program involves making a public speaker or a psychiatrist out of the foreman. Very little attention is given to training him to do his job. Why, in one firm I visited, they even had the foreman reading Plato. This is handy in running the department. The company's president was more interested in making men than a product. Someone reminded him that if the company didn't do a better job on its product, perhaps there would be no men around to make.

Continuing through the organization, there is another group that is very vital to any company. and that is the engineering department. Most workers in the plant feel that engineers are not human. It is generally felt that they sit up in their ivory towers creating the product, without giving any consideration to the tools with which the worker has to make it. Now whether this is true or not is not too important. It is what the worker thinks that is important.

All too often he finds that when he makes an error in his work his machine is sometimes idle for one, two or more days while someone tries to get the engineer down from his ivory tower to tell him what to do next. In these periods of discussion about "what do you do now," very little thought is ever given to what is good for the company. The engineer can't bear to see his creation altered, and the worker just can't understand why the engineer isn't a little more flexible in going along with some modifications to save the particular part he is working on. Again, this is team work.

The next area I would like to discuss is the accounting division of a company. All too often today we find situations where instead of accounting being a service to the company, the company is servicing the accounting group. I've even seen cases where the company was facing bankrupcy, and when it was suggested to the accounting group that they change their methods to provide understandable help for people doing the job, they just wouldn't do it. You just couldn't bastardize a good system. The fact that the company was going bankrupt had little meaning. We have found, under proper conditions, that the contribution which accounting can make toward lower cost is tremendous. They are the pulse of the organization. They know where the problems are, but it is a matter of getting the people who make the product to understand the problems so that they can do something about them. Just to say we are losing money to a group of workers is meaningless. Remember, they have heard this at every negotiation. But telling them where the company is losing money sometimes can make a real difference.

Team work also enters into the office group. I don't know how many times during the past ten years I have visited offices and heard someone approach somebody's private secretary and ask her to come out and help the girls in billing or tab or some other department and get the response, "That's not my job; I'm So-and So's secretary." The fact that Mr. So-and-So was in Washington or some other place for two or three days and the girl was reading Gone With the Wind was not important. You see, the important thing to her was that she was someone's private secretary and what would he think if she lowered herself to help someone else in some other department. With real participation I have discovered that office people can make just as much of a contribution toward betterment as anyone else in the plant. Their lack of understanding about what is going on with respect to their jobs today is unbelievable. In particular, they hear rumors concerning the elimination, they think, of their jobs by these new electronic monsters that are being installed. It is no wonder that some of these very important and beneficial systems have such a difficult time getting into operation in many companies.

I have tried to enumerate for you some conditions that prevail in many plants today. Please believe me, time does not permit, but there are many, many more. It just amazes me that these companies can remain in business with so much "I" going on and so little "we" concerning the day-to-day operating of a plant.

The Scanlon Plan means doing away with these restraining influences. It means replacing a so-called "I" relationship with one of a "we" relationship. You see, all too often what I do in a given situation is not quite so important as what we can do together.

To Joseph Scanlon there was no such thing as an indirect worker. Everyone working for a company from top to bottom, to his way of thinking, was a direct worker. They all had a contribution to make, either in making the product or in servicing it. Now if they didn't, then they shouldn't be around. He felt quite strongly that if you are going to have an incentive system, everyone possible ought to participate in it. The incentive payment should be placed on a better product going out the shipping door at a lower cost. You all live or die by that. The so-called enemy to the work force quite often is not the company they are working for, as they sometimes think, but someone else, in some other place, possibly in some other country, making the same product, doing a better job, and getting the business that maybe this company should be getting. It seems to me that a company has a difficult enough time in our competitive society competing with other companies who are in the same line of business without having to compete with 300, 500, or 1,000 or whatever number of employees they have who are also in business for themselves.

We have discovered that we don't know what efficiency is. We have found that if everyone, from top to bottom, working for a company has the same objective, and somewhere, somehow finds in himself a relation to that objective, the results are quite amazing. You can sit back with your slide rule and compute what you think people can do, but please believe me, when properly motivated, what they will do can be quite different.

The Plan, by any stretch of the imagination, does not mean that management gives up its right to manage. In fact, our experience has shown that under the Plan the better management the company gets, the healthier and stronger the Plan is. All too often companies go out looking for some magic formula or gimic that can be applied to their operations and somewhere, somehow expect that change will come about. Please believe me, the Scanlon Plan is not a formula or a gimmick It needs leadership, and the better the leadership the better it will work. However, one big change that does come about under the Plan is the opening up of an area in which the union or employee can state how he or she thinks his or her job should be done. It is our belief that there is a vast reservoir of ideas on how a job should be done held by the people who are doing it. This is the area the Plan opens up. Then, it is up to management to take these ideas and put them into effect. The Plan entails giving specific problems to people to solve concerning their operations.

In measuring change in situations that have applied the Plan, we have tried to make the measurement as simple as possible. We find that there is a great deal of danger when working people participate in something they don't understand. This is why we shy away from profit sharing if at all possible. You see, if a worker doesn't know why he gets something, he will never understand why he doesn't get it. We have tried insofar as possible to tie the worker over what he has control of. This he understands very well. Most of the measurements we have applied have been relating the wages received by the entire group against what those wages produced. In developing a measurement, we recommend that a full year or a cycle of the business be used as a base. However, we strongly recommend that you should pay incentive earnings as close as you can to when they are earned. So in most situations the performance is computed on a monthly basis. We have found that this can be done with complete safety for the company by setting up adequate reserves for unforeseen developments or seasonal fluctuations of the company. We also recommend that the incentive bonus recognize skills and be paid on a percentage basis. By that I mean if the performance in a given situation totaled 10 per cent in a given month, the plant manager would get 10 per cent more pay and the floor sweeper would get 10 per cent more pay. Insofar as composition of the team, we recommend that it be as broad as possible. In some situations it is up to and including the president of the company. There is a great deal of strength in having everyone under the same plan. Most people are very suspicious when there are many different plans in a given situation. Everybody is always wondering who is on the better plan. Certainly these measurements have to correlate with the earnings of the enterprise.

In the above I have tried to briefly state some of the tools we have used in the overall measurements we have applied. This session could be spent solely in the area of measurement, but I think a more important element of the Scanlon Plan is the joint cooperation that brings about the change in whatever yardstick is used. I would like to point out that the Scanlon Plan is not a substitute for collective bargaining. All too often companies come in and talk with me concerning the application of the Plan, and the only reason they are seeking something is that the union wants a wage increase that the company doesn't want to give and are very often facing a strike. However, they'll give them some kind of a plan instead. Any time a group of people take a plan, no matter what kind it is, as a substitute for a wage increase they might be seeking in collective bargaining, and any time the substitute doesn't pay whatever they were after, the plan is in trouble. My best advice to these people is to get your bargaining out of the way as best you can; then, after this is done, maybe both of you, the company and the union, can explore the possibilities of joint union-management cooperation. If this procedure is followed, you are then building on good firm ground. You see, the test of a plan is when the company faces adversity. Anything will work when the company is loaded down with orders. It has been our experience that companies with the Plan find it is just as active when the going gets rough as when they are real busy, in some cases even better. There is a lot that people will do to protect something that is theirs rather than some gimmick that has been applied.

To implement participation we recommend that the company be divided up into what we call production committee areas. The plant I came from originally had eight such Production Committees. The divisions at this company were generally set up by department. A Production Committee is composed of both company and union or employee representatives. The management appoints its side of the committee. It should be the boss in the area covered--someone who can make decisions. The union, where they have bargaining rights, or the employees in areas such as the office where the union does not cover, elect someone from their group to represent them on this production committee. The size of the committee is completely dependent upon the areas covered. If it is a large department, there could be three union representatives or three employees elected by their group; or, if it is a small department, possibly only one representative would be elected.

It is the duty of this committee to meet once a month, or more often if necessary, to go over problems concerning their particular area It is mandatory that the management member of the committee give to his committee member prior to the production committee meeting any problems that he would like to discuss during the coming meeting. The union or employee member will bring into the meeting any suggestions that his or her fellow workers might have concerning how they think their job should be done. The production committeeman has the right to bring one or two people to the meeting with him if he feels that they might better explain their idea than he. Minutes are kept of this meeting. The minutes comprise the suggestor's name and the suggestion the individual has made along with the disposition of it. There is no voting as to whether a suggestion is accepted or rejected at this level. It is up to the union or employee members of the committee to convince the management member that the suggestions they have deserve consideration and should be tried. It still is left to the management member to decide whether or not the ideas can be tried. These committees meet individually in their own areas. A transcript of the Production Committee's minutes is then sent to what we call the Screening Committee. This committee is composed of the top management of the company along with elected union and employee representatives plus the president of the local union. Its meetings are scheduled regularly, once a month or more often if necessary. In the plant I came from, the membership of that committee from management included the following: the executive vice president, the treasurer, the chief engineer, the plant manager, and someone from production control.

The first function of the Screening Committee is to go over the performance of the previous month--figures such as the payroll for the month, the sales, and if inventories were used, the change in inventory. After screening through these figures, the bonus or deficit is announced to the plant. The following is an example of a bonus computation. These are the figures that would be screened by the committee. The controller or treasurer answers questions pertaining to these figures that are asked by the committee.

Calculating the Bonus

Scanlon Plan - January, 1957

Gross Sales		$ 898,780
Less Freight Out	$ 12,268	
Less Sales Returns	3,465	15,733
Net Sales		$ 883,047
Plus Increase in Inventory		67,076
Sales Value of Production		$ 950,123
Allowed Payroll (38.2% of 950,123)		362,947
Actual Payroll:		
Factory Payroll	$ 206,674	
Office and Salary Payroll	88,574	
Reserve for Vacations and Holidays	12,402	307,650
Bonus Pool		$ 55,297
*Reserve for Deficit Months (25%)		13,824
Bonus Balance		$ 41,473
Company Share (25%)		10,368
Employee Share (75%)		$ 31,105
**Bonus Paid as % of Participating Payroll (i.e., 31,105 ÷ 295,248)		10.5%

*Reserves are set up on an annual basis.
**Participating Payroll equals Total Payroll minus Vacation and Holiday Reserve. (i.e., 307,650 - 12,402)

The next order of business of the Screening Committee is generally the laying out of problems by the company that they are facing with respect to competition, quality, business available or anything that can keep the work force informed about what is going on. I have seen on occasion a competitor's product brought into the meeting so that the committee could become more familiar with the competitive situation. If the committee felt there was merit in some of this information going down through the Production Committee, then this was accomplished. The final function of the Screening Committee is to go over all of the minutes from the various production committees. Those suggestions that have been agreed upon and put into effect at the production committee level are put into the record, and decisions are made concerning those suggestions which were not resolved at the lower level. This means that when a suggestion has been rejected at the production committee level, and the employee or union side of the committee still feels it has merit, it is reopened at the Screening Committee level and thoroughly discussed, and a decision is then made by the Screening Committee concerning this particular suggestion. Again, there is no voting at the screening committee level. It is up to the union and employee side of the committee to convenience the company that the suggestions they have made should be tried. It is then up to the company to make its decision on whether they should be adopted or not.

Experience has shown that this committee acts as a court of higher appeal and that quite often good suggestions that are not accepted at the production committee level were adopted at this screening committee meeting. We have found that the decisions at the screening committee level are not made based upon some personality back in the plant but rather upon what is good for all concerned. The Plan doesn't mean turning the plant over to the union. The following statement may sound strange, but I don't know any union that wants the responsibilities of running a plant. They have enough problems in running the union. Under the Scanlon Plan all we are talking about is providing an opportunity for people to say in an adult society how they think their job might best be done. It is up to management to take it from there. It means workers thinking a little bit more about who gets the job after them, and how they might make it easier for them. The Plan means that the older, more experienced worker gives his ideas on how the job ought to be done to the newer worker. It means that the younger worker may be more physically able to help or make his contribution to the older worker.

This Plan doesn't mean giving people a sense of participation--workers don't want that. This Plan means giving them real participation. If you will take the time to look at plants who have undertaken this union-management cooperation, you will discover that we have no set formula, that the Plan has worked in these varied situations because of the desire of both management and labor to get together and mutually solve problems that will help them be more competitive in this industrial society of ours. It means working with your brains instead of your backs.

I imagine that many of you here, after listening to me, have come to the conclusion that all the Scanlon Plan involves is operating the company the way it should be, management facing up to its responsibilities, doing its job, and the employees and union willingly doing their jobs. This is true, but remember, it involves getting rid of all of the restraining influences that make it impossible for participation to flourish. Individual incentive has to be disposed of. It means giving the foreman back his job of leadership in his department. It means a willingness on the part of engineering to work as close as it can with the plant. I just wonder if you can visualize the role of the industrial engineer when he is completely free to do his job--the change that comes about. With the payoff point of the incentive on product going out the door, it means that the worker on the machine can call the industrial engineer down and say I've got an idea here on how this job might be done, but I don't have the technical ability to develop it. Will you help me? This is a little different than having to hide ideas because it might cost the individual money. This means doing away with individual awards for suggestions if such a plan exists in the company, because under the Scanlon Plan any savings that are made through a suggestion are a contribution to the group. Strangely enough, we have found that we get at least ten times more suggestions under this type of system than under the best award systems that are going on in this country today. It means the accounting people giving the various departments the tools they need to work with on how they are doing. You see it is only possible to get this kind of a relationship, or as you people commonly say, team work, if you can get rid of the conflict of interests and put everyone in a plan that ultimately pays off by what they all do together rather than by some individuals.

I would like to close my remarks with the following observations. A person who has to work today, and this is in excess of 60 million in this country, spends approximately 2/3rds of his waking hours related to his job. I don't think it is inconceivable to think that if these hours can be reasonably happy, and please understand me, I don't mean peaceful, because I think you die in peace. There certainly is room for healthy differences of opinion. This environment also will make the man or woman a better person at home. If, as a worker, you feel you are part of the company rather than a pawn, your attitude towards your job can be a great deal different. We have found in the past ten years that bonuses are important when the company is doing well; but we have also found in many instances that effort on the part of those involved has been greatest when the company faced its most trying times. Also during these trying periods, when in most cases it was impossible to make a bonus, the participants in the Plan were just as enthused and just as willing to do all they could to better the situation. I sincerely feel that there are satisfactions that a person gets from within that far exceed any monetary value that you could hope to place on them.

NEW CHALLENGES FOR INDUSTRIAL ENGINEERS

Warren R. Mellin
Director of Industrial Engineering
United Air Lines Executive Offices
Chicago, Illinois

INTRODUCTION

It is a sincere pleasure for me to have the opportunity of participating with you in this, the 13th Annual Industrial Engineering Institute. The phrase, "Lifelong Learning," has been used for some time by the University of California in many of its brochures and publications. No doubt this motto has application to all areas of knowledge, but certainly those of us in this room will agree that it strikes a very familiar chord in the field of industrial engineering. Recent years have seen rapid and dramatic advances in the profession.

In our discussion today, I would like to develop comments in three basic areas.

First, a discussion of the factors responsible for the current transition period and renaissance in the field of industrial engineering.

Second, a review of the organization of the industrial engineering function within United Air Lines, so that we have a frame of reference for understanding.

Third, a portrayal of the principal areas in which the Industrial Engineer may make his greatest contribution to the future.

TRANSITION PERIOD

Most of us recognize the fact that industrial engineering currently is in a transition period. It is always difficult to determine when the transition began or the full duration of it, but those of us who have been practitioners for many years have recognized in the last few years that the transition is dramatic and that there are significant trends that have begun to emerge.

To understand something of the nature of the transition, we might look at the factors or trends that seem to be at work.

1. There is an increased awareness of the existence of total systems in operation. In this connection, we refer, for example, to the total manufacturing or production process or system, the distribution system, reporting system, or possibly the total system used in the operation of an entire company. We seem to be more aware today than ever before that there is a need to optimize the whole and to achieve the optimum results from the total system. There is still a need to understand each part of it, but there is increased emphasis on the need to comprehend the interaction of the parts. In this understanding of the total system, there is a growing emphasis on the need to predict and influence what will happen rather than merely to account for it on an after-the-fact basis.

2. The need for improved communications is demanding recognition. The flow of information within a system and between systems is being recognized, as well as the need of management for timely and appropriate types of information necessary for decision-making. All too often decisions in the past have been made on inadequate facts as a basis for understanding. This is not to say that these decisions have necessarily been wrong, but improvement in communications and information flow should greatly increase the probability of the right decisions.

3. Today we have better tools and techniques than ever before in terms of ability

to gather data, develop measurements, and predict results. The development and increased use of statistics and mathematics, and the growth of management sciences are well known to us. Some of the so-called newer concepts in the areas of probability, queueing, and work sampling have made it possible for us to achieve a deeper explanation and understanding of the underlying nature of problems, as well as unlock answers and develop alternate solutions to problems.

4. The development of electronic computers is certainly an important breakthrough. This one element is so significant that it deserves a category separate from that of "better tools and techniques". The computer, apart from its ability to process data faster than ever before, has enabled us to use linear programming approaches and simulation. The computer makes it possible to measure, manipulate, and predict in advance the effect of possible changes of input into a system. These inputs may be in the nature of policies, methods, facilities, inventory, and manpower. Measurement of the variance resulting from alternate inputs will lead us to know and predictable outputs in terms of quality and quantity of product, or service, or whatever output we may be concerned with at a given point in time.

5. There is a greater emphasis on the significance of research and development and the need for long range planning. The Industrial Engineer has come to be more than only a staff member for an operating department concerned with the functions of work methods, work measurement, or layout. The contributions that have been made in the development of totally new concepts have lead, in many companies, for this individual to be considered in terms of his ability for creativity and innovation.

6. These five trends in this transition have interacted between themselves to precipitate another factor which in a sense is an outgrowth of the other factors but also a very real one in itself. As a result of the practicality of new approaches and the contributions that have been made, there has been a change in management's attitude toward the functions of an Industrial Engineer. Thus, management has begun to see the Industrial Engineer in an emerging role. He is being given a new image as an individual that is an aid to management and indeed, in most organizations today, is a member of management. The change in management toward the Industrial Engineer has been a subtle and gradual process, but it has resulted in a better climate and atmosphere in which an Industrial Engineer may work.

7. All these factors really have resulted in another one--a change on the part of universities and educators toward the needs of management and industry in the field of industrial engineering. Many of you men in the audience are the product of some of the newer curricula that have been adopted by forward-thinking universities. The curricula that you and I see today in the field of industrial engineering can hardly be compared to that of five or ten years ago. This change means that men coming out of school today have a broader base than the graduate of a decade ago. They have the potential of faster development and the ability to make significant contributions to a company in a minimum period of time. Thus, we have an accelerated process which daily is gathering momentum and will further enhance the value of an Industrial Engineer to management.

ORGANIZATION

In order to provide ourselves with a frame of reference that will enable us to understand the concept of industrial engineering within United Air Lines, I would like to spend a moment on the over-all structure of the company.

United Air Lines - United has three basic management control centers, or offices, in addition to the installations at the 82 cities it serves.

The Executive Offices are located at Chicago, and the top management of Sales and Advertising, Community Relations and Publicity, Finance and Property, Personnel, and Economic Controls Administrations is located at this point. The titles are probably self-explanatory with the exception of Economic Controls, which is a top management staff and service organization reporting directly to the President, and serving the business research and management and industrial engineering needs of all other departments.

The Operating Base is located at Denver, and the top management of the Flight Operations and Transportation Services Administrations is at this point. Flight Operatios controls all flight crews and the ground functions of flight dispatch and communications. Transportation Services is responsible for the administration and control of all stewardesses and ground operating personnel at all cities United serves.

The Maintenance Base is located at San Francisco. At this point is located United's Engineering and Maintenance Administration. The major overhaul of all aircraft is performed here.

As you can appreciate, the needs of a company with three offices and with installations at 82 cities demands an over-all point of view and a total systems engineering approach to the solution of present problems and the ability to meet future needs.

Industrial Engineering - The Economic Controls Administration, headed by a Senior Vice President, plays a key role in top management planning and control. This Administration has two basic functions at Chicago--Business Research and Industrial Engineering. In addition, there have been field offices at Denver and San Francisco in order to serve the needs of the operating organizations located at those points. The Business Research Department embraces the activities of economic research, market research, airplane schedules, and budgets. Industrial Engineering has four basic divisions:

Organization Planning guides and plans the company's organizational growth. It maintains a program of job analysis and job evaluation for both management and non-management positions; conducts organizational reviews and studies, both long and short range; and keeps abreast of the latest advances and techniques in the field.

Regulations and Forms edits and publishes company-wide regulations and procedures for all phases of the company's operation, thereby providing a uniform method of communicating with personnel in the field through a system of regulations. This group also designs company forms and analyzes reporting systems.

Operations Research and Development is responsible for keeping abreast of the latest developments in applied statistics and applied mathematics and for encouraging operating departments to use these techniques. This division also performs systems engineering functions, including appraisal of the need for computer applications.

Work Analysis administers the work and service level measurement program, develops and stimulates methods improvement projects, publishes a facility planning guide governing the amount and type of space for all fixed plant facilities, and encourages the operating departments in quality control installation and applications.

We might emphasize the fact that the nucleus of the industrial engineering function was created by Mr. W. A. Patterson, United's President, in 1940. Even though we recognize the tremendous contributions that dozens of individuals have made over an extended period of time in the Industrial Engineering Department, we would like to stress and fully credit the climate created by Mr. Patterson himself. This over-all atmosphere, his alertness and expectation of innovation and progress, and his communication of ideas for continued growth and forward momentum to all Vice Presidents has been a prime factor in whatever contributions may have been made by individuals in the department.

NEW CHALLENGES

It would seem that the future holds at least three major challenges for those of us practicing industrial engineering.

Research and Development - First is the area of research and development. The need for more research and development effort is being recognized, and the need must be fulfilled in order to develop long range plans and come up with totally new and different ways of doing business. We need to be sure of having at least a few individuals in this effort that are insulated from the fire-fighting projects that must be done now. At the same time insulation is provided to them, we must somehow build a bridge that they have contact with real life and so that the results of their efforts may have meaning and practical application on a long term basis. Here we have the customary industrial engineering problem at any given time of either going too deeply into a problem or not deeply enough. The establishment of a research and development effort should be a continuous long term effort, and might well foster a cleaner break point in some of the short range projects as to the extent of the depth that is desirable.

Any individuals set up for this mission must have the freedom to pursue ideas and concepts without any expectation on the part of management for an immediate return from their efforts. These men should be able to explore the frontiers, and their personality should lead them to be inquisitive, with a perspective and bent for innovation. From time to time there may be some merit to having them participate on certain projects with representatives of operating departments to enable them to retain touch with current problems. There is a need for balancing effort between work to be done for others and work that we must start for ourselves in the area of research. Even if the initial effort is only two or five per cent of the total amount of industrial engineering time, it is a beginning.

The research and development effort should be relatively broad in scope and there should be no limitation on the channels to be followed in research. Some research may lead to a questioning of management policies. The research may be unrelated to traditional areas of industrial engineering. The effort may well lead to reviews of financial concepts, rate of return on investment, markets, consumer reaction, or other problems affecting not only a given company but also the industry in which it is located.

Systems Analysis - Second, we spoke earlier of the need for understanding an entire system, and there is very little question but that the role and scope of systems analysis, design, and engineering constitutes one of the real challenges for all of us. The need to understand each part of a system and how it interacts is significant, but the goal of optimizing the entire system is paramount. The first time or two that we draw back and take a look at a total system should result in "gold nuggets", as far as significant improvements and savings are concerned. Many years from now, after a systems analysis approach has been utilized many times, we may be "panning" for gold, and it may take a long time to accumulate a small pile of gold dust, but the first time or two we will be reaching and finding "gold nuggets".

In the systems approach, the need for recognition of variability is stressed as well as the need for understanding the probabilistic nature of both the inputs and outputs of a system. The proper design, control, and feedback from a system, both in-process and as a result of the complete cycle, must consider the need for predicting results in advance. We must consider the extent to which we can manipulate parts of a system, perhaps through simulation, to design a system that will achieve optimum results. We need to have less emphasis on after-the-fact measurements and more emphasis on before-the-fact control and direction. As the systems analysis approach is activated and projects are undertaken, the results should further widen the door for more work and borader scope in the future.

Management - Third, the need for assistance to management appears to be a fertile field and one with real challenge for us in future years. As mentioned, management needs a timely and meaningful flow of selected information for decision-making. Management is certainly not looking forward to having all possible facts accumulated by a computer, processed more rapidly thaneever before, and resulting in a three-inch report on a weekly basis for review. However, management is looking for the significant information flow that will be helpful to them for control and decision-making purposes. They are looking broadly for a way to optimize gains in all areas and minimize risks. Management wants a quantitative picture wherever possible in balancing the costs and all other factors associated with decisions.

There is a need for all of us in industrial engineering to recognize and be sensitive to the needs of management. In many areas the Industrial Engineer can serve as a catalyst, a communications link, and an adhesive that can weld together divergent factors and provide coordination at a level below that of the President. The Industrial Engineer can serve the needs of management by penetrating the departmental barriers that exist in some companies at some times. In this area the Industrial Engineer should avoid competition with operating staffs. Instead, he should serve to complement and weave together varying skills, experience, and know-how into a composite pattern for management decision and understanding. Fundamental to all of these endeavors is emphasis on economics, the need for achieving a fair return on invested capital, and the maximization of profits on a short and long range basis.

Participation endeavors such as these will further accelerate the image that is being formed by management of industrial engineering.

In the final analysis, the Industrial Engineer will be judged not by what we define industrial engineering to be. Rather, management will judge the Industrial Engineer by what he does and the contributions he makes on a practical and timely basis.

SUMMARY

Gentlemen, there is no question but that industry, and indeed the free world, is looking for men with concepts to meet the challenges of modern management, to push back the frontiers, to broaden knowledge, and to achieve understanding. You men, as Industrial Engineers, have the training, experience and the viewpoint necessary. In addition, you are in a very strategic position to effectively meet this challenge. I have every confidence that you will meet it!

MOTIVATION CONTROLS

Max B. Skousen
Management Training Specialist
2339 Honolulu Avenue
Montrose, California

INCREASING EFFICIENCY FOR EVERY SUPERVISOR

Robert Owens, the famous English philanthropist of almost two hundred years ago, inherited a factory. He was not an industrialist, but he was a great student of human nature. He arrived at his new plant with three spools of colored ribbon - yellow, green and red. One morning the workers came to work and found a piece of ribbon tied to each machine. Some machines had one color, some another. Everyone buzzed with curiosity. After several days, the word got out. Red ribbons were tied to all machines that were producing above the factory average. Green ribbons represented the average output. Yellow represented below average. Owens made or implied no threats. He was merely using the ribbons to let people know how they were doing. The effect on the people was electrifying. Within two months every ribbon in the factory was red. Production had never been so high; morale so strong.

This amazing experiment was conducted almost two centuries ago. Yet in the years that have followed, many people in management positions have failed to apply its significant lesson. The colored ribbons enabled the workers to keep score, to compete with each other, and to set up personal objectives. Owens had used a simple, economical, but extremely effective Motivation Control. Why did it work so well?

WHAT WE WORK FOR

Most of us work because we get paid for it. Yet none of us will work for money alone, because money alone has no value. Money is important to the extent that it buys security, recognition, achievement, and comforts. Our jobs are the best way we know to get this money. But lucky is the man who works at a job that not only gives him dollars, but also furnishes such additional rewards as personal recognition, a sense of achievement, the reality of accomplishment, and freedom of expression. In addition to his wages, such a man is getting real "satisfaction pay" for his efforts.

Most supervisors realize the motivational power of recognition, yet few use it often enough. A work force produces the power for a factory just like the engine produces power for an automobile. A car cannot run on gasoline alone. It must have the proper mixture of oxygen to allow the fuel to fully ignite. To a work force, the "wages" are the basic fuel, but "recognition" is the oxygen. If we persistently choke down the recognition, we may get a fast start but it won't be long until the monetary fuel is running out the exhaust without providing the production for which it was intended.

Gas + Oxygen = Prrrr

Most of us realize this. Then why do we hold back the recognition? Some say we are too busy. "We just don't have enough time to bother." "Why praise a man for doing what he is being paid to do?" Consider the wife who was determined to get her husband to praise her cooking. She finally prepared the most perfect feast of his life. As the meal was almost over and he had said nothing, she asked in desperation, "Do you like the dinner, George?" George looked up in amazement and replied defensively, "I'm eating it, ain't I?"

Since appreciation and encouragement are powerful job motivations, failure to provide such stimulating recognition to our people costs more than we can imagine. When a worker fails to obtain a feeling of achievement from his job, he has little incentive to do more than just get by. He finds little challenge in his work. His job, and therefore he, himself, seems unimportant. In addition, since most workers are required to do a rather specialized, restrictive job-operation, they often find little opportunity for growth in skill and knowledge. Some supervisors seldom encourage their groups to show initiative and to be creative. Often when the workers do a good job, little if anything is said.

What is the solution?

Some supervisors have found ways of overcoming these voids in job stimulus by purposely developing a plan or system which provides stimulating recognition, competition, and achievement among their workers. Such systematic programs come in all kinds of forms, shapes, and sizes, but most of them can be classified under the title "Motivation Controls."

A great variety of Motivation Controls have been built and are now being used by first line foremen to increase their production and to eliminate problems. In the following pages, we will discuss suggestions that may help in establishing such control devices. A Motivation Control, if properly handled, can enable a foreman to almost automatically control and encourage his people. In many cases, systems can be devised that will operate so simply that several dozen aspects of the job can be controlled simultaneously.

IMPORTANCE OF PERFORMANCE RECORDS

Motivation Controls succeed because they help people to better identify and improve their work objectives. This is important because the first step toward success in anything is to have an objective. Any high jumper can go higher if he has a bamboo pole to jump over than if he merely leaps up in the air. The runner who broke the 4-minute mile trained with the objective in his mind for many months. It is said that "success is the power to visualize the objective." Yet, so many of our people have very meager performance objectives, other than putting in their time. This is our fault as supervisors, not theirs. It is also said that "he who aims at nothing is sure to hit." This is one of the reasons why the average worker contributes less than 50% of his basic capacity to his job.

Industrial engineers proved that productivity in most jobs can be increased an average of 40% by applying effective job standards. Think of it! 40% more! Such improvement usually surprises the workers as much as it does the foremen, because few realize how much better most jobs can actually be done.

However, job standards will not automatically do the job alone. The individual must feel a personal responsibility and pride in the relation of his performance to the standards. This is what a Motivation Control succeeds in doing. Usually through a chart or other visual, descriptive means, the worker is able to see where he stands. He gets greater recognition for his progress and achievement, thereby feels greater challenge and incentive. Higher productivity is not only a result of greater physical effort, but it also comes from greater mental effort which results in reduced waste and improved methods.

HOW TO ESTABLISH BASIS FOR STANDARDS

The primary requirement for a Motivation Control is in finding a numerical basis for evaluating performance. The approach varies according to the type of work, particularly whether the work is repetitive or non-repetitive.

Repetitive Jobs: If the work consists of the same recurring operation, it is simple to determine a numerical score or comparison for what is good or poor performance. Since complete production figures are almost always kept on repetitive jobs, the basic material for a motivation control is already at hand. All the foremen need do is to find a visual means of showing the relative significance of the figures.

A foreman whose group assembled bicycle seats came up with a Motivation Control without intending to. For his own interest, he had drawn

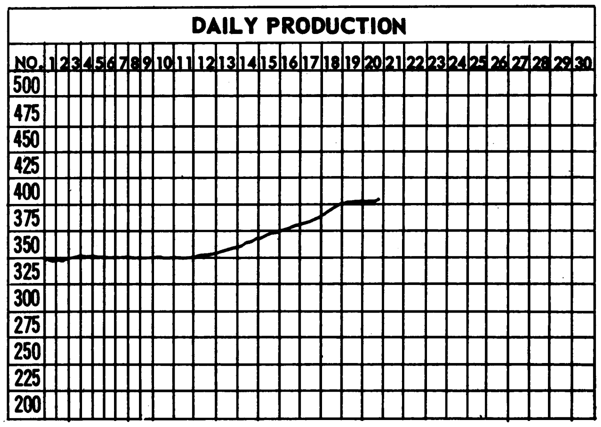


Chart Showing Units Produced

up a chart showing the total seats produced each day. The daily plotting showed an average of between 350 to 360 units a day. But gradually he became aware of an upward change in his graph. After several weeks, production had climbed to over 400. He was completely puzzled until one day during a lunch period he found all of his crew crowded around the chart. The workers had become interested in the total output and had been seeing how many times they could break previous records.

Non-Repetitive Jobs: But everyone seems to ask, "What about non-repetitive jobs?" Production standards become much more difficult when variables enter the picture. However, job objectives and standards can and should be worked out. We usually give up too easily. Here are four different approaches that can be used:

1. DEVELOP AVERAGE STANDARDS

Although the jobs are variable, the overall aspects of most work is still repetitive. For example, a garage mechanic is not doing what one would call repetitive work, yet over a month's period, he will repeat a number of repair jobs on radiators, transmissions, tune-ups, etc. Even doing one job after another is repetition. By taking a category of a job, keeping track of the hours spent on each such job, an average for that category can be determined. Such an average can be the basis for a standard. Although these average-based-standards would not be a fair measurement for any single day, they do tend to be meaningful over a longer period, so they can be the basis for weekly or monthly ratings.

The Navy had a large housing project near San Diego during World War II. A staff of civilian maintenance men took care of the trouble calls. The housing officer felt that the men were taking too much time on their calls. But how was he to prove it, let alone do anything about it? For example, a call regarding a clogged toilet could mean a few minutes, or in some cases, a few days work. It seemed impossible to control the men by any standard measurement.

He resolved the problem by developing "average standards." Service calls were segregated into 16 major categories and complete records kept on hours used. After several months enough data was accumulated to determine the average time for each type of service call. The "average standard" was set at 25% below the actual average in order to provide an incentive target. The men were instructed that a single job might run over or under, but the jobs would average out for the month if they did the best they could on each job. A chart, posted daily, showed each man's accumulated average and the average for the group as a whole. Within two months, the average hours per service call had been reduced 50%.

2. CONTROL CONSTANT REQUIREMENTS.

If it is felt that even the overall job is not repetitive enough to make "average standards," then you should look for specific things about the job that are constant requirements. An example would be keeping the place clean, achieving good attendance, having the men sign out faithfully, getting certain forms completed, and similar things about the work which can be described as "always being with us."

A research engineering supervisor found it difficult to establish performance objectives. Each of his men were specialists, working on numerous assignments, some lasting months and others years. His men worked steadily, but many of the jobs were dragging on too long. In analyzing the operations, he realized that with every job the one factor each man had to repeat was a final report. He knew reports were something the men disliked doing. So he made a Motivation Control to stimulate making out reports.

A chart was placed on the wall listing each man's name at the top of a blank column. As project reports were turned in, the title of each report would be recorded under the man's name. The titles were accumulated for twelve months and then a new sheet was started. No attempt was made to rate the value or magnitude of each report for the total explained its significance to those involved. The effect of the chart was clearly evident. Reports increased in volume, schedule improved, and produtivity increased in general.

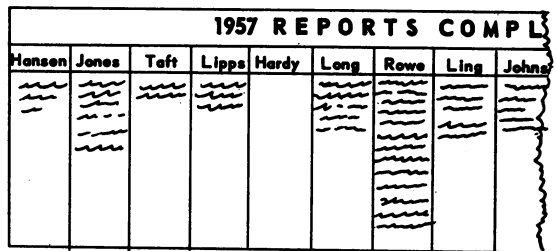


Chart Posting Engineering Reports Completed

3. CONTROL THROUGH PROBLEM REPETITION

Another way to find measurable elements is to examine the frequencies of problems. A problem grows serious because of its frequency, and frequency means repetition which is the basis of measurement. For example, if the group is continually forgetting to do a certain thing, a completion chart can be made showing which items have been done for each period. Another example might be the problem of not getting enough method improvement suggestions from the group. A completion chart giving credit for each individual's contributions will keep the idea before the people.

A senior buyer was plagued by complaints that his buyers were occasionally using the wrong terms of payment on purchase orders. He brought the errors to the attention of his buyers, but the problem continued. His next step was to accumulate the errors and circulate a list, showing each error and persons responsible.

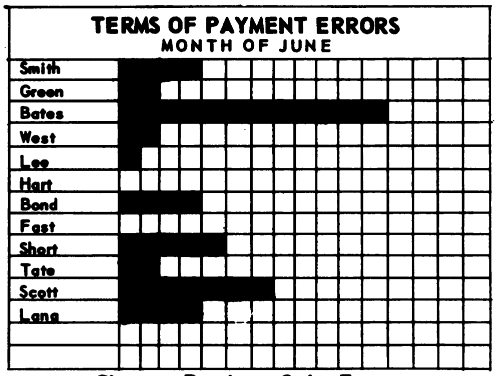


Chart on Purchase Order Errors

But this still did not correct the problem, so he made a visual presentation of the problem. He listed each buyer on a chart, filling in a square behind his name for each error. Four errors would make a bar four squares long. Ten errors would be a bar 10 squares long. The idea worked and did not have to be repeated.

4. CONTROL BY SAMPLING

Many factors on a job are too numerous to keep track of. When we do not keep track, we lose the power of tight control. There is an effective way to get the needed information on such factors through a system known as Ratio Study or Sampling. It is possibly the most valuable means of control for non-repetitive type of work.

Facts and figures have greater meaning when they are related to other factors. We use percentages frequently because a percentage shows the ratio of one thing to another. For example, if a worker averaged four rejections a day this week as compared to five a day last week, we can better appreciate the ratio of change by expressing it as a 20% improvement.

When we realize that figures usually become more meaningful when expressed as ratios, we can often save time by taking a sample, count the frequency of each factor in the sample, and easily obtain the ratio of the various factors. Sampling allows control in many areas where 100% record keeping would be unthinkable.

Sampling is frequently used in making surveys, particularly in the area of quality control. The same system also allows us to determine how workers are using their time. In a later section when we discuss the process of sampling in greater detail, we will give examples of worker sampling. But for now, let us consider an example of how sampling can be used as a motivation control to improve quality.

A tool control department became greatly concerned about the inaccuracy of its inventory files. An estimate was made of how much a complete revamping of the files would cost. $20,000 was the price. The job was much needed and the money would be well spent. However, merely correcting the files would do nothing about the careless work habits. Therefore, errors would renew the same problem in the future.

Instead of the expensive revamping program, a small, random sample was taken of the files in each tool crib. The ratio of errors in each group's sample was posted as their accuracy score. A list was published, showing each crib in its rank order. The best on the list had 20% errors; the worst had 40%. Everyone was informed that another sample would be taken in thirty days. A considerable improvement was shown by the second sample. By the third sample, the poorest crib was down to 20% errors and some were down to almost no errors at all.

WHY MOTIVATION CONTROLS WORK

Let us repeat a previous statement. Motivation Controls succeed because they help people better identify and improve their work objectives. And work objectives should be based upon the relation of job performance to some numerical standard of reference.

The five examples of Motivation Controls listed above, as well as the story of the colored ribbons of Robert Owens, demonstrate how easily a foreman can build the "spirit of the game" into the production situation. The increasing efficiency was not the result of fear, nagging, or threatening. It was the result of a systematic way for giving recognition, just as the scoreboard or a baseball park keeps everyone aware of just where the game stands. With such aids, the foreman does not have to worry about production when he leaves the department for a few hours. Workers become as interested in production as he is.

It has been said that individuals usually produce more when they know the following things about their work:

1. What they are supposed to do.

2. What authority they have.
3. What their relationships are with the other people.
4. What constitutes a job well done in terms of specific results.
5. What they are doing exceptionally well.
6. Where they are falling short.
7. What they can do to improve unsatisfactory results.
8. That there are just rewards for jobs exceptionally well done.
9. That what they are doing and thinking is of value.
10. That the boss has a deep interest in and concern for them.
11. That the boss is anxious for them to succeed and progress.

The power of Motivation Control comes from the fact that they help the foreman provide many of these critical needs for his workers. In the examples mentioned, production had been only fair - far below the potential - because the supervisors were unable to provide real challenge and appreciation for their people.

As one looks down the above list of things workers want to know, he can see how these Motivation Controls, simple as they are, enable the supervisors to provide this needed knowledge to their people. The workers become aware of specific objectives-thereby knowing more of what they were supposed to accomplish. They begin to feel a greater responsibility for the work, thereby realizing the authority they possess. They begin to appreciate the efforts of others since it is important in the achievement of the goals, thereby understanding better their relationships with other workers.

As the bar charts begin to form a more and more economical standard, it is easy for all, including the foreman, to see what constituted a job well done. When the people did exceptionally well, or when they fell short, everyone knew about it. The charts showed the workers that the foreman was really interested in what they were doing, especially in their improvements. They had no doubt about getting due recognition for a job well done because the charts on the wall were the center of attention.

Motivation Controls work best when some simple rules are followed. On the following pages are ten rules vital to effective controls.

Helps in Developing Motivation Controls

1. SELL THE PURPOSE TO THE GROUP

Before you introduce a Motivation Control, get your group sold on the importance of the goals and objectives to be achieved. Workers need to understand how the control will help them, why the things being measured are of real significance, and how the control will enable them to receive recognition for their contribution towards their desired goals. They must see that the goals are both reasonable and necessary. Workers also need to understand why improved performance objectives and job measurement are essential to reach the new goals. Many times a foreman has expected little more than compliance from those below his level, but in those instances where the foreman has brought his people in on the whys and wherefores, he has received more enthusiastic cooperation.

2. GET THE PEOPLE IN ON THE PLANNING

All of us tend to resent dictatorial or unilateral restrictions. It is up to the foreman to decide whether a Motivation Control is to be installed, but it will help if the people are allowed to plan some of the details. One of the best ways to do this is to hold an open conference. After selling the purpose as discussed above, explain the general plan for control, and then give your people choices as to details, i.e., "Do you want the charts posted or kept in my desk? Do you want your names shown on the chart or represented by a coded symbol? Do you want to post the information yourselves or have me do it?" By letting the people participate in the planning, you show trust and respect for their willingness to cooperate. They will find it easier to believe that the control will be used to help rather than hurt them. Furthermore, people will usually establish tighter restrictions on themselves than they will cheerfully accept from others.

3. APPLY CONTROLS ON SMALLEST GROUP POSSIBLE

Individuals are motivated when they feel that their part is significant. The larger the group, the more difficult this is. A lineman plays hard on the football team because he understands how critical is his position. Generally, the smaller the group, the easier it is for the individual to understand the significance of his contribution. It is many times more difficult to get high individual motivation in a group of 1,000 than a group of 10. The strongest motivation is to combine individual recognition with team or group recognition. It is possible to work out many controls which honor both the top individuals and the top groups.

4. DELEGATION IS THE KEY

It does little good to get our people enthused about solving problems and improving work if we allow them little initiative through denials, restrictions and limitations. Let your people know you respect their interests and ideas enough to back up their recommendations. Delegation means more than the right to run errands. Delegation means the right to make decisions and carry responsibility on the way things should be done.

5. PROVIDE VISUAL COMPARISON

Cold, comparative figures come to life when they are portrayed in some visual form. There are many and various ways information can be translated to some form that would enable everyone to see at a glance the true significance of differences or changes. The following rules should be considered when using visual controls:

1. Display should be as simple as possible, easily understood.
2. If numerous factors are involved, separate charts should be used to show each single or group of factors.
3. Visual material should be neat and well prepared.
4. Information should be kept up to date.
5. The display should be placed so that it will receive proper attention.

Following are some of the visual controls that are in common use:

1. Bar chart: which shows a vertical or horizontal bar depicting quantity or percentage.
2. Target chart: such as the thermometer type, which depicts a progressive accumulation towards a particular goal.
3. Trend or line charts: which connect postings on a scale to show a general trend.
4. Completion chart: which shows filled in squares for the accomplishment of particular goals.
5. Check list: which depicts sequence of accomplishment.
6. Reports: explaining results, use of time, or conclusions and findings.

6. EASILY MAINTAINED

One of the most difficult factors in devising a control is to find some simple and economic way to obtain the information upon which the control is based. If an elaborate system is necessary, the burden may be as unbearable as the original problem. Sometimes the controls can cost more than their possible maximum savings. Generally speaking, any time the paperwork on a control is elaborate and complex, the foreman should analyze his problem again and see if some other method might not be better. The first question to ask is whether the control would work just as well with random sampling. Perhaps the information needed for the control is already available through existing records. Sometimes it is possible to have the employees furnish the information themselves, provided automatic safeguards are built into the plan.

7. SELF-ADMINISTRATING IF POSSIBLE

Very often when workers are asked to help solve a problem, they will offer to administer their own control system. Such controls usually work because the group is anxious to see their own proposal succeed. Usually, the supervisor should have some part in the program so that the workers realize that he is vitally interested in the success of the control. If it is practical, workers can keep their own records and fill in the control chart. One supervisor with a housekeeping problem had his men take turns being housekeeping judges. He was happily amazed at the results.

8. CONSTANT ATTENTION

Usually a control will receive no more interest by the group than given it by the foreman. Many controls have become meaningless because the workers found from experience that the "boss" never seems to pay attention whether the report is good or bad. The supervisor should find continuing methods of bringing the results of the control to the attention of his people. This can be done in group meetings, by departmental memos, letters to his boss that are also circulated to the group, or special notes on the bulletin board. When the workers see that the supervisor's boss is showing real interest in the latest trend, their interest is bound to increase.

9. POSITIVE NOT NEGATIVE PRESSURE

Controls work best when the emphasis is on recognition and praise for those doing the most satisfactory work. If the workers feel that the information is going to be used as the basis of blame, they will try to find ways of justifying themselves or "rigging" the information. It is not easy to have a control that's 100% fair in every respect since there are so many factors that are in part beyond his control. If a person

is blamed because of things beyond his control, he will feel justified in becoming resentful. The supervisor, therefore, should make every effort to operate the control on a fair and equitable basis and not to use the information for blame. Through encouragement and recognition, it should be used as a positive motivation for his workers. The supervisor's attitude to those who appear to be doing poorly should be that of helpfulness and cooperation. The full weight of a blunt and sincere ultimatum should be used only as a last resort.

10. FOLLOW UP

A control should be continued only as long as it is needed. As soon as this need has been met, the control should be either modified or dropped. If it is thought that the problems might reoccur as the control is stopped, it might be reduced to a skeleton control which would show trends but not require full reporting. In many cases, the control will have promoted the proper attitude toward the situation and may no longer be needed. However, while the control is needed and is in use, there should be constant and systematic on-the-job-follow up. Controls only highlight that improvement which the supervisor has encouraged his people to attain. Improved methods, double checking for accuracy, more efficient use of time, preventive problem solving, and many other ways of increasing productivity will be found by the worker if his supervisor shows close interest in suggestions. It must be remembered that controls work only because they provide a healthy environment for on-the-job follow-up.

A very wise man once said: "Control is primarily a state of mind." It is important that we make certain that it is a healthy state of mind.

With these ten rules, the basic approach to Motivation Controls should be fairly clear. However, since everyone's job is different, the task of adapting these principles to any one particular situation is never easy. So, for this reason, we have some additional information. We will explain sampling in more detail, some additional ideas for using charts, and some more ideas for controling non-repetitive work.

How to Make a Worker Sample

Good management is possible only when sufficient information is available to permit wise decisions. Yet in many cases, adequate information is lacking. Sometimes the common methods used for gathering facts are too cumbersome or costly to use. In such situations, inaccurate evidence or opinion is used and causes many problems.

Work Sampling is a method of acquiring the necessary information in sufficient amount to make a wise decision. Work Sampling is extremely easy to set up. It can be changed as often as findings warrant and can be discontinued when sufficient evidence is available. Work Sampling can be done by the foreman or his delegate providing him with vital information about his own operations.

HOW TO USE A WORK SAMPLE

First, determine those activities on which you desire additional information. Assign symbols to these activities. For example, you may wish to know the percentage of time that your people are: "on-the-job," "away from the area," "talking," and "loafing."

You might assign the following symbols to these activities:

On His Job . . . . J
Away From Area . A
Talking . . . . . . T
Loafing . . . . . . W
(W for waiting which is better than L for loafing)

Now a work sheet is needed. Take a piece of paper that is ruled into squares and list the names of the employees to be studied on the left hand edge. Each vertical column on the work sheet is used to record the observations of a "trip." The date and hour that the "trip" is made is entered on the top of the column.

A "trip" is the phrase used to denote one instantaneous observation of the activity of all of the employees included in the sample.

At random each day make a tour or glance about your area and record, after the name of each employee, the symbol which more nearly describes the activity in which each employee is engaged in at that moment.

When 100 or more symbols have been recorded, figure the percentage of occurrences for each symbol. This percentage for each symbol indicates the percentage of time during the period that the group is engaging in that particular activity. The chart below interprets the hypothetical results of such a study:

ACTIVITY	SYMBOL	OBSERVATIONS	PERCENTAGE OF TOTAL TIME
On His Job	J	60	60
Away From Area	A	18	18
Talking	T	10	10
Waiting	W	12	12
TOTAL		100	100%

WORK SAMPLING IN INSPECTION SUPERVISION

Let's consider some instances in which industry has used work sampling. An Inspection Supervisor wanted to know why it was that in spite of having more than enough inspectors on the floor the work of his group was far behind schedule. He decided to sample four activities: Actual inspection, writing of Inspection Tags, miscellaneous work, and idle. To each of these activities he assigned the following symbols.

J - Inspection or On-the-Job
I - Writing Inspection Tags
M - Miscellaneous Work
W - Waiting

Using these four symbols, he observed and recorded two samples a day for three days. After adding up the number of each of the four symbols and determining the percentage of each in relation to the total number, he found that 60 per cent of the total symbols were "I's." He concluded, therefore, that his inspectors were spending approximately 60 per cent of their time preparing Inspection Tags. He was aware that this amount of time was disproportionate to the amount of time the men should be spending in the actual inspection process. Work sampling gave him sufficient information to recognize the nature of his problem and he took steps to reduce the amount of time inspectors were using in the preparation of "I" Tags. His corrective action was so effective that within two weeks his group was on schedule.

WORK SAMPLING IN A TOOLING SHOP

A foreman in a tooling shop decided to use worker sampling to determine how much of his group's time was spent doing actual constructive work on tooling. He felt that his people were doing too many "other" things. Since the sample was only for his own information, he did not tell the workers about his new fact finding system.

He used the following factors:

W - Direct work
T - Talking
WK - Walking
TC - At Tool Crib
CU - Cleaning Up
I - Idle
WI - Waiting on Inspection

The results of his first week's sample showed direct work to be only 63%. This confirmed his fears. He decided to continue sampling privately to see how successful his new emphasis on "more direct work" would be. The second week, he found that the percentage of direct work time was practically the same, being 64%. The third week was even a little worse, 62%. The fourth week was 64% again.

At the beginning of the fifth week, in desperation, the foreman decided to let the workers in on the little score keeping program. In telling the group about the new sampling program, he introduced it as something that would be started at that time. He never told them of his preliminary sampling nor did he ever attempt to use the previous information when counseling. He knew the men would resent not having been informed ahead of time that they were being checked.

In explaining the purpose of the sampling program, the foreman stressed that it would measure his own ability to provide steady on-the-job work for the men and to reduce their interruptions. The reaction of the men was very favorable. The men began to watch their time much better because they were aware that it was now a matter of record. That week direct work time went up to 78%. The next week it was up to 82% and the following week it was up to 87%. Total hours per tool began to decline as productivity increased. The men held the line at between 87% and 91%.

WORK SAMPLING & THE WORKER

Like the tooling foreman, you may want to run your own private sampling program before introducing it to the group. A trial run will enable you to become more familiar with the sampling method and you will also find out what the performance is before the workers have reason to change. However, remember, that when you use sampling without first informing the people, the information obtained should never be identified. Sampling is not a way of spying on your people. It is merely a scientific method of obtaining the performance averages so that you can evaluate that performance more accurately.

When a sampling has been properly explained to the workers and administered fairly, the reaction has been positive and stimulating. Workers fear something they do not understand. It is therefore essential that you explain how work sampling operates, why it is being used and what use will be made of the final date. If a group does react with suspicion and resentment at first, they will relax just as soon as the foreman demonstrates that sampling increases his ability to be helpful and fair.

A well administered Work Sampling Program indicates that people do their best work when they know their behavior is being thoughtfully observed. We call work sampling a motivation control because it gives a worker an incentive for wanting to make a good record. In many cases, workers actually watch the accumulation of sampling scores in a healthy, competitive spirit.

Sampling's greatest by-product comes through counseling with the workers. The discussion of individual performance should be confined to the person involved. Since you need to show him the whole work sheet, it is advisable to either code the name or cover them up. The individual can compare his own performance with the rest of the group without making personal comparisons.

If a worker complains about a specific entry and offers some explanation, be very willing to change it to whatever he suggests. There is no need to argue. The real objective has been obtained since the worker will be more watchful of his behavior in the future. He is unlikely to repeat his excuses more than once or twice. Your willingness to make the change in the record is ample evidence of fairness.

HELPFUL HINTS ON TRIPS

1. Unless you are actually going to speak to each employee at the time of the observation, limit the number of factors to be observed to five or six. Having only a few factors will enable you to note your observations mentally instead of making recordings in the presence of the employees. As you observe, make mental note of those who are exceptions to the normal activity. By remembering the exceptions, you automatically can recall the rest.

2. Determine the time at which each observation is to be made. It is important that you pick a completely random time. This will insure that your checks do not follow a habit pattern that can be anticipated by your workers. Some foremen use a stack of numbered cards or the pages of a book

to determine the time at which they will make their "trips." This procedure avoids an unconsciously established pattern of observation. An observation should always begin at the pre-determined time you selected at random. It should not be made just because some immediate, undesirable condition has just been noticed.

3. If the whole area to be observed is in view, the observations may be made from a fixed location. The observation may also be made while walking through the area, hence the phrase, "trip."

4. When you return to your desk, record on the work sheet the proper symbols. This procedure of unobtrusive, mental observation and later re-recording, permits a truly representative sample. Certainly the observer should not carry with him his work sheet, stop, observe, and record activities. This will give a false picture, due to the fact that work patterns will change at this time.

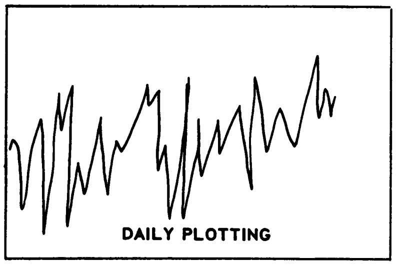
5. You may find that some characteristic that you are checking is not going to give the results that you originally anticipated. Then quit using it. Draw a vertical line on the work sheet to indicate the point of change. The same thing can be done when you want to add a new symbol for added breakdown.

6. Unfortunately, work sampling will stand up in court only when taken by a disinterested third party. Therefore, a foreman cannot use his own sampling as proof-positive regarding the work performance of an individual. The information may be absolutely correct, but he will not be able to prove that he had not chosen biased times to sample. Sampling is excellent for personal counseling, but not to prove the fairness of disciplinary action. Such proof must come from specific instances rather than sampling averages.

How to Use Charts

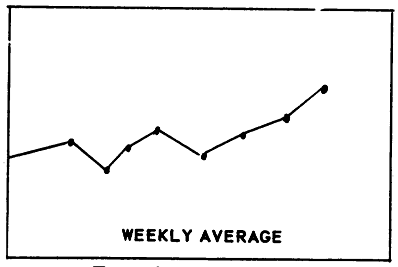
It is said that one picture is worth a thousand words. The purpose of a chart is to make a simple picture story out of a mass of numerical information. Considerable imagination is often required to determine the most effective way to present figures. Following are a few suggestions.

HOW TO SHOW TREND. In the first chart shown below, it is obvious that the line see-saws so much that there is little meaning in the picture. If daily report figures fluctuate extensively, it is well to change to some type of trend indicator line instead of daily postings. The second chart shows the same information based on the average for a longer period, in this case a week. By this means, the performance trend is definitely recognizable as being upwards.



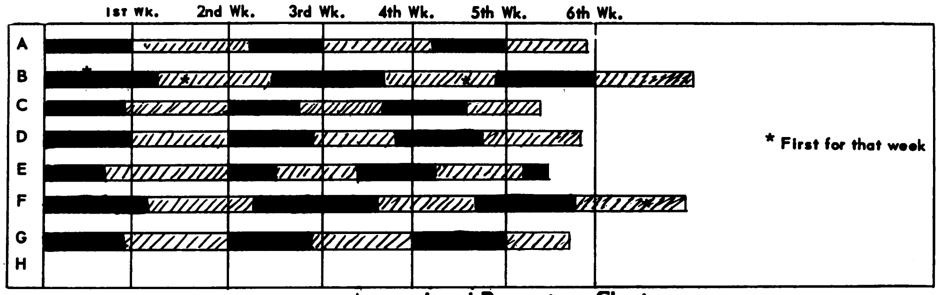
See-Saw Chart

Another type of trend indicator can be based on the daily moving average, showing a posting for the average of the previous five days. The moving average has the advantage of showing some change each day. Another way to show trends is to use accumulated totals, as explained next.



Trend Indicator Chart

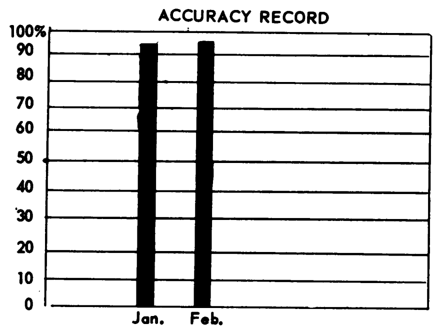
HOW TO ACCUMULATE PERFORMANCE. So frequently charts and data reports show only the information for a particular period. There is often no attempt to relate the current figures with previous periods. An excellent way to give greater continuity to a report is to show an accumulation of scores. A chart designed on such a basis is particularly effective. From such a chart it is possible to tell who did the best each week and also who has done the best over the whole period.



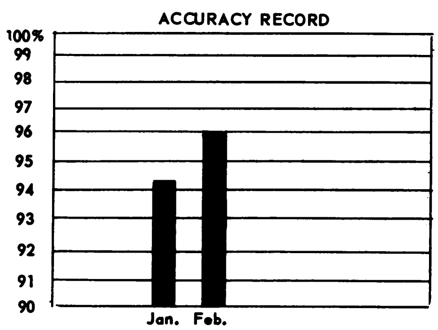
Accumulated Percentage Chart

Whether performance is measured in units of output or percentages, the information can be accumulated on a chart by advancing the bar each week. Small comparative differences between groups compound as time goes on. In the example above, a vertical line is drawn to show where 100% would fall each week.

HOW TO DRAMATIZE SMALL PERCENTAGE CHANGES. Changes of one or two per cent on a 100% scale will not appear nearly as dramatic as they actually may be. For example, the two charts below show the same increase of accuracy, from 94% to 96%. On the first it is hardly noticeable. On the second, the true significance of the change becomes more apparent. Since the error ratio has been reduced from 6% to 4%, there has been a 30% improvement in quality.



Full Percentage Chart



Partial Percentage Chart

HOW TO MAKE GOALS ATTAINABLE. If a group feels that a goal is out of reach, there will be little incentive to strive toward it. A goal of 100% may actually depress the incentive of a group doing 48%. In such a case, the foreman might set a goal for the following week of 55%, then 60% for the next and so on, until the group is nearer to the real goal of 100%.

Another method is to establish a "factor." If a group is hindered by handicaps which are either beyond their control or difficult to resolve, then their actual productive score could be multiplied by a factor allowance. In the above case, if the 48% score was due to a number of new people or perhaps some current problems with the work, then a factor of 1.8 might be justified. Their production score would be multiplied by 1.8, thus bringing their allowed score up to 86%. The goal of 100% would then be close enough to be tempting. As the handicap conditions could be brought under control, the factor of 1.8 would be gradually reduced to the basic norm of 1.0.

HOW TO KEEP THE CHARTS ALIVE. Charts are effective only as long as they are the center of meaningful attention. Charts may stay "alive" for a few weeks or even a few months because of their natural momentum, but to keep them alive, special features must be added from time to time. The group needs to be given new challenges based on some type of new goals, recognition, competition, or incentive. Simple awards, prizes, notices of commendation, or even a special treat will help to stimulate greater improvement. A victory party is especially valuable. The group likes the "boss" to be "pigeon" if he does it as an expression of good humor and appreciation.

HOW TO USE COMPLETION CHARTS. In contrast to the usual line or bar chart, a completion chart has squares to be filled in when certain requirements or conditions are completed. Not only are these charts simple to make and easy to maintain, but they open vast new areas to measurment control. Following are a few examples.

1. Experience Chart. An experience chart is a means of motivating workers to in-

crease their job skills. Each worker is listed in a column on the left side of a chart. The various jobs or skills required in the group are listed at the top of the chart. If a worker has no experience in a given job or skill, the square in the corresponding column by his name is left blank. If he has a little skill, one corner of the square is filled in.

If he knows the job but would need a little refresher, a small corner is left blank. If he is fully experienced, the full square is filled in. The results of this type of completion chart has been amazing. Not only does it stimulate the workers to acquire additional skills, but it assists the foreman or leadman in making training or replacement assignments.

2. Personal Equipment Chart. If a foreman finds difficulty in motivating his people to have the necessary amount of personal tools, he can use the completion chart to solve the problem in a hurry. The desired list of tools would be shown at the top of the chart. If the man had a certain tool, the square by his name, under the tool, would be filled in. Otherwise, it would remain blank. The resulting picture is worth a thousand words. It usually does not take long to see the chart completely filled in.

3. Achievement Chart. Whenever your people need to be stimulated to complete certain assignments, the completion chart is one of the best ways to do the job. If the foreman wants all of his men to read certain bulletins, job instructions, or any other special reading, he can use the chart to give automatic recognition to those who have done the job. In the chart shown below, instead of listing the jobs across the top, reading assignments would be listed. As the people complete an assignment, they get to fill in a square. If timing is desired, colors can be used indicating whether it was completed on schedule or behind schedule.

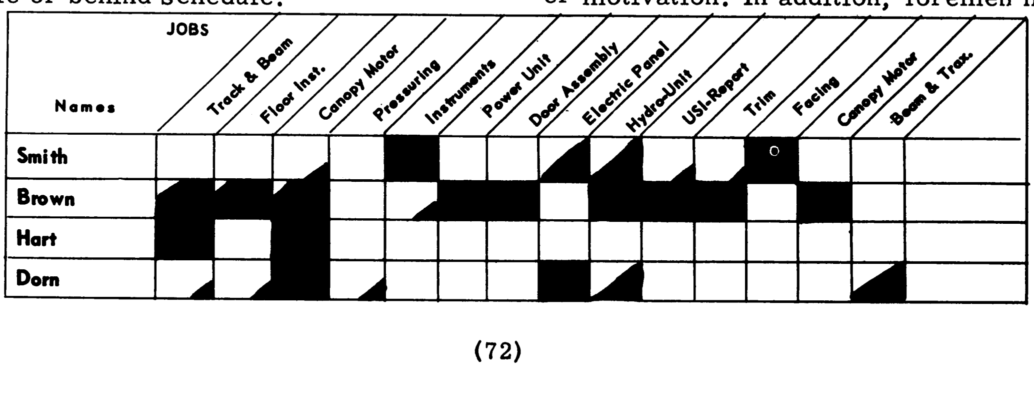
ADDITIONAL MEANS FOR CONTROLLING NON-REPETITIVE WORK

Besides those methods discussed earlier, there are three additional means for measuring non-repetitive work. Which of the three you can use depends upon whether your work units consist of short, medium, or long span jobs. Short span jobs are those which range from a few minutes to several hours in length. Medium span jobs are those which usually range from several hours to several days or even a week. Long span jobs are those which range at least a week to a month or more. Following you will find an approach to each type. Those who have tried them have been very pleased with the results. If your work consists of a combination of all three types, the use of all three programs might be necessary.

SHORT SPAN WORK. Why not try some form of tally system for your short span work? All you have to do is develop a system for your people to keep a tally record of how much they get done. If the work consists of several different types of functions, a worksheet can be provided so that the people tally how many they complete of each type. It may even be possible to develop a weighting ratio for each type, so that the totals can be weighted to produce a single score for the month. For example, if there are four types of work processed in the group, each type would be given an average value as compared with the others. If it was found that type A was generally twice as much work as type B, type C was five times as much work as type B, and D was the same work as B, then a monthly score would be computed as follows:

JANUARY			
Type	Completed	Factor	Score
A	518	X2	1036
B	420	X1	420
C	610	X5	3050
D	10	X1	10
		JANUARY TOTAL	4,516
		DECEMBER TOTAL	3,930

Even if average weighting is not used the tally system will provide a strong surge of worker motivation. In addition, foremen have been



impressed with the value of tally information for enabling them to do a better job of making decisions. The one caution that should be stressed is that considerable thought should be given to developing the very simplest system for collecting the tally information. The system will not last long if it involves too much paper work.

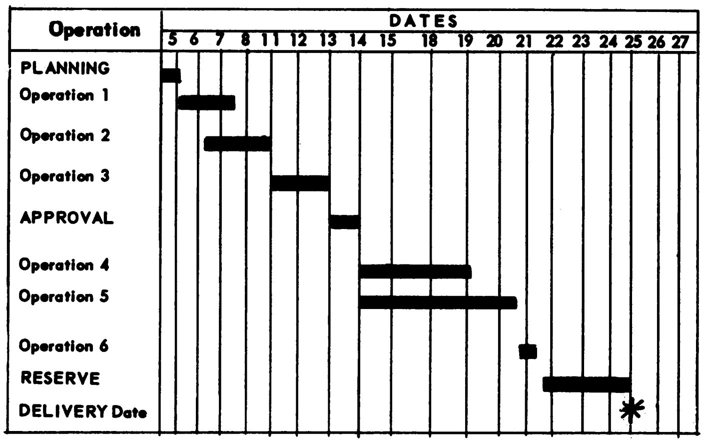
MEDIUM SPAN WORK. There is no excuse for not having job estimates on medium span jobs. If the company does not provide them-or if the ones they do provide are unreliable-then develop your own as the basis of internal control. If it is too much work for you to make good estimates on every job, let the workers make their own estimates subject to your approval.

Estimated job standards require a follow-up system to record hours worked on each job. The hours actually used must be compared to the estimated hours. A comparison of a week's total of actual hours to estimated hours will give a percentage of realization for each worker for the week. Since this realization score is based upon estimates, too much significance should not be given to any one week's performance. But if the scores are charted in some form of "accumulation chart" (explained in the section "How To Use Charts"), the over-all level of the man's performance will become evident.

LONG SPAN WORK. If a job is so big that many days, or even weeks, are required to complete it, an overall job estimate or target is even more essential than on medium span jobs. However, when a deadline is weeks away or when a budget allows for hundreds of manhours, there seems to be little pressure during the early stages of the job. The worker feels that there is plenty of time until he discovers that half the hours have been used and yet much less than half of the job has been accomplished. Long span jobs need intermediate goals to put pressure on the job right from the start. The men need to know whether they are behind schedule after the first few days.

Intermediate goals or estimates can be determined by the people doing the job, subject of course to your approval. Planning and scheduling is not easy and it takes valuable time. However, those who use this system stress that the pre-thinking process involved in making intermediate estimates increases the overall efficiency enough to more than pay for the time used.

The first step is to break the job down into the sequence of steps or operations. Each segment should be estimated so that the total of all segments comes to only 80% of the total job estimate. The workers are to be allowed to dip into the 20% reserve only as necessity requires during the progress of the job. Below is a typical job estimate and schedule.



CONCLUSION

To summarize, Motivation Controls will greatly increase your managerial ability to both control and motivate. They will not be considered childish by your people if you have clearly identified the value of attaining the things being measured. Motivation Controls will work only as long as they are kept alive through genuine interest and appropriate recognition. They will not be resented if they are used to assist rather than accuse those who need help.

Motivation Controls are not new. Their use by top management has been essential to the building of large companies. The purpose of this paper is to encourage the first and second level of management to learn how to use such measurement controls as well. It is up to the foremen and supervisors to meet the ever increasing demands of more complex industrial processes. Effective use of Motivation Controls is a big part of the answer.

FILM SHOW

BERKELEY

I. Introduction to Work Sampling

II. Making a Work Sampling Study

III. Work Sampling

IV. Establishing Work Standards by Sampling

V. One Hoe for Kalabo

LOS ANGELES

I. The Supply Manager's Dilemma

II. The Foreman Discovers Motion Study

III. Establishing Work Standards by Sampling

IV. One Hoe for Kalabo

ROSTER OF ATTENDANCE

BERKELEY

ALLEN, Joseph G.
Conner Spring Co.
1599 Shrader Street
San Francisco

ARNOLD, Robert L., Jr.
TWA, Inc.
380 Madison Avenue
New York 17, New York

ASHLEY, H. H.
Fieden, Inc.
San Leandro

BAIN, William
Friden, Inc.
San Leandro

BAKER, George P., Jr.
Food Mach. & Chem. Corp.
475 Chapman Drive
Campbell

BARNEBEY, Hoyt R.
Boeing Airplane Co.
7755 E. Marginal Way
Seattle, Washington

BARKER, G. H.
Southern Pacific
65 Market Street
San Francisco

BARNETT, William A.
USAF
Mc Clellan AFB
Sacramento

BARTON, David L.
Calif. Chem. Company
Lucas & Ortho Way
Richmond 4

BASTHOLM, J. W.
IBM, Gen. Prods. Div.
Monterey & Cottle Rds.
San Jose

BEALL, Edwin S.
Wilsey, Ham & Blair
1805 Fernwood Way
Belmont

BELLINGER, E. E.
G. E., Transformer Div.
5441 East 14th Street
Oakland 1

BENSON, H. L.
Tidewater Oil Company
Martinez, California

BERGWALL, Phillip H.
Mare Island Naval Shipyard
100 Rincon Way
Vallejo

BERNARDO, Jose A.
Pacif. Cally Products
2402 S. California Street
Stockton

BLACK, James T.
Alameda NAS
398 Euclid Avenue
Oakland 10

BLACK, Kenneth
C&H Sugar Refining Corp.
215 Market Street
San Francisco 5

BLAIR, R. J.
IBM, Gen. Prods. Div.
Monterey & Cottle Rds.
San Jose

BLAKE, William
Lenkurt Elect. Co.
1105 County Road
San Carlos

BLATTNER, W. O.
Columbia-Geneva Steel Div.
120 Montgomery Street
San Francisco

BOGGS, J. C.
Colgate-Palmolive Co.
2700 - 7th Street
Berkeley

BOHUSLAV, Conrad
Permanente Services, Inc.
1924 Broadway
Oakland 12

BOSETTER, Ernest
Food Mach. & Chem. Corp.
San Jose, California

BRANDT, R. G.
Alameda NAS
c/o Mr. Nivola
O&R Training, Bldg. 5

BUCHTER, C. G.
Columbia-Geneva Steel Div.
P.O. Box 471
Pittsburg

BUNNELL, George E.
USAF
HQ Westaf
Travis AFB

BURNHAM, Donald H.
Westinghouse
1374 Colinton Way
Sunnyvale

BURROWS, Constance E.
U. S. Civil Service Comm.
630 Sansome Street
San Francisco

CARNEY, Wright M.
USAF
HQ 28th Air Div (SAGE) (28CMO)
Hamilton AFB

CARPENTER, J. S.
Dow Chemical Co.
P.O. Box 351
Pittsburg

CARROLL, T. L.
Columbia-Geneva Steel Div.
120 Montgomery Street
San Francisco

CARTER, W. R.
Pacific Fruit Express
116 New Montgomery St.
San Francisco

CETINICH, J. N.
Southern Pacific
65 Market Street, Rm. 665
San Francisco

CHEW, Rowland
Cutter Labs.
4th & Parker
Berkeley 10

CLARK, J. H.
Columbia-Geneva Steel Div.
P.O. Box 471
Pittsburg

CLARKE, B.
Alameda NAS
c/0 Mr. Nivola
O&R Training, Bldg. 5

CLAUGUS, Jarold W.
Procter & Gamble Mfg. Co.
Power Inn & Fruitridge Rd.
Sacramento

CLAYBAUGH, Donn R.
Aerojet-General
8754 Corinne Drive
Orangevale

CLEARY, J. J.
Aerojet-General
P.O. Box 1947
Sacramento

CLEMONS, Harry
Mil Sea Trasp Serv
Fort Mason
San Francisco

COLBURN, F. H.
Shell Chem. Co.
P.O. Box 751
Martinez

COLBURN, J.
Aerojet-General
P.O. Box 1947
Sacramento

CONTON, Lee E.
Staff Indus. Engineer
Nat'l. Ave. & Broadway
Redwood City

CONWELL, Rolf W.
HQZ Company
P.O. Box 425
San Jose

COOK, Anthony M.
Colgate-Palmolive Co.
2700 Seventh Street
Berkeley 10

COOK, Frederick G.
Columbia-Geneva Steel Div.
San Francisco

COOPER, Lloyd
Oleum Refinery, Union Oil
Company of California
Rodeo

COX, James C.
U. S. Navy
2508 Fordham Drive
Richmond

CRAWFORD, Allan D.
Crawfords TV Service
6424 Portola Drive
El Cerrito

CROCKER, Angus M.
Lenkurt Elect. Co., Inc.
San Carlos

DAHL, Osborne H.
Mare Island Naval Shipyard
41 Mohawk Avenue
Corte Madera

DANE, Charles M.
Oakland Naval Supply Center

DANEK, J. V.
Aerojet-General
P.O. Box 1947
Sacramento

DAVIS, Thornton
Cutter Labs.
4th & Parker
Berkeley 10

DeBRECHT, Eugene F.
Novato Unified School Dist.
58 Shields Lane
Novato

DEROMEDI, Frank D.
Cutter Labs.
4th & Parker Streets
Berkeley

DERRICKSON, Jim L.
Owens-Illinois Glass Co.
331 D Street
Niles

DETTMER, Charles L.
Shop Superindendent, Herrick Iron Wks.
P.O. Box 3007
Hayward

DEVEREL, W. L.
Columbia-Geneva Steel Div.
P.O. Box 471
Pittsburg

DEWART, William
Marquardt Corp.
16555 Saticoy Street
Van Nuys

DEWBERRY, D. A.
Columbia-Geneva Steel Div.
P.O. Box 471
Pittsburg

DIETZ, Carl T.
Caterpillar Tractor Co.
San Leandro

DIFFERDING, Charles
U. S. Navy
1340 Park Avenue
Alameda

DODDS, J. W.
Lockheed Aircraft Corp.
Sunnyvale

DORWARD, John G.
Lawrence Radiation Lab.
9 Charles Hill Circle
Orinda

DOUCETT, Walter L.
Food Machinery & Chem.
760 Coakley Drive
San Jose 28

DOWS, Robert N.
Aerojet-General
P.O. Box 77
San Ramon

DRY-HENICH, J.
Columbia-Geneva Steel Div.
P.O. Box 471
Pittsburg

DUBUQUE, Charles G.
Orangeburg Mfg. Co.
4975 Whitfield Avenue
Fremont

ECKSTEIN, Robert
Standard Register Co.
2101 Livingston Street
Oakland

EDBROOKE, Stanley W.
Continental Can Co.
235 Montgomery Street
San Francisco

EDWARDS, Frank A.
U. S. Navy
3799 Victor Street
Pinole

EDWARDS, Capt. R. B.
Oakland Naval Supply Center

EHLERS, Jack K.
Fairchild SemiConductor Corp.
545 Whisman Road
Mt. View

ERICKSEN, Neil
Fibreboard Paper Prods. Corp.
W. Church Street
Stockton

ERNEST, A. F.
Aerojet-General
P.O. Box 1947
Sacramento

FACER, James
Standard Register Co.
2101 Livingston Street
Oakland

FERRIS, G. B.
EBMUD
2130 Adeline Street
Oakland 23

FETTERLEY, Purl
Sharpe General Depot
Lathrop, California

FOHT, Kennth J.
Aerojet-General
2225 North Avenue
Del Paso Hgts.

FORD, Leonard
Varian Assoc.
Palo Alto

FOUQUET, Richard J.
Fairchild SemiConductor Corp.
545 Whisman Road
Mt. View

FRANKLIN, D. W.
Colgate-Palmolive Co.
2700 - 7th Street
Berkeley

FROST, J. R.
C&H Sugar Refining Corp.
Crockett

FROST, William F.
MINS.
2612 Adrian Street
Napa

FULLER, Herbert
Mare Island Naval Shipyard
1167 Lewis Avenue
Vallejo

GANTZ, Stephen L.
Lockheed Aircraft
889 Hanover
Sunnyvale

GERBER, Dieter C.
Matson Navigation Co.
215 Market Street
San Francisco 5

GLEASON, Richard O.
Weston Hydraulics, Ltd.
7500 Tyrone Avenue
Van Nuys

GOLDSMITH, N.
Alameda NAS
c/o Mr. Nivola
O&R Training, Bldg. 5

GOLF, George P.
Eitel-McCullough, Inc.
301 Industrial Way
San Carlos

GRAMS, Stanley
Hewlett Packard Co.
1501 Page Mill Road
Palo Alto

GRAY, Robert F.
Aerojet-General Corp.
6221 Kiernan Drive
Carmichael

GREEN, David L.
Food Mach. & Chem. Corp.
326 North 3rd Street
San Jose

GREENLAND, Joshua A.
De Laval Turbine Pacific Co.
220 Lexington Drive
Menlo Park

GRIFFIN, Burt L.
Cutter Labs.
4th & Parker Streets
Berkeley

GRIFFIN, Dale E.
Fibreboard Paper Products
W. Church Street
Stockton

GUTHRIE, Bob
Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon

HANSEN, Elmer
Friden, Inc.
San Leandro

HANSEN, W. C.
Moore Bus. Forms, Inc.
5750 Hollis Street
Emeryville

HARRIS, M. V.
Friden, Inc.
San Leandro

HARRISON, Terry D.
Adhesive Products
745 Grizzly Peak
Berkeley 8

HAWLEY, H. Richard
Cutter Labs.
4th & Parker Streets
Berkeley

HAZEL-ATLAS GLASS DIV. (2)
Div. of Continental Can
8717 G Street
Oakland 21

HECHINGER, B. L.
United Air Lines
S. F. International Airport

HELM, Jack
Fulham Bane. of Calif.
12 Sabastapol Avenue
Santa Rosa

HERMANN, John I.
U. S. Coast Guard
2843 Greenwich Street
San Francisco

HERNANDEZ, H. Paul
Lawrence Radiation Lab, UC
Berkeley 4

HEUBACH, Henry H.
C&H Sugar Refining Corp.
215 Market Street
San Francisco 5

HEYM, Howard F.
US Naval Ammunition Depot, Concord
155 Las Juntas Way
Pleasant Hill

HERINES, Alfred W.
U.S. Naval Air
3006 Thompson Avenue
Alameda

HILSINGER, W. N.
Aerojet-General
P.O. Box 1947
Sacramento

HIXSON, Charles R.
Aerojet-General
5000 Oakleaf Avenue
Carmichael

HOLLOWAY, R. E.
Tidewater Oil Company
Avon Refinery
Martinez

HORST, J. A.
Moore Bus. Forms, Inc.
5650 Hollis Street
Emeryville

HUEBNER, H. R.
Pac. Vegetable Oil Corp.
San Francisco

HUESGEN, A.
Lenkurt Elect. Co., Inc.
1105 County Road
San Carlos

HUTAFF, G. Harry
Bank of Calif., N. A.
400 California Street
San Francisco

HYDE, David M.
Aerojet-General
P.O. Box 1947
Sacramento

HYDEMAN, W. R.
Lockheed Aircraft
1123 N. Mathilda
Sunnyvale

IRVING, G.E.
Lockheed Aircraft
Sunnyvale

JACOBY, Jerrold J.
Coast Mfg. & Supply Co.
P.O. Box 71
Livermore

JEWETT, R. S.
Lockheed Aircraft
Sunnyvale

JINDRICH, H. G.
Lockheed Aircraft
1123 Mathilda
Sunnyvale

JOHNSON, C. E.
Lockheed Aircraft
Sunnyvale

JOHNSON, John J.
Johnson & Johnson
4100 Bayshore
Menlo Park

JOHNSON, R. L.
Lockheed Aircraft
1123 N. Mathilda
Sunnyvale

JONES, K.
Alameda NAS
c/o Mr. Nivola
O&R Training, Bldg. 5

JOSSIS, S. A.
Grove Valve & Regulator Co.
6529 Hillis Street
Oakland

JUBINA, William
Ducommun Metals & Supply Co.
4890 S. Alameda
Los Angeles

KADRI, Sal M.
G. E. Transformer Div.
5441 East 14th Street
Oakland 1

KAHN, Roy
Plant Engr.
38801 Cherry Street
Newark

KLEEGAN, J. L.
IBM
Monterey & Cottle Roads
San Jose

KLAAS, Barry D.
Microwave Electronics Corp.
4061 Transport Avenue
Mt. View

KNAPP, Sinclair
870 Devonshire
San Leandro

KNOLL, Henry L.
Hexcel Products, Inc.
2332 Fourth Street
Berkeley

KOBRIN, Donald M.
Fairchild SemiConductor Corp.
545 Whisman Road
Mt. View

KOHL, Moroslav
Fisher Body Div. of G. M.
2138 Center Street
Berkeley 4

KOPAS, George
Pac. Vegetable Oil Corp.
San Francisco

KUCHLER, Herman E.
Oakland Naval Supply Center

KURTZ, Gerald T.
Procter & Gambol
Carmichael, Calif.

KUYKENDALL, Gene
IBM
1955 The Alameda
San Jose

LANTZ, Edward L.
Int. Min. & Chem. Corp.
12747 Lantana Avenue
Saratoga

LA RIVIERE, P. D.
S. F. Naval Shipyards
c/o Supply Officer, Bldg. 815

LARKIN, Donald G.
EBMUD
2130 Adeline Street
Oakland 23

LARSEN, J. W.
Moore Bus. Forms, Inc.
5650 Hollis Street
Emeryville

LAZAR, Cornell J.
Lockheed Aircraft
3817 Shasta Drive
Santa Clara

LEHTIN, Laurie L.
Tri-Valley Packing
240 Battery Street
San Francisco 11

LEITNER, R. T.
Amer. Pipe & Construction
Company
2001 W. Alquire Road
Hayward

LEWIS, Charlie E.
USAF
HQ 28th A D (SAGE)
Hamilton AFB

LININGER, Harold J.
Pacific Fruit Express Co.
116 New Montgomery St.
San Francisco 5

LOFTUS, N. H.
TWA, Inc.
Mid-Continent Int'l Airport
Kansas City, Missouri

LOMBARDI, Richard C. (Capt.)
Mare Island Naval Shipyard
Vallejo

LUCHETA, Harry W.
R. Torre & Company
249 Glay Street
San Francisco

LUTZ, James F.
Philco Company
3875 Fabian Way
Palo Alto

MARX, John B.
Ampex Corporation

MATHEWS, Howard H., Jr.
Ampex Instrumentation Prod.
Company
Redwood City

MATLOCK, Kern T.
Fibreboard Paper Products
1st & L Streets
Antioch

MC CHESNEY, J. G.
2 Harrison Street
San Francisco 9

MC CORMICK, G. H.
Alameda NAS
c/o Mr. Nivola
O&R Training, Bldg. 5

McGEHEE, William M.
Lockheed Aircraft
252 Stanford Avenue
Menlo Park

MC HENRY, R.
United Air Lines
S. F. International Airport
San Francisco 2

McNEAR, John E.
LP McNear Brick Co.
P.O. Box 1380
San Rafael

MEDWAY, E. C.
Telsta Corporation
2900 Spring Street
Redwood City

MEYERS, Dan
Standard Register Company
2101 Livingston Street
Oakland

MIDDLEMISS, W. J.
Alameda Naval Air Station
c/o Mr. Nivola
O&R Training, Bldg. 5

MIELICH, D. C.
Moore Bus. Forms, Inc.
5750 Hollis Street
Emeryville

MILLER, Dale C.
U. S. Food & Drug Admin., S. F.
205 Del Rosa Way
San Mateo

MITCHELL, M. W.
Lockheed Aircraft
1123 N. Mathilda
Sunnyvale

MOORE, George
Hewlett Packard Company
1501 Page Mill Road
Palo Alto

MORRISON, James H.
Boeing Airplane Company
7755 E. Marginal Way
Seattle, Washington

MOSOLF, L. E.
Oakland Naval Supply Center

MOURA, J. S.
C&H Sugar Refining Corp.
Crockett

MULKEY, O. C.
Columbia-Geneva Steel Div.
P.O. Box 471
Pittsburg

MUNGER, Milton P., Jr.
Mare Island Naval Shipyard
Code 394 M.I.N.S.
Vallejo

MURRAY, L. J.
Columbia-Geneva Steel Div.
P.O. Box 471
Pittsburg

NEELY, J.
Calif. Tech. Industries
1421 Old County Road
Belmont

NEESHAM, Jack C.
Food Mach. & Chem. Corp.
1532 McKinnon Ct.
San Jose

NOON, W. L.
Memorex
1668 Foothill Park Cir.
Lafayette

NORDAHL, James D.
Coast Mfg. & Supply Co.
P.O. Box 71
Livermore

O'CONNOR, C. S.
G.E. Transformer Div.
5441 East 14th Street
Oakland 1

O'HARA, C. E.
Mare Island Naval Shipyard
217 Lamont Ct.
Vallejo

O'NEAL, Robert
Federal-Mogul-Bower
Bearings
Redwood City

O'NEILL, E. J.
Columbia-Geneva Steel Div.
P.O. Box 471
Pittsburg

ORR, W. F.
Basic Vegetable Products, Inc.
Vacaville

OSTMAN, S.
Alameda NAS
c/o Mr. Nivola
O&R Training, Bldg. 5

OTTENHEIMER, R. J.
Line Materials Industries
P.O. Box 1427
Visalia

OTTERSTEIN, James L.
Colgate-Palmolive Co.
2700 Seventh Street
Berkeley 10

PAGE, Edward
M. Greenberg's SOS, Inc.
765 Folsom Street
San Francisco

PARKER, V. L.
United Air Lines
S. F. International Airport

PARVIN, Robert
Bechtel Corp.
1120 Montgomery Street
San Francisco 11

PECK, E.
Columbia-Geneva Steel Div.
P.O. Box 471
Pittsburg

PENNINGTON
Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon

PETRIS, G. C.
Moore Bus. Forms, Inc.
5750 Hollis Street
Emeryville

RACINE, J. G.
Columbia-Geneva Steel Div.
P.O. Box 471
Pittsburg

REARK, Robert T.
Fibreboard Paper Products
1st & L Streets
Antioch

REARWIN, W. H.
Friden, Inc.
San Leandro

REED, Edward W.
Federal-Mogul-Bower
Bearings
Redwood City

REYNOLDS, Lawrence
Weston Hydraulics, Inc.
7500 Tyrone Avenue
Van Nuys

ROBINSON, William
Friden, Inc.
San Leandro

ROBISON, Ross W.
Alameda NAS
38140 Glendale Drive
Fremont

RODGERS, Joseph F.
Colgate-Palmolive Company
2700 - 7th Street
Berkeley

ROGERS, L. Gifford
US Steel Products Div.
1849 Oak Street
Alameda

ROSKI, J. C.
Alameda Naval Air Station
c/o Mr. Nivola
O&R Training, Bldg. 5

RUTHORFORD, Charles E.
Mare Island Naval Shipyard
244 Daniels Avenue
Vallejo

RYDNER, Paul B.
Lockheed Aircraft
22350 Starling Drive
Los Altos

SAINT, Avice M.
Oakland Naval Supply Center

SAMBERT, Herbert C.
UC, School of Forestry
Berkeley

SARBER, Charles
Permenente Services, Inc.
Oakland

SCALES, Henry H.
Nat'l. Starch & Chem. Corp.
735 Battery Street
San Francisco 11

SCHIFFERIE, Joseph H.
U. S. Navy, Treasure Island
1036 Oak Knoll Road
Lafayette

SCHMIDT, M. E.
IBM
Monterey & Cottle Roads
San Jose

SCHOENDORF, Walter J.
Bakery Div.
999 Nehall Street
San Jose 8

SCHULTZ, L. F.
Alameda NAS
c/o Mr. Nivola
O&R Training, Bldg. 5

SCHWING, Richard
Varian Assoc.
Palo Alto, Calif.

SEHLMEYER, E. G.
United Air Lines
S. F. International Airport

SHALLENBERGER, Charles F.
US Navy
19 D Street
Vallejo

SHAVER, Harry
Varian Assoc.
Palo Alto

SHORT, William
Standard Register Company
2101 Livingston Street
Oakland

SIEVERS, Roy S.
Western Production Mgr.
999 Newhall Street
San Jose 8

SIMENSON, Louis
Dow Chemical Company
P.O. Box 351
Pittsburg

SIMMEN, David B.
Safeway
1201 - 45th Avenue
Oakland 1

SIMMONS, B. W.
Alameda NAS
c/o Mr. Nivola
O&R Training, Bldg. 5

SIMONS, M.
Alameda NAS
c/o Mr. Nivola
O&R Training Bldg. 5

SMITH, K. V.
Columbia-Geneva Steel Div.
P.O. Box 471
Pittsburg

SMITH, R. L.
Columbia-Geneva Div.
120 Montgomery Street
San Francisco 6

SOUTHARD, Everett
Permenente Services, Inc.
Oakland

SPAYDE, R. L.
G.E. Transformer Div.
5441 East 14th Street
Oakland 1

SPINA, Fred H.
Division Indus. Engr.
999 Newhall Street
San Jose 8

STAFFORD, Thomas
Plastic Prod. Dept.,
Cutter Labs.
4th & Parker Streets
Berkeley

STAIB, Donald A.
US Steel Products Div.
1849 Oak Street
Alameda

STANTON, Edward C.
Friden, Inc.
San Leandro

STEEN, M. V.
Lockheed Aircraft
Sunnyvale

STENGELE, F. H., Jr.
Indus. Engr.
65 Market Street
San Francisco

STEWART, Ferguson C.
Industrial Security,
6th Army
Presidio of San Francisco

STEWART, S. G.
C&H Sugar Refining Corp.
Crockett

STONE, Gary G.
PG&E
245 Market Street
San Francisco

STROPE, W. E.
S. F. Naval Shipyard
c/o Supply Officer, Blgd. 815

STUBBLEFIELD, George W.
Alameda NAS
3327 Moraga Blvd.
Lafayette

SULLIVAN, Tom
Connor Spring Mfg. Co.
75 - 14th Street
San Francisco

THACHER, B. L. (3)
Johns-Manville
Stockton

THOMAS, Charles H.
Ampex Instrumentation Prod.
Company
Box 5000
Redwood City

THOMAS, J. A.
Tidewater Oil Company
Avon Refinery
Martinez

THOMPSON, Frank
Ampex
275 Ventura Avenue
Palo Alto

THOOLEN, Swen I.
Matson Navigation Co.
215 Market Street
San Francisco 5

TOLOSKI, Carl H.
Bethlehem Steel Company
1105 Fernwood Drive
Millbrae

TONEY, James A.
Crown Zellerbach Corp.
2101 Williams Street
San Leandro

TORBURN, Donald
General Precision, Inc.
1451 California Avenue
Palo Alto

TRAURB, Robert J.
Food Mach. & Chem. Corp.
1921 The Alameda
San Jose

TROTTER, Robert
Eitel-McCullough, Inc.
301 Industrial Way
San Carlos

TRUESDALE, J. D.
Lockheed Aircraft
Sunnyvale

TRYON, W. W.
Columbia-Geneva Steel Div.
P.O. Box 471
Pittsburg

ULLMAN, N. F.
Safeway
401 Jackson Street
Oakland

UBRICKSON, H. P.
Lockheed Aircraft
Sunnyvale

WAGGONER, J. F.
G. E. Transformer Div.
5441 East 14th Street
Oakland 1

WAHL, Karl N.
Allied Chemical Corp.
335 Alcatraz Avenue
Oakland 18

WALDE, Leonard O.
American Standard
San Pablo

WALKER, Robert
Standard Register Co.
2101 Livingston Street
Oakland

WALLACE, M. H.
Amer. Pipe and Construct.
Company
2001 W. Alquier Road
Hayward

WARDWELL, Robert H.
DYMEC
395 Page Mill Road
Palo Alto

WEBSTER, D. A.
Alameda NAS
c/o Mr. Nivola
O&R Training, Bldg. 5

WEISENBERG, J. O. Cdr.
Alameda NAS
c/o Mr. Nivola
O&R Training, Bldg. 5

WELSCH, James L.
Calif. Western University
3902 Lomaland Drive
San Diego 6

WENDEL, D. N.
Southern Pacific
65 Market Street
San Francisco

WEST, C. W.
Southern Pacific
65 Market Street
San Francisco

WHITED, R. L.
Alameda NAS
c/o Mr. Nivola
O&R Training, Bldg. 5

WILLIAMS, E. R.
Telsta Corp.
2900 Spring Street
Redwood City

WILLIAMSON, Calvin C.
Soule Steel Company
1750 Army Street
San Francisco

WILLNECKER, Carl B.
Oakland Naval Supply
Center
Oakland

WILSON, Earl
Cutter Labs.
4th & Parker Streets
Berkeley 10

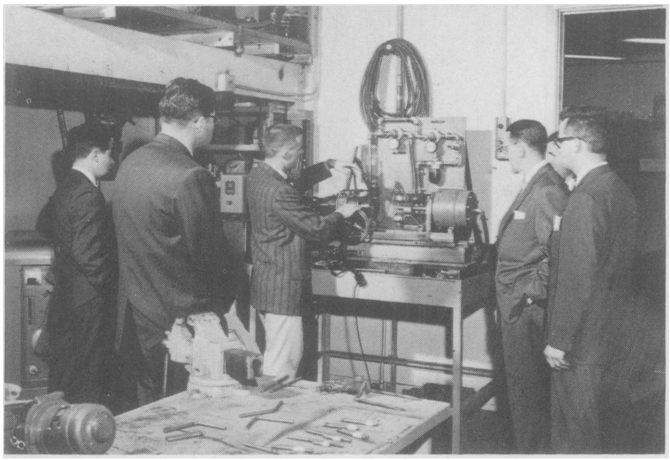
WINKLER, Allen J.
Nat'l. Container Corp.
7th & Terminal Streets
Oakland

WOLD, R. L.
C&H Sugar Refining Corp.
Crockett

WOOD, R. D.
Alameda NAS
c/o Mr. Nivola
O&R Training, Bldg. 5

WORTMAN, Calvin B.
Mare Island Naval Shipyard
6000 Wild Horse Valley Road
Napa

WYATT, G. E.
Alameda NAS
c/o Mr. Nivola
O&R Training, Bldg. 5



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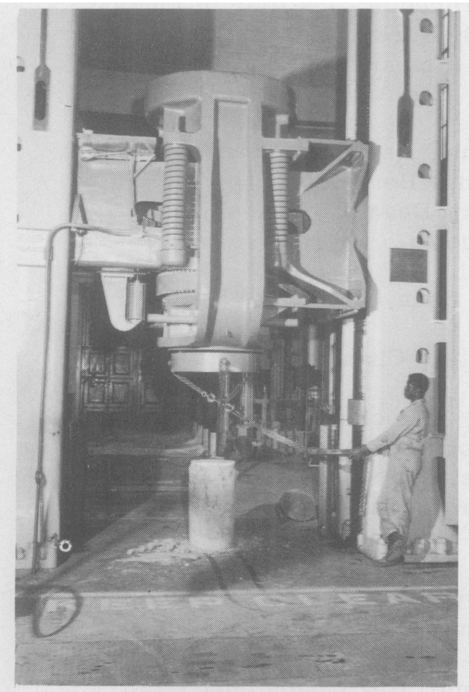

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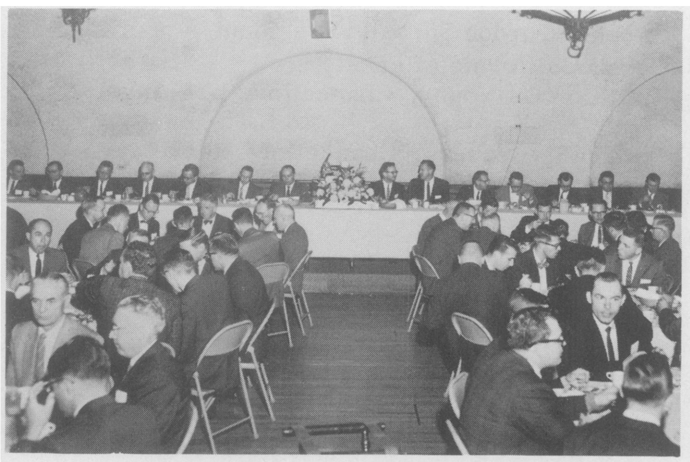

Luncheon Session I
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CHRONOLOGY-ALL INSTITUTES

No.	Date	General Chairman and Editor	Welcoming Speaker
1	1949 May 21	D. G. Malcolm	Richard G. Folsom, Chairman Mechanical Engineering, Berkeley
2	1950 Jan. 27 - 28	D. G. Malcolm	M. P. O'Brien, Dean, College of Engineering, Berkeley
3	1951 Feb. 2 - 3	D. G. Malcolm	George A. Pettitt, Assistant to President, Berkeley
4	1952 Feb. 1 - 2 Feb. 4 - 5	D. G. Malcolm	H. A. Schade, Director, Institute of Engineering Research, Berkeley Wesley L. Orr, Assistant Dean, College of Engineering, Los Angeles
5	1953 Jan. 30 -31 Feb. 2 - 3	D. G. Malcolm	E. Paul DeGarmo, Assistant Dean, College of Engineering, Berkeley L.M.K. Boelter, Dean, College of Engineering, Los Angeles
6	1954 Jan. 29 - 30 Feb. 1 - 2	Bruce G. McCauley	M.P. O'Brien, Dean, College of Engineering, Berkeley Raymond B. Allen, Chancellor, Los Angeles
7	1955 Jan. 28 - 29 Jan. 31, Feb. 1	Joseph D. Carrabino (Gen. Ch.) Bruce G. McCauley (Ed.)	Paul H. Sheats, Associate Director, University Extension, Los Angeles Arthur M. Ross, Director, Institute of Industrial Relations, Berkeley
8	1956 Feb. 3 - 4	John R. Huffman	M.P. O'Brien, Dean, College of Engineering, Berkeley David F. Jackey, Dean, College of Applied Arts, Los Angeles
9	1957 Feb. 1 - 2	Louis E. Davis	E. Paul DeGarmo, Chairman, Industrial Engineering, Berkeley L.M.K. Boelter, Dean, College of Engineering, Los Angeles
10	1958 Feb. 7 - 8	Robert B. Andrews	Robert Gordon Sproul, President, University of California, Berkeley William G. Young, Chancellor, Los Angeles
11	1959 Feb. 6 - 7	E.C. Keachie	Glenn T. Seaborg, Chancellor, Berkeley Vern O. Knudsen, Acting Chancellor, Los Angeles
12	1960 Feb. 5 - 6	John G. Carlson	L.M.K. Boelter, Dean, College of Engineering, Los Angeles John R. Whinnery, Dean, College of Engineering, Berkeley
13	1961 Feb. 3 - 4	George P. Redman	Franklin D. Murphy, Chancellor, University of California, Los Angeles Ronald W. Shephard, Chairman, Department of Industrial Engineering, Berkeley

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