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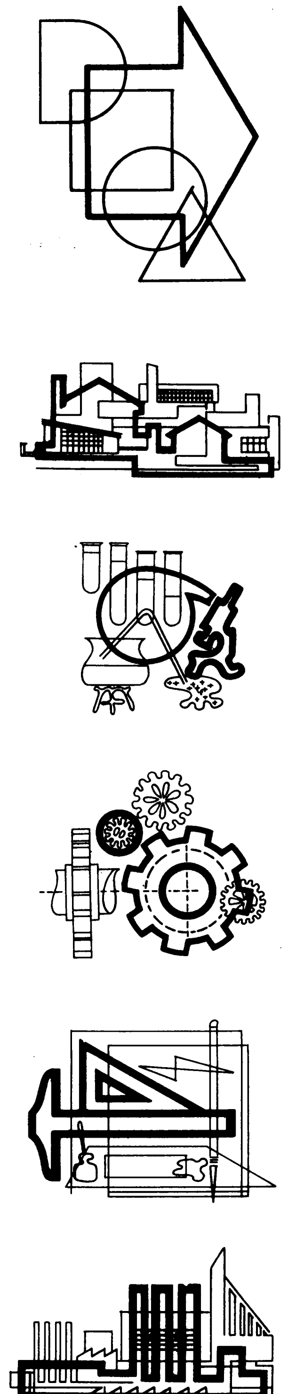
SIXTH ANNUAL INDUSTRIAL ENGINEERING INSTITUTE



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PROCEEDINGS

SIXTH ANNUAL

INDUSTRIAL ENGINEERING INSTITUTE

BRUCE G. McCAULEY
EDITOR
Assistant Professor of Mechanical Engineering
University of California
Berkeley, California

UNIVERSITY OF CALIFORNIA

BERKELEY

Friday and Saturday
January 29 and 30, 1954

Presented by:

DIVISION OF MECHANICAL ENGINEERING

SCHOOL OF BUSINESS ADMINISTRATION

INSTITUTE OF INDUSTRIAL RELATIONS

UNIVERSITY EXTENSION

In cooperation with:

AMERICAN INSTITUTE
OF INDUSTRIAL ENGINEERS

AMERICAN SOCIETY
OF MECHANICAL ENGINEERS

SOCIETY FOR ADVANCEMENT
OF MANAGEMENT

AMERICAN SOCIETY FOR
QUALITY CONTROL

LOS ANGELES

Monday and Tuesday
February 1 and 2, 1954

Presented by:

THE COLLEGE OF ENGINEERING

SCHOOL OF BUSINESS ADMINISTRATION

INSTITUTE OF INDUSTRIAL RELATIONS

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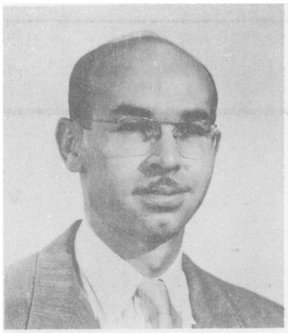

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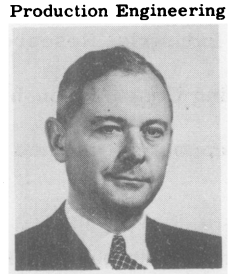

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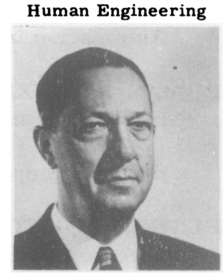

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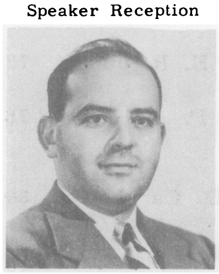

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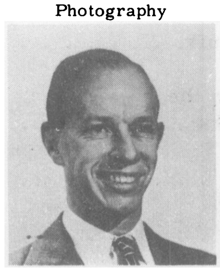

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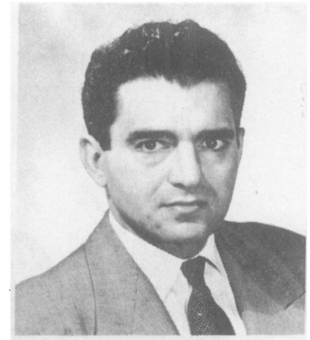

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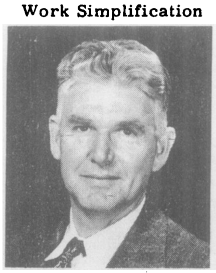

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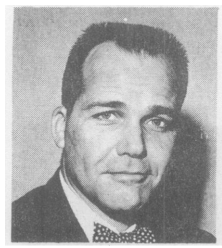

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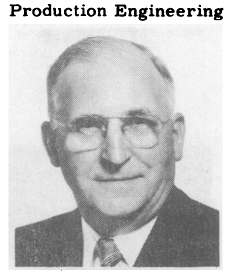

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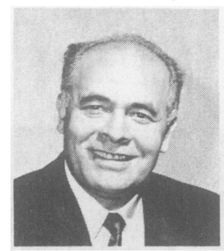

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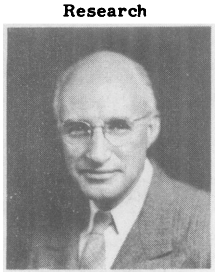

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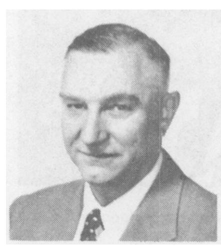

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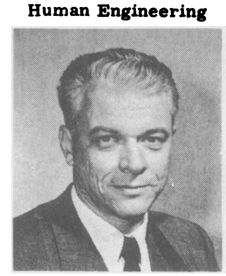

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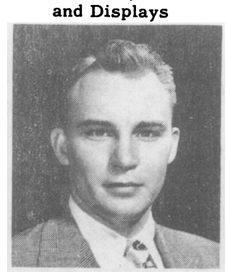

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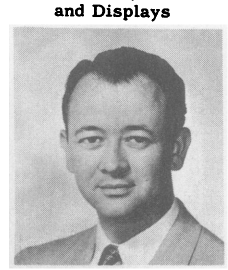

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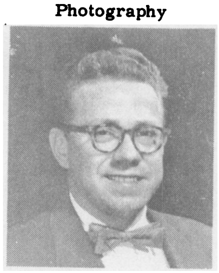

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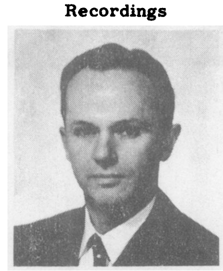

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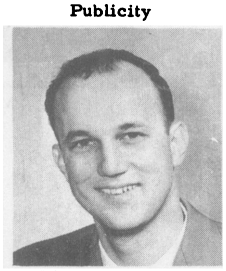

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Production Management Laboratory
at Los Angeles

L. M. K. Boelter introducing luncheon speaker

Production Management Laboratory
at Los Angeles

D. A. Gustafson, O. McIntyre, G. W. Papen,
M. Kronenberg, J. N. Landis

Seated: S. Ramo, E. D. Howe.
Standing: B. G. McCauley, J. T. Lapsley

FOREWORD

No classical definition of industrial engineering has yet been established. However, for the purpose of defining the fields of interest most concerned with these annual Industrial Engineering Institutes, perhaps the following definition will suffice:

> Industrial Engineering is the design and development of systems and methods of applying scientific knowledge to operational and environmental situations so as to effect an optimum combination of men, materials, machines and money for the purpose of reducing and controlling costs in conjunction with increasing productivity and human satisfaction.

Within the excellent papers that compose the contents of this publication will be found many valuable contributions to the purpose indicated in the above definition. In the following pages the reader will find articles by well-qualified engineers, managers and scientists in such fields as work simplification, production engineering, industrial engineering in small businesses, automation, human engineering, areas for future growth, and recent results of scientific research in industrial engineering. Adding to these fields the additional subjects covered at past Institutes indicates the variety of situations with which the industrial engineer is most concerned today. These former subjects include: motion and time study, wage incentives and job evaluation, operations research, production planning and control, synthetic time standards, work sampling, quality control, industrial organization and management, engineering economy, human and industrial relations, cost reduction and control, and material handling systems.

Well may the industrial engineer feel his responsibility to reduce costs and increase productivity. If the standard of living in our country is to continue to improve at its present rate, every man and woman working today in our factories, offices, stores, farms, mines and government activities must be producing much more a few years from today. Not enough people realize how very much our productivity must increase if our standard of living is not to suffer.

One of the best efforts in emphasizing the importance and magnitude of our need for increased productivity is the meritorious treatise on this subject presented in the April 1952 issue of Factory Management and Maintenance. This excellent summarization of past and present statistics with regard to the standard of living, national defense, industrial expansion, national population, and total work force, quantitatively determined that the output of goods and services per worker must increase 43% between 1950 and 1960 if the present rate of increase in our standard of living is to be maintained. Of equal significance is the fact that this 43% increase in productivity is more than twice the rate obtained in the preceding decade from 1940 to 1950.

Here indeed is a challenge to our nation's industrial engineers. Here indeed is the reason for the fact that the industrial engineering profession is one of the most rapidly growing fields today. The following table emphasizes the magnitude of this growth. The tabulation was furnished by Willys G. Stanton in the January 1954 issue of The Journal of Industrial Engineering, a publication of The American Institute of Industrial Engineers, one of the professional societies sponsoring these annual Institutes.

DISTRIBUTION OF ENGINEERS *

Branch	1940	1950	% Increase
Civil Engineering	105,500	124,600	18
Mechanical Engineering	85,500	98,600	15
Electrical Engineering	55,700	93,400	68
Industrial Engineering	9,800	46,700	**376**
Chemical Engineering	11,600	31,100	168
Metallurgy & Mining	9,800	25,900	164

*Data from U.S. Census Bureau

The ever increasing attendance at and interest in these Industrial Engineering Institutes presented annually on the Berkeley and Los Angeles campuses of the University of California are a further proof of the growing stature of industrial engineering. As would be expected, the great majority of attendees come from the West Coast, but each year a few attend from our eastern states. The Proceedings of these Institutes are read all over the world. Requests for copies have been received from almost every state in the Union, from Canada, Alaska, Hawaii, the countries of Western Europe, from Australia, New Zealand, Japan, India--in fact, from essentially every area not behind the iron curtain.

Needless to say, such interest is heartening. I know that it in itself is sufficient reward to those who worked so diligently to make the Sixth Institute possible. My sincere appreciation goes to each and every one of them for a job well done. To you goes my hope that you will be able to be with us at the Seventh Institute next year.

BRUCE G. McCAULEY
General Chairman

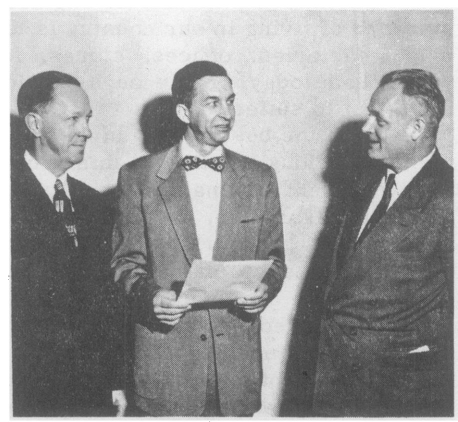
SCENES AT BERKELEY

B. G. McCauley, W. H. Park, R. W. Jastram, J. T. Lapsley

Demonstration in Industrial Engineering Laboratory

B. S. Graham, T. H. Martzloff, N. A. Lamberti

P. Jurs, M. S. Meyers, W. R. Willard



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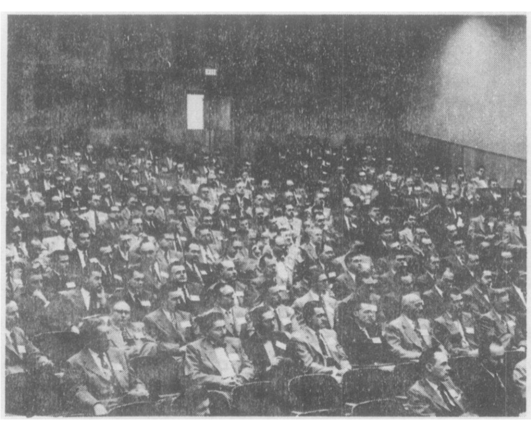


View of part of Berkeley audience

Demonstration in Production Engineering Laboratory

WELCOMING REMARKS

WELCOME TO THE BERKELEY SESSIONS

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

Dr. Baldwin Woods, who planned to welcome you this morning, had to be away. He is Vice President of the University, and in this capacity is one of our state-wide officials and cannot always predict his movements and availability. I apologize for him. It is my pleasant task to welcome you this morning.

The functions of the University are at least threefold: one is to create new knowledge through research; another is to store and make available knowledge; and the third is to transmit it. Our primary means of transmitting knowledge is through our organized program of instruction, graduate and undergraduate. In recent years more and more attention has been given to opportunities of the type requested by this Conference in which there is a meeting of academic and industrial people for the mutual exchange of ideas. I hope that this conference will be profitable to you; we have a selfish interest in the matter because we feel that we gain also, because the discussions at the meetings, the formal papers, and the informal discussion add to our store of material available for classroom use. There is the opportunity for us to appraise the state of the field and thus to guide our research programs. So we feel there is a mutual advantage. I am sure there is a gain for us and I hope there is also for you.

Judgment based on experience is, I think, one of the principal tools of the engineer. In developing that judgment one is helped, of course by the study of formal subject matter, including science in its various aspects; but observation and experience are also an essential element. In solving novel problems one's own experience is not pertinent; otherwise it is not novel. So all of us have an obligation as professional men to extend our experience vicariously by participating in the experience of others. In this respect, I think, institutes such as this one are particularly valuable. First one observes and possibly uses later the techniques and methods of this field. Most important of all one adds to his indirectly obtained experience the philosophy and the methods which others have used to attack novel and difficult problems. It is important that industry encourage the organization of sessions such as this one in which there is an exchange of ideas -- a review of the situation with mutual benefit.

Reviewing the Proceedings of the preceding five conferences, I have been struck with the fact that industrial engineers are making substantial progress in providing a scientific basis for their work. I do not pretend to have special knowledge in this field, but having been, I should say, indoctrinated in it by Professor DeGarmo and others who wished to establish industrial engineering here, I have had some opportunity to learn what industrial engineers do and some of the philosophy behind their work. What has struck me in looking over the Proceedings of the preceding conferences is the extent to which you are providing quantitative relationships and general laws in this very difficult field.

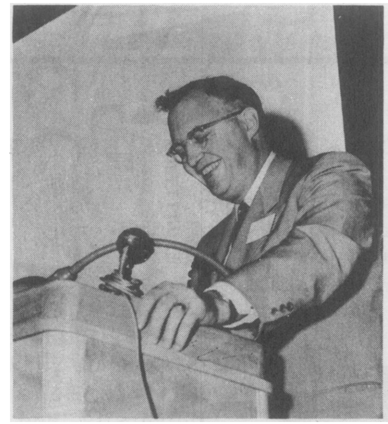
In most of engineering, the primary concern is with physical phenomenon. In your work you bring in very prominently economics which affects all of engineering, and, in addition, physiology, psychology, and certain other sciences. I congratulate the industrial engineers on their persistent quest for these general relationships which aid in the reduction of cost and improvement of quality. I think the industrial engineer has a particularly great responsibility at this time and the responsibility will grow. Many of you have undoubtedly read the report of the Paley Commission on our situation as regards raw materials. We are becoming an importing nation and that situation will grow -- a larger and larger percentage of our raw materials will come from abroad. The only way we can pay for those raw materials is by manufactured goods which must be sold competitively in a world market. We must pay for the transportation inward of the raw materials and we must pay for the transportation outward of the finished product. Consequently we must produce at a lesser cost if we are to compete with other nations elsewhere in the world. This factor will be important in the development of the American economy over the next fifty years. I think you industrial engineers have a very great responsibility to continue to reduce costs and improve quality in order to meet this requirement for world trade.

It is a great pleasure to welcome you to the Berkeley Campus. I hope to see you again with us next year.

SCENES AT LOS ANGELES

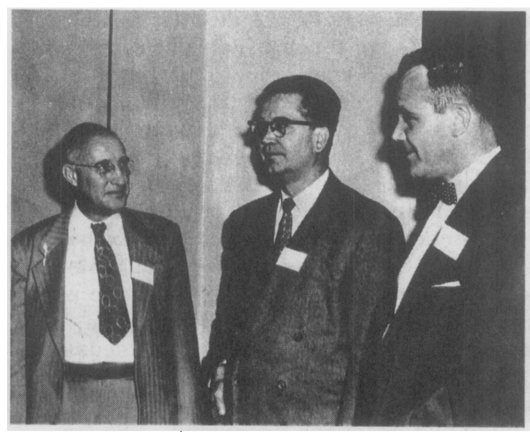
J. D. Carrabino, N. A. Lamberti
F. K. Shallenberger

Inspection of Production Management Laboratory



Welcome address by R. B. Allen

View of part of Los Angeles audience



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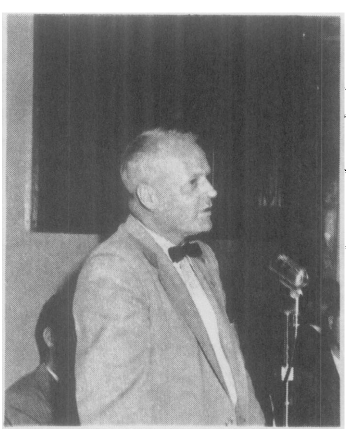


Luncheon address by G. Brighouse

Demonstration in Production
Management Laboratory

Luncheon address by S. Ramo

WELCOME TO THE LOS ANGELES SESSION

Raymond B. Allen
Chancellor
University of California
Los Angeles, California

I wish, on behalf of the University, to welcome each of you here today, and to congratulate the organizations you represent and yourselves for taking advantage of this opportunity to explore for a short while some of the more significant advances in the fields of technology and engineering and management. I well realize how crowded your days are, and how busy are the fine faculty members from here and Berkeley who are joining with you. I would like to suggest to you quite seriously that there are most important developments in these fields. I refer to the increasing interest and concern on the part of universities and top management in industry and business in the progress of our society, as evidenced by concern about important developments of ideas and technologies in relationship to our industrial and technological civilization. And, it is on such meetings as this, our research organizations in industry and universities, and in the minds, creative minds of management in industry that the future security of our nation and of the free world resides and depends. That security depends upon the success with which men like yourselves approach these numerous problems.

Recently, an interesting and very profound book called Survival Through Design and written by Richard J. Neutra, the great architectural designer and community planner, was published by the Oxford University Press. This is a work in which one cannot read more than a few paragraphs, as I have done, without having one's mind stimulated in numerous directions. I mention this among any number of other important contemporary works that could be mentioned as indicative of the kind of creative thinking -- and profound and creative thinking it is -- that is being done about the place of industrial development and management design in our society.

I seriously believe that if we are to survive in this difficult period in which we are living, this period of transition, this period of crisis, leaders in industry, in business and in our universities must design our society, not in an authoritarian way, but a democratic design for those environments within which you and I, workers everyone, can live and survive in health, in freedom and happiness.

I believe that in this age, this stimulating, challenging, inspiring age in which we are living, that the greatest renaissance in the history of the human mind and spirit is occurring. You people are helping to lead that renaissance. The engineer of today, the manager of today, is continously broadening his horizons. He explores the world around him in an effort to understand everything that is going on and applies to what he does the great works, the great minds, the great ideas of the past brought up to date. This is the theory back of engineering education today. Surely technology, the "science" of engineering and engineering education is important and provides it. But the basic education of all of us is essential to the solution of the problems around us, including engineering problems. In short, the modern engineer is a man who looks upon his particular job as a job of tuning up the environment, creating the conditions in this room, in the great buildings on this campus and laboratories in which the individual can be free to be creative. The essential task of the modern doctor and the modern executive is no different. The essential environmental treatment, every problem of design, is focused on creating the most efficient, the most desirable situations, safety factors, productivity factors that are possible with the tools and imagination of man today, to the end that the individual will be free of every conceivable and possible impediment to the making of his contribution to the success of his total enterprise, in the factory, in the home, in the community, and in our society. This has happened, gentlemen, in our lifetime, this understanding and appreciation of the role of management and of design in our society. The marvelous and inspiring thing about it is that it has occurred under conditions of terrific stress and tremendous difficulty. There have been two World Wars in our lifetime and a great depression, and yet we have risen to these responsibilities and these opportunities as challenges and we have mastered them, sometimes without too much help from the government. We have mastered these problems in the truly American cooperative way which is the way in which America has been built, by doers, and doers who have been thinkers as well. And the creation of this tremendous industrial enterprise of America is one of the great wonders of the world. It has been created by men like you who have not realized the drama -- you have been so busy building -- and the inspiration of what has been accomplished. I salute you. Here is an opportunity at this Institute to exchange ideas and listen to those who have some particular idea in management engineering to advance. In the typical American way we will debate those presentations; adopt them if they are good; discard them if they are not so good.

THE SEVENTH ANNUAL INDUSTRIAL ENGINEERING INSTITUTE WILL BE HELD ON THE FOLLOWING DATES

LOS ANGELES - January 28, 29, 1955

BERKELEY - January 31, February 1, 1955

WORK SIMPLIFICATION SESSION

Session Chairmen: At Berkeley - THOMAS H. MARTZLOFF, Chairman, San Francisco Bay Area Section of ASQC, and Associate, McKinsey & Co., San Francisco.
At Los Angeles - RALPH M. BARNES, Professor of Engineering and Production Management, University of California, Los Angeles.

REDUCING COSTS THROUGH PAPERWORK SIMPLIFICATION

Benjamin S. Graham
Director of Methods Research
The Standard Register Co.
Dayton, Ohio

In reviewing the program for this two-day institute, I noticed that in spite of the fact that most of today and a good share of tomorrow is devoted to highly technical subjects, the program tomorrow closes on the human note. I am glad to see the emphasis in this field. While from the subject it is not obvious, we will develop much the same emphasis this morning.

What I have to say does not include any world shaking theories or magic formulae. Very little will be new to you, but I hope I can say it in a little different way, put it in a new relationship to what you are already doing or vary the emphasis.

If, for example, I were to say that if we in business, industry and government would eliminate the waste in paperwork, the savings would balance the national budget, pay all the interest on national debt and contribute substantially toward amortizing that debt, you might begin to wonder whether I knew what I was talking about or not. Well, I did say it and I'm glad I said it. That is one of the reasons why I think paperwork simplification is important.

How do I figure that? How can we do it?

These are legitimate and logical questions. Let us see whether we can't develop the answers.

Paperwork

First I think we should answer the question, "What is paperwork?" After talking with hundreds of groups, and in many cases with the smaller groups, working out the definition together, I have concluded that the best definition is in terms of the end results or objectives we hope to accomplish through paperwork. In those terms paperwork may be defined as the recording, storing, analysis and reporting or transmitting of information or facts for two major purposes. First, certain units of government tell us that if we want to stay in business, we had better file our income tax, social security, unemployment insurance and other reports. If we want to stay in business, we had better have the facts to meet those requirements. Fortunately many of the facts required for that purpose are also usable for the other purpose, so they are not a total loss. The second and more important purpose is to have the facts in proper shape to help somebody do his job better.

For years I said the major purpose was to have the facts to help management manage better. In recent years I have seen many people working at benches or machines in the shop or at desks in the office honestly trying to do a good job being needled by their supervisor to produce more of better work. They didn't know what was expected of them or how they were doing. As a result they were thoroughly frustrated. So it seems to me almost as important to have the facts to let people know what is expected of them and how they are doing against that goal -- almost as important as it is to have the facts for management.

Considering paperwork from this point of view, it may be that we can keep it in its proper prospective and not consider it solely from the traditional record-keeping or accounting point of view.

The term "paperwork" is used, rather than office work simplification for several reasons. Relatively little paperwork starts and finishes in the office. Most systems start outside the office, cross departmental lines, affect production and sales, as well as the record-keeping function. Actually the office is primarily a service function for receiving, storing, analyzing and transmitting the information or facts involved in the various paperwork systems. It might even be likened to the communications center in a communication system or the brain as the hub of the nervous system.

Growth of Paperwork

Let's get back to my initial statement. How big is this paperwork? The last census told us that there were 8,000,000 clerical workers in the country, roughly 13-1/2% of the total labor force. In the last three years this percentage has probably increased since the trend over the last fifty years has been a continually increasing percentage. However, whether it is 13% or 15% makes little difference, it still does not begin to measure the actual total time devoted to paperwork. Many of the man-hours of people not included in the clerical classification are devoted to various phases of paperwork. All the time of office supervision, significant proportions of the time of many production people and production supervision, a substantial proportion of the time of staff people, such as inspection or quality control, production control, industrial engineering, maintenance, etc., are required. Competent estimates indicate that the total manhours including the clerical will run 25% or more on a national average.

With a national personal income this year of roughly $286,000,000,000, this means that over $71,000,000,000 are paid in salaries alone for paperwork manhours. I could give you several instances to bear out this estimate; for example, one highly successful manufacturing company in a competitive industry numbers over 40% of its payroll at the factory among the clerical workers. Of course, most of the manhours of banks, insurance companies and other similar service businesses are devoted to paperwork.

Waste in Paperwork

How much of the paperwork is waste? This is the next question in developing our initial premise. For several years I have estimated that between 30% and 50% of the paperwork when measured in terms of our definition -- that is, necessary for government reports or to help someone do his job better -- will not measure up. Many illustrations of waste in paperwork are available. I could cite instances for the balance of my allotted time. One or two will have to suffice. One company using an intelligent approach to examine their paperwork found at the end of six months that they had eliminated 30% of all their forms. In another instance, a sales executive who had been responsible for most of the sales analysis, when elevated to the top position in his sales department, examined all the sales reports at one time. This was the first time he had ever gotten them together and compared them. There were over 70 reports. A careful examination disclosed many duplicates and some obsolete reports. As a result over one-third of all the reports were eliminated. From these and other experiences, I feel sure that 30% is a conservative estimate of the waste in paperwork. It hardly takes into account the waste in methods in systems which are producing necessary paperwork.

Thirty per cent of $71,000,000,000.00 is over $21,000,000,000.00. If we allow $8,000,000,000.00 for balancing the budget, $8,250,000,000.00 to pay the interest at 3% on a $275,000,000,000.00 national debt, we have left about $5,000,000,000.00 which can be applied toward amortizing the national debt.

You can't make these savings. I can't make these savings. The only way it can be accomplished is for each of us to do our bit. The cumulative result of all our efforts would exceed $21,000,000,000.00 in savings by the elimination of waste in our paperwork.

Why do we have so much paperwork?

No plane ever flew higher or faster because of paperwork. No automobile ever looked better or rode better because of paperwork. Although our paperwork is a totally nonproductive function, it is essential. Actually it is the foundation of all of our controls: cost, production, quality, inventory, sales, personnel, financial and others. It is literally the nervous system of our economic society.

Several factors have contributed to the accumulation of so much unjustified paperwork. Since paperwork is a nonproductive function, the tendency has been to neglect it and let it grow "literally like Topsy". In a sense it is an intangible which presents some difficulties. Also because production brings in the dollars, the best brains have been devoted to improving production methods and techniques rather than to the paperwork which provides information.

Another factor has been the undue emphasis on techniques -- particularly accounting. Not enough attention has been paid to the fundamental purpose of paperwork -- to help someone do his job better.

The third important factor is lack of appreciation of who should be responsible for paperwork. Since the major product of the office is paperwork, the tendency has been for office people to assume that paperwork is their responsibility. In many instances this lack of appreciation of responsibility has led to tremendous duplication of effort, as well as inaccurate source records. And too often the office approach when handling the paperwork responsibilities for other functions of the business has been to approach it from the standpoint of policing the other functions.

In one manufacturing organization I found that the payroll, cost, production control and material control departments had each set up their clerical organizations to record production facts throughout the factory. The only significant difference between what was recorded by the various clerks was that the payroll clerk related the production to the clock number for piecework pay purposes. And, as so often happens, no department was ever able to balance its figures with the other department. The obvious answer was to place the responsibility for reporting what happened with production. With one set of clerks reporting the information to the office, they were then able to process the facts for payroll, cost, production control and material control, keep the figures in balance and produce more accurate records and reports. Costs were cut about 40% and with proper checks and balances, the entire organization was benefitted.

In recent years, although more attention has been paid to paperwork than formerly, the lack of appreciation of the scope of paperwork and of what constitutes a sound approach to the paperwork difficulties has contributed to the perpetuation of waste. Unfortunately our paperwork has gotten to be so bad that when any attention is paid to it, improvements result. Several approaches to the elimination of waste in paperwork treat the effect rather than getting at the cause of the trouble. While these superficial attempts may produce rather spectacular results, they do tend to perpetuate the waste when they fail to get at the causes. A saying attributed to "Boss" Kettering of Dayton and former Research Director of General Motors, "A problem well defined is half solved," is a good one to keep in mind in meeting all of life's situations and problems, as well as those of paperwork. Literally, when we isolate the causes of our difficulties and define our problem accurately, we are halfway toward our goal.

What are the problems in paperwork?

We have mentioned those involving total waste, the records or reports or systems which do not measure up in terms of our definition. In addition there are the inefficient methods used in producing necessary end results which can be improved. In recent years mechanization has become very popular. Unfortunately in many cases mechanization of every detail of a manual method with emphasis on the detail of the system rather than the end results, has destroyed the value of the mechanization.

A second major area of waste connected with paperwork, in most cases much greater than the waste in the paperwork itself, is the waste in other functions of the business due to lack of information, inadequate or inaccurate records. Many situations arise in other functions which could be better handled if more information was available; but since we are spending so much for paperwork now, we can't afford to get the additional facts. Eventually, such situations may become so acute that something has to be done. Such a situation involved the production and use of tools in a manufacturing shop. Tool deliveries were far behind schedule. Costs were high. Investigation showed that although four different sets of forms were being written in connection with the ordering, production and use of tools, no available records showed the usage made of the tools or where they were located after they had been used for a fraction of their lives. As a result, many sets of tools were being produced not only twice but often three or four times as frequently as necessary. A simple yet adequate system provided the facts in usable form to show what tools were on order, what tools were available, where they were and what the usage had been. One additional clerk was needed to maintain all of the records. At the end of the first year an adequate system properly maintained showed savings in toolroom manhours alone worth in excess of $140,000. This did not take into account the savings in production delays or materials.

The third major area of waste has to do with the people involved in paperwork. I have seen many studies of productivity of clerical people. Rarely have any indicated that people were producing at more than 50% of their capacity. If our 8,000,000 clerical people produced at 75% of capacity (which wouldn't hurt any of them) we would be able to produce all the necessary usable information to aid in these other functions.

In our definition I believe we have a common ground of understanding of what paperwork involves. We have defined our major problems: first, the elimination of waste, both total and in methods; second, the elimination of waste in other functions through adequate and better paperwork and finally the increase in productivity of our people involved in paperwork.

How can we solve these problems?

I am going to show you a short movie which illustrates a work place as it was originally and the improvements developed.

The improved work place enabled the operator to cut the time per order by one third or increase production by 50%. While the improved work place was not perfect by any means, I think you will all agree it was a good improvement.

Not long ago, with the Controller and one of his assistants, I visited the department in a large company which handled the preparation of monthly statements. The company, a sales organization, distributed both to industry and consumer. The assistant controller rather proudly explained how, after a detailed study of the statement writing operation, they had developed improvements which saved 10% of the cost of the operation, $50,000 per month. Although the study was a difficult one involving a great deal of work, it paid off handsomely.

Not long ago I was taken through a new storage area which had been developed for handling inactive filing. The enthusiasm of the people in charge was not surprising in view of the thousands of dollars which had been saved.

These are a few examples of what can be accomplished when we begin to pay attention to our paperwork. But let's look back at these three examples again. (Editor's note: At this point a short film was presented.)

Six months after the film you have just seen was made, I was transferred from New York to Dayton. My first assignment was to develop a film to illustrate the potentials in applying work simplification to clerical operations. Having seen this film, I looked for that operation. It wasn't where it should have been. I finally traced it to the carpenter shop where they had just finished breaking it up. The explanation was that when they examined the over-all procedure, they found the operation was not necessary.

In the Statement Writing Department I asked what percentage of the customers were industrial, what consumer. The answer was 60% industrial, 40% consumer. I then asked how many industrial customers paid on the invoice. Ninety-five per cent was the answer. Of course, the next obvious question was--why not cut out the statement for 95% of the industrial customers thereby cutting the cost 57% instead of 10%, without the detailed study, but with savings almost six times as great as those resulting from the detailed study. Critical examination of the end result of the system as to whether it was necessary or not could have indicated major savings immediately.

Critical examination of the filing -- setting up an adequate record retention plan -- providing cheap storage for inactive records are all good. This approach can in some cases cut filing and storage costs as much as half; and insofar as the records moved from active files to inactive storage, the cost can be cut as much as 90%. Of course, those records which are destroyed, and they may be substantial, result in 100% savings.

But, actually how much is this filing cost? Remington Rand has estimated that it costs 20 times as much to create a piece of paper as it does to file it for a year. If you spend $25, $2500 or $250,000 for paperwork, your filing costs are probably approximately $1.25, $125 or $12,500.00 respectively. If we can eliminate all filing, effect a 100% saving, which is extremely difficult, it only equals a 5% saving on paperwork.

Another popular approach today is to tackle the forms, to standardize the size, quality of paper, set up combination runs to cut printing costs and control the reprinting to bring all forms in line with the standards. This approach has saved substantial amounts for many companies. But again the forms cost only about as much as the filing and storing. Writing, handling and usage of the forms is again about 20 times the cost of the forms themselves. A critical examination of the end use of the forms may eliminate the form entirely. Examination of the system may indicate duplications or possible combinations which will eliminate or drastically reduce the cost not only of the form but the writing and handling. The common approach in tackling the forms to standardize and cut their cost may save 10, 20 or even 50% of the cost of the forms. On the other hand, a 10% saving in the system, the writing, handling and subsequent use, equals the savings which could be achieved by the complete elimination of the forms and the final filing or storing. A 10% savings in this system is much easier to achieve.

How can we do something about these paperwork problems?

First, let's examine the end use. Is the result necessary for government reports or to help somebody do his job better? If not, eliminate the entire system. Second, examine the detail in those systems producing necessary end results to make them as effective as possible. Third, provide adequate information promptly in usable form to help people do their jobs better. Fourth, in doing all of this, do it in such a way that we develop a desire on the part of the people doing the paperwork to want to produce more.

Which is more difficult -- to develop the improvement or to get people to use the improvement effectively? Almost unanimously people have told me that the second, to get people to use the improvement effectively, is by far the more difficult.

Why don't people accept better methods?

The most frequent answer to that question is -- people resist change. And people do resist change. A story has been used to illustrate the point. If you have a dog at home, when you go home tonight and find the dog sitting in front of the fireplace, take hold of his collar and pull to see what happens. You know just as well as I do that he will dig in and try to stay there. You may think you are using the wrong approach, so you go around behind and push. Again, he will dig in and try to stay there. That's resistance to change.

If we are going to lick our problems, I believe we must treat causes and not effects. If we treat resistance to change as a cause, it seems to me we are no more treating the cause than we would be if we put a bucket on the living room rug to keep it dry when we had a leak upstairs in the bath room. In the case of the dog, when you get through pushing and pulling him around, walk over and sit down in your easy chair and see what happens. The odds are a thousand to one he'll come along behind you wagging his tail. It wasn't the change he was resisting but the method of applying the change. And, you and I don't like to be pushed or pulled around, or told.

What are the causes back of resistance to change?

There are many. I won't attempt to cover them all in this brief time, but I do want to mention a few that I think are particularly important. One is resentment of criticism--a normal reaction. We all resent criticism. Some of us have of necessity adjusted ourselves to endure it, but we don't like it.

You folks probably play bridge, don't you? I do when I can't get out of it. You may have been in the situation I have been in, having to play with your wife as your partner. We bid a game. I had to play it. I failed to take a finesse, went down a trick and when I got through said--if I had only taken the finesse I would have made the game. That's perfectly all right. However, a few hands later we bid another game which I had to play. I didn't take a finesse, went down a trick and before I had a chance to open my mouth my wife said, "If you had only taken that trick we would have made the game". What is my reaction then? I haven't yet developed sufficient courage to throw down the cards and go home; but, I can do an excellent job of proving that if I had taken the finesse and it had failed, we would have gone down two tricks instead of one. It makes all the difference in the world where the criticism comes from. We'll take it from ourselves till kingdom comes and we don't mind it. But from another source, even one as close as that, we don't like it.

The standard approach to methods of improvement is the expert approach. Inherent in this approach is criticism, at best indirect criticism of the person who has been on the job for not having developed the improvement himself. The operator won't come out and accuse the expert of criticizing. But the operator can very effectively obstruct the use of the new method, or even prove that it isn't as good as the old one. And we interpret that as resistance to change.

Another important cause of resistance to change has developed as a result of the overemphasis of our techniques of scientific management. By techniques I include everything from scientific organization, aptitude testing, personnel selection, job evaluation, time study, motion study, accounting, cost accounting and all the others. Not one of the techniques is a pure science. Not one will produce the one right answer. Every one of them is an excellent guide to better judgment when intelligently used. However, overemphasis tends not only to destroy the confidence of our people in the findings, but frequently in our over-all judgment as well.

If there is any question in your mind about any of them being a pure science or producing the one right answer infallibly, let's consider cost accounting. This is largely mathematics which is about as close to a pure science as any. If you have any question about it, look up the bulletins of the National Association of Cost Accountants for the last 12 or 15 months. Pick out the articles by experts on how to value inventories. Select the two extremes. Apply the one extreme to a given situation and you can make it look highly profitable. Apply the other extreme to the same situation, again by an expert, and you can "bust" the company. If there is that much difference in the opinion of experts in that field, certainly when we get into the fields that involve human attitudes and reactions, we do not have a pure science.

Ed Chefits, former national president of the Mine, Mill and Smelter-worker's Union and for the past seven or eight years executive assistant to Eric Johnson of the motion picture industry, has told a story which effectively illustrates this point. An operation involving the gluing of the sole to the partly finished upper of a shoe is the subject. The methods men developes the best work place under the circumstances. An endless belt conveyor was provided to bring the partly finished uppers to the operators. Each operator had a stack of soles, pot of glue and brush. Because of physical characteristics of the building, the best method for disposing of the finished operation involved an endless belt conveyor with hooks on it, placed in back of and above the workers. The new operation was set up. The operator picked the partly finished upper off the belt, glued the bottom, stuck the sole on, then turned around and hung it on the hook on the conveyor. When all the operators were sufficiently proficient, the job was time studied and standards set on the basis of 80% of a normal day's work as standard. An operator doing a normal day's work would then make 125%. The standards were installed. The reports the first day showed each operator made about 125% except one who exceeded 200%. This was considered an error in the records, but after several days with one operator in the neighborhood of 200%, they ran a study on that man. When the figures were analyzed, they came out right on the button and that day he made 125%; but the next day he was over 200% again. After several more such days one of the time study men pulled a trick some have been known to pull. He hid behind the post and watched the man. This operator was picking up the upper, gluing the sole on and tossing it over his shoulder -- and he never missed the hook. Investigation disclosed that he was a circus juggler out of work. The problem then was whether to rate it as a circus juggling job or a shoe making job.

None of the techniques is perfect. None is a pure science. Every one of them is an excellent guide to better judgment if we use it intelligently. But overemphasis of the techniques or the exact validity of the findings has tended to create resentment, destroy confidence and is an important factor behind resistance to change.

Fear of the techniques -- as a matter of fact, fear of anything not understood -- is an extremely important cause of resistance to change.

Better organization -- proper delegation of responsibility all the way down the line -- better understanding of the importance of profit in our economy to everyone involved -- are all important to confidence in management. And they are all part of a background which when not present contributes to resistance to change.

One more cause is worthy of attention. It has to do with the growth of our economy and social system. During the past 50 years we have seen the growth of mass production. The benefits in terms of contribution to our material standard of living have been tremendous. There have been some weaknesses involved. The answer, of course, is to correct the weaknesses, not destroy the system. Mass production has meant a high degree of mechanization. This has in many cases destroyed the skilled craft jobs and a great deal of the job interest. In addition, we have been prone to emphasize how much the machine does and how little the man does in the way of work. If the emphasis were changed to bring out the tremendous responsibilities that men now have in handling these expensive machines which do the actual labor for them, we could build up the importance of the individual instead of depreciating the man in relation to the machine. Another result of mass production has been the development of large organizations with top management isolated and pretty well insulated from the workers.

Supervisors, until recently, have been selected too often because they were the best operators instead of for leadership ability. They have not been trained in the art of leadership, or even had the job described as one of leadership. Lack of understanding has bred fear and lack of confidence so that they provide excellent insulation. This situation often gives top management the appearance of being autocratic.

During the same period we have seen a tremendous growth in our educational system. In 1900 12% of our young people had an opportunity to go to high school. In 1940 it was 70%. Today it is much higher. In 1900 only 4% of our young people had an opportunity to go to college. In 1940 it was 14%, today about 25%.

Of course, more education is designed to better fit people to enjoy a fuller life. But in addition, it seems to me it should stimulate the interest, initiative and ambition of every one of our young people. If that is true, what is the net result? Many of our better educated young people have been forced to take unskilled, uninteresting jobs in what at least appears to be an autocratic atmosphere. When you have such a situation, what is bound to be the result? As far back as you can go in history, hasn't it always been rebellion? Isn't that what we have been seeing for the last 15 or 20 years?

How can we avoid criticism-- remove fear of our techniques, of the system, of the unknown?

What do people want?

What do you want? Your wants, my wants, the other fellow's wants are substantially the same. They differ primarily in the intensity of the want or the relationship of one want to another.

Whiting Williams, Personnel Consultant, for 20 years spent six months of each two years living and working as a laborer in mills and mines all over the world. He worked in the coal mines of Wales and China, the mills and mines of Europe, South America and Africa. Whiting says there are three major forces motivating our people in their work activities. These are fear -- pride -- opportunity.

Fear, the desire for self-preservation, is a motive of desperation. Its effect is limited. When income reaches the level where the necessities of life are assured with some surplus so that individuals may choose which luxuries to buy, fear is relatively unimportant and a weak stimulus.

Pride is far more important. Are you proud of your company, product or service, your boss, your job? Did you ever do good work in a situation where you were not?

Do you remember the survey of employee opinion conducted by Western Electric Company when one of the most important results indicated a need for advertising to the consumer market to build prestige? Their workers continually met new people. They were asked "Where do you work?" When they answered "Western Electric," the comment usually was -- you make washers, irons, light bulbs, etc. The worker had to reply, "No, you are thinking of Westinghouse. We make telephone equipment." How could that fellow be very proud of his job when most people he met didn't even know or recognize his company? Even though Western Electric sells primarily to one customer, they have conducted a consumer advertising program to correct this situation.

Opportunity is the third force. Fortunately opportunity does not mean the same thing to each of us. To many it does not mean promotion, because that involves responsibility they hesitate to accept. But everyone wants and needs the opportunity to express himself, to accomplish something and be recognized for it, to feel important, to belong.

Eliminating fear, avoiding criticism, stimulating pride, providing opportunity add up to a selling job of the highest order to develop acceptance of better methods. The best answer I have found yet to meet these requirements is work simplification.

Work Simplification

Work simplification is simply defined as the organized application of common sense by everyone to find better and easier ways of doing work or to eliminate waste--waste time, energy, materials, equipment, space, waste of any kind.

With apologies to my good friend, Ralph Barnes, I would like to give you what I believe are four simple principles of work simplification. I can't remember twenty-two. Even ten confuse me. But I find that these four will remind me of how to accomplish the principles.

The first principle is "Activities should be productive." Conversely, non-productive activities should be reduced to a minimum.

The second principle is "Activities should be arranged to provide smooth flow from operation to operation in a process or a balanced or rhythmic motion pattern for an operator at a work place."

The third principle is "Activities should be as simple as possible."

The fourth principle -- "Participation with know-how built on understanding stimulates interest, initiative, imagination, and results in enthusiastic cooperation."

(Editor's note: A demonstration of collating four 8-1/2 x 11" sheets was then used to illustrate how the first three principles aid in improving an operation. The initial demonstration used the right hand to pick up one of each of the four stacks with the left hand receiving and holding the sheets. The second method illustrated the use of both hands to pick up and assemble. The third method used two wedges located between the first and second and the third and fourth stacks. The demonstration was accompanied by questions and the development of some participation from the audience.)

"Do you see how through the use of the principles you can help yourself improve an operation or a method? This demonstration is a rather effective one. There is one major fault in it. It illustrates the first three principles. We have not paid enough attention to the fourth, by far the most important. I have been telling you. If we had time and you worked this out for yourselves you would buy it a lot quicker than with me telling you."

I have used this demonstration for six or seven years. I have been very proud of it. It was my own brainchild. I created it. About a year ago, however, I was presenting a program to some of our factory people. At the conclusion of the program one of the men asked me, "Do you remember when so-and-so used that demonstration about 11 years ago?" When he reminded me I did remember it. Subsequently, in reviewing Ralph Barnes' book "Motion and Time Study" I found his picture of almost the identical improvement which I had seen many years before. Since then I have had to console myself that I had developed this through research a la Don Copell. Don is chief engineer for Mrs. Wagner's pies. Don defines research in this way--if you steal one idea, that's plagiarism, if you steal many ideas, that's research. Research rather than creative thinking has had to be my consolation. For those of you who don't know him the following may illustrate his attitude and sense of humor. We like to kid him about his job by accusing him of determining how much plaster of paris to put in the chocolate pies so they won't settle while being transported around town. Last spring he said he had a new assignment, that of determining how much shellac to put on the crusts to keep them shiny.

I wish that we had more time this morning so that we could develop a number of these ideas together, rather than having me tell you. Right now I would particularly like to give you a simple problem and in solving that develop the basic approach to problem solving. For lack of time I'll have to give you what I believe is the pattern we must use in solving problems successfully.

Logical Approach

Of course, the first step in solving any problem is to recognize a situation requiring attention. In business this may be a bottleneck, a process or operation that involves too much running around, one which delays related processes, or one involving excessive costs. We recognize the situation because of effects. At that point we do not know what the problem is.

The next step is to get all the facts involved in or having any bearing on the situation. These facts should be organized in relation to each other and, if possible, visualized so that they may be seen not only as elements but as a whole. In gathering the facts we should uncover the causes back of the effects which attracted our attention. Of tremendous value in gathering the facts are the various charts which have been developed, not only in Industrial Engineering but in many other techniques. The important thing is to use that form of visual aid suitable to the specific problem. If the president of your company has to make a decision as to whether or not he will add to the production facilities, or if the sales manager is confronted with a decision as to whether or not to open new territory, the flow process chart, man and machine chart, or other form of chart in that field will be of little help.

On the other hand, statistical analyses, bar charts and graphs expressing costs, production relationships, etc., will be of immeasurable value. Charts should be used only when they will help in solving or selling the solution of a problem. A chart just for the sake of making a chart is itself waste. When we have the facts properly organized and visualized we can then define our problem in terms of causes.

The next step is to analyze and evaluate the facts. In doing this we want to question every detail in the process or operation. Listing possible alternatives can also be helpful.

The fourth step is to improve. In this step we may develop a new method as the result of our questioning or we may select what appears to be the best alternative. Part of this step must be to evaluate the improvement in terms of the cost compared with the savings anticipated. In some cases it may be advisable to set up a pilot installation to test the improvement.

Finally all of the work up to this point is of no avail unless we take the fifth step and use it. As a preliminary we may have to sell the boss. The improvement must be installed. We should then follow through to check the results and make sure that the savings actually realized justify the improvement. Finally we should always be alert to re-examine to see if there are further possible improvements.

This pattern - (1) Recognize a situation requiring attention; (2) Get all the facts; (3) Analyze and evaluate the facts; (4) Improve; and (5) Use it - is a logical orderly approach to the solution of problems. The phraseology differs somewhat from the patterns which have received wide publicity in recent years such as -- pick a job to improve; make a chart; question every detail; develop the improvement; and apply the improvement. The latter pattern can be used by workers and lower levels of supervision. Unfortunately, a program built on such a pattern tends to become a program of exploitation of these people rather than a true program of participation. The pattern which I have given you is one which must be used by anyone who consistently makes decisions with a reasonable percentage of success. This is true whether the individuals are conscious of the fact that they are following the pattern or not. This pattern is the basic technique, the foundation of the know-how of Work Simplification. Coupled with participation from top to bottom we have the key to sustained interest.

Results

I have made a lot of statements. I have been "telling" you. You may disagree with some of the things I have said. In any event, I hope I have stimulated your thinking. But the proof of the pudding lies in the eating. Rather than tell you what results you can expect, an illustration of what did happen may be more effective. We started our program in the factory with a group of pressmen. We have continually worked through groups rather than individuals. This group of six pressmen selected as their first project to which to apply what they had been learning in five training sessions, a four-part tray ticket which they made out. I use this illustration because it illustrates how production workers will get into paper work projects and make excellent savings.

The potentials are not limited to the office by any means. Their first reaction was to eliminate the tray ticket entirely. However, they recognized that three other departments, two of them in the office, would be affected by this action. They invited the other departments to have representatives sit in with their group.

During the work on the project they found that two departments did not need the information immediately and that half of the information written on the tickets was not used by anyone. The final result eliminated half of the writing and cut the four-part ticket to two parts. This represented a worthwhile savings. However, more important than that, the factory people got to know the office people. They each realized the others had problems. Each began to appreciate and respect the other fellow more. Another very real benefit was the interest developed by the representatives of the other departments. They had fun working out the answer. They recognized the possibilities for working in their own area and began to ask to be included in future training programs. This helped to spread the activity.

At the end of six months we measured the results. Individuals had participated in five two-hour training sessions a week apart. They were permitted to work on projects for not more than two hours per week. Actually, about 1% of the total time of the people trained was spent on projects. At the end of six months, the ideas submitted and put into effect were worth by measurement a 5% increase in production. Production had actually increased 35%. Why? Certainly not because the work was so much easier? The only reason I can see is that the people were getting a "kick" out of the activity. As a result, they were more interested in doing a good day's work in their working time. Certainly, a 35% increase in production justifies the training and expenditure of 1% of time.

Even in a giant organization doing business measured in billions, $250,000 a month savings through the proper approach is not small. $150,000 saved in a tool room can't be discounted.

The key to lasting results

If there is one general rule which we can use as our guide in business and social activities, it is the golden rule. In my opinion, it is the best ever. It is a sound foundation for work simplification which is largely selling. The best sales manual ever written was written about 2,000 years ago in the New Testament. Some of the finest examples of highly effective low-pressure selling - not telling - will be found there. How to stimulate the individual to work out answers for himself is the key. And we buy our own ideas enthusiastically.

However, some people think this is mixing sentiment with business and shy away from it. For them I would suggest that they be just as hard-boiled and realistic as they know how. Then, they must recognize that there are about ten votes at the bottom of the pile for each one in Management. That is being realistic.

If the ten can't have confidence, understanding, be proud, have the opportunity to express themselves, to achieve, to be recognized, to feel important, they won't like the atmosphere in which they work. To them this atmosphere represents the boss' version of freedom, free opportunity, or free enterprise. If they don't like the conditions created by the boss, they will vote against those things the boss favors.

To preserve freedom, free opportunity or free enterprise in our republican form of government (it is not a democracy) let's put some of these satisfactions into the daily life of our people through work simplification. Better paperwork, substantial material savings will amaze you; but most important of all, your people will kill all the "isms" by voting with you to save and preserve the freedom they enjoy and want.

THE APPLICATION OF INDUSTRIAL ENGINEERING TECHNIQUES IN PURCHASING

N. A. Lamberti
Assistant to Vice President, Manufacturing
Director of Materiel
McCulloch Motors Corporation
Los Angeles, California

The field of Industrial Engineering has always been interesting to me. It is a profession which is achieving a greater degree of importance and prestige every day. It appears that a significant quota of tomorrow's top management personnel will be drawn from the ranks of today's Industrial Engineers. The tools and methods of this new industrial management profession we have and are being used in many fields. Today, we will discuss the application of Industrial Engineering techniques in the Purchasing profession.

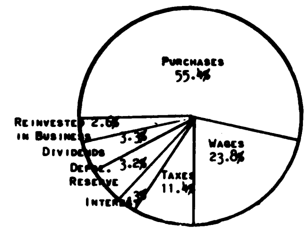
In order that we may start with a common understanding of the subject, let me give you a broad definition of Industrial Engineering. It is that science in which the application of its techniques gives effective, efficient and economical management. Industrial Engineers are found today in practically every field of endeavor -- banks, hospitals, chain stores, government offices, armed forces, schools, etc. They are particularly numerous and have discovered their greatest challenge in the operation of manufacturing industries. Here, they are mainly concerned with the production problems of planning, scheduling, routing, time study, plant layout, machine loads, cost studies and material control.

I am in the unique and fortunate position of having been able to put into effect the subject matter which is to be described here today. You see, I was formerly the Chief Engineer at the McCulloch Motors Corporation before being placed in charge of its procurement function, approximately three years ago. We have several Industrial Engineers in the Buying and Inventory Control positions. The McCulloch Motors Corporation is the world's largest producer of gasoline powered chain saws. In addition, we produce water pumps, post hole diggers, lawn mowers, superchargers, aircraft equipment, precision lenses and target engines. The company has a sales volume of approximately $25,000,000 a year and employs 2300 people. We have one of the most modern and progressive plants in the Los Angeles area. Following is a photograph of the main plant. (See Photo A)

Getting back to the main topic of discussion -- where does the field of Industrial Engineering enter into the problems of Purchasing. First of all, the importance of the Purchasing function in today's manufacturing plant must be investigated.

A significant study was made by the National City Bank of New York of what happens to the income dollar of the one hundred largest United States corporations. The figures ranged from Standard Brands Corporation's income of 383 million dollars to General Motors Corporation's income of approximately 7-1/2 billion dollars. These corporations reported sales revenue of one million dollars or more per day in 1952. The list included 77 manufacturing companies, 15 trade organizations, 6 railroads and 2 utilities.

DISTRIBUTION OF THE SALES DOLLAR IN 77 LARGEST MANUFACTURING COMPANIES



	77 Mfg. Co.	15 Trade Org.	2 Utilities	6 R.R.	100 Companies Total
1. Total Sales Income in Millions	76,921	16,362	4,475	4,245	102,003
2. Cost $ of Increase					
A. Cost of goods & Services purchased from others	55.4%	80.1%	16.1%	23.4%	56.3%
B. Wages and salaries	23.8	13.1	43.1	50.6	24.1
C. Federal Income and Excess Profit Taxes	5.9	2.6	9.7	5.0	5.5
D. Other Taxes	5.5	1.2	8.4	5.9	5.0
E. Interest Paid	.3	.1	3.0	3.0	.5
F. Reserves for Depreciation	3.2	.7	9.3	4.9	3.1
3. Total cost of Operation	94.1	97.8	89.6	92.8	94.5
4. Net Income	5.9	2.2	10.4	7.2	5.5
	100.0	100.0	100.0	100.0	100.0
5. Dividends Paid	3.3	1.4	8.0	2.7	3.1
6. Reinvested in Business	2.6	.8	2.4	4.5	2.4

Figure 1

The compilation emphatically confirms the importance of the Purchasing Department function by showing that substantially more than half of the total sales dollar income is expended for goods and services purchased from others.

The Purchasing Department in today's modern manufacturing plant represents the greatest area of untapped potential for cost reduction. Many industrial leaders in attempting to increase their company's profits, talk of increasing sales, reducing burden, improving methods, utilizing new equipment, improving quality, etc., but few attach the importance necessary to wise spending.

Consider, for example, the case of a company doing a business of $50,000,000 a year spending 50% of the sales dollar on purchases and making a profit of 10% before taxes. It is easy to picture the management of such a company growing ecstatic about a $10,000,000 increase in sales, and plans and programs are constantly being formulated and executed to increase sales. But does Management of that company devote the same degree of effort and ingenuity to reducing the costs of purchases by $1,000,000. Probably not -- yet the net result, when carried to profit, would be identical. For this company, and many others, a 4% savings in the cost of purchases is just as important, profitwise, as a 20% increase in sales.

From 1950 to 1954, the McCulloch Motors Corporation spent several million dollars in the purchase of several allied manufacturing corporations. The Industrial Engineering Department played a very important part in investigating, analyzing and establishing new cost standards, procedures and policies in these absorbed corporations. Some of the most critical and common problems that were encountered in these companies were those dealing with materials.

Analyses were made on the status of:

1. Amounts and prices of materials on order.
2. Total dollar value on order
3. Months inventory on hand
4. Dollar value of inventory on hand
5. Quality of the material on hand
6. Dependability and capability of vendors
7. Receiving, Stores and Shipping areas and function
8. Materiel Department Personnel
9. Materiel policies and procedures

From the above investigations, conditions were found of overextended purchase order commitments, surplus material inventories, poor quality of goods, undependable vendors, incompetent personnel, and inadequate and confusing operating procedures. It isn't difficult to understand how the above situations could easily cripple any manufacturing operation. Because of our own past experiences, and those discovered in acquiring our subsidiaries, our corporation stresses a great deal of importance to the materiel function.

Our corporation at present spends approximately $1,000,000 per month on materials and services procured from others. Fifty-five per cent of the company's standard manufacturing cost is in purchased materials. Yes, the application of the Industrial Engineering techniques of cost analysis, methods improvement standardization and organization in the procurement departments could save the company thousands of dollars every year.

And so with these introductory thoughts behind, let us delve into the relations and application of the function of Industrial Engineering to the Purchasing field. Some of the techniques are more important than others -- but all are applied in some degree. Those items to be discussed are as follows:

1. Organization charts, job descriptions and evaluations
2. Methods and procedures improvement and department layout
3. Work measurement and wage incentives
4. Statistical analyses and inventory control
5. Quality control
6. Cost and performance reports

The first item in which Industrial Engineering training could be effectively used is in drawing up a departmental organization chart. It is a tool which can be grossly misused. Charts must be intelligently drawn, showing lines of authority. Individual responsibilities should be clearly defined. The relation of the individual in the department, and that of the department to other operating departments, must be shown. Jobs have to be described, evaluated, and rate ranges established to show each employee his relative worth to the company. The proper functioning of a department, and in some cases an entire plant, can be insured by the careful analysis and placement of the various responsibilities in a corporation organization chart.

In our corporation the Materiel Department is composed of the following sections:

1. **Production Buying**
2. **Non-Production Buying**
3. **Inventory Control**
4. **Receiving**
5. **Stores**
6. **Shipping**

In other words, this Purchasing Department is responsible for practically the entire material cycle. An important industry trend has been in the placement of the inventory Control and Stores Departments under the Purchasing function.

In the past, the material requisitions were issued by the Production Department, whose basic interests were only in getting large quantities of material to keep their machines and personnel busy. Most of the decisions were already made when Purchasing was left to buy the materials. As a result, unused price breaks, single bids, fair quality, poor deliveries, overstocked inventories, overcommitment of materials on order, were the rule and not the exception. In operating by the above methods, the purchasing man's hands were tied.

For our particular type of manufacturing, the placement of the above sections all under the Purchasing Department has resulted in a more efficient and economical operation. Another of our problems was the drawing of a comprehensive parent corporation and subsidiary Purchasing Department organizational chart. There were several subsidiaries to take into consideration. Each were of a relative size and importance to the Main Plant.

Job responsibilities were defined and lines of authority were shown for each Purchasing position. A senior buyer was in charge of Purchasing at one subsidiary, an Assistant Purchasing Agent was head of procurement at a second subsidiary, another had a full Purchasing Agent as head, etc.

A Director of Materiel at the parent plant established and coordinated all of the Purchasing Department's policies and procedures. Following are some organization charts which show the relation of the Purchasing Department to other departments in the corporation.

Figure 2

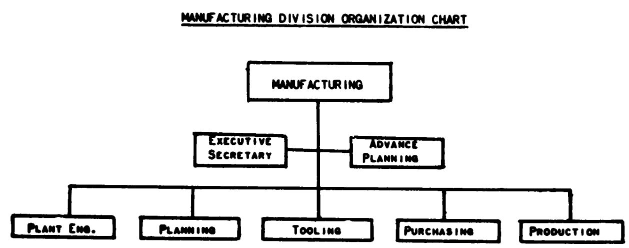
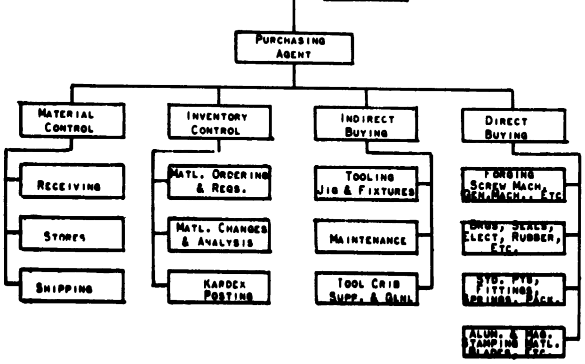


Figure 3

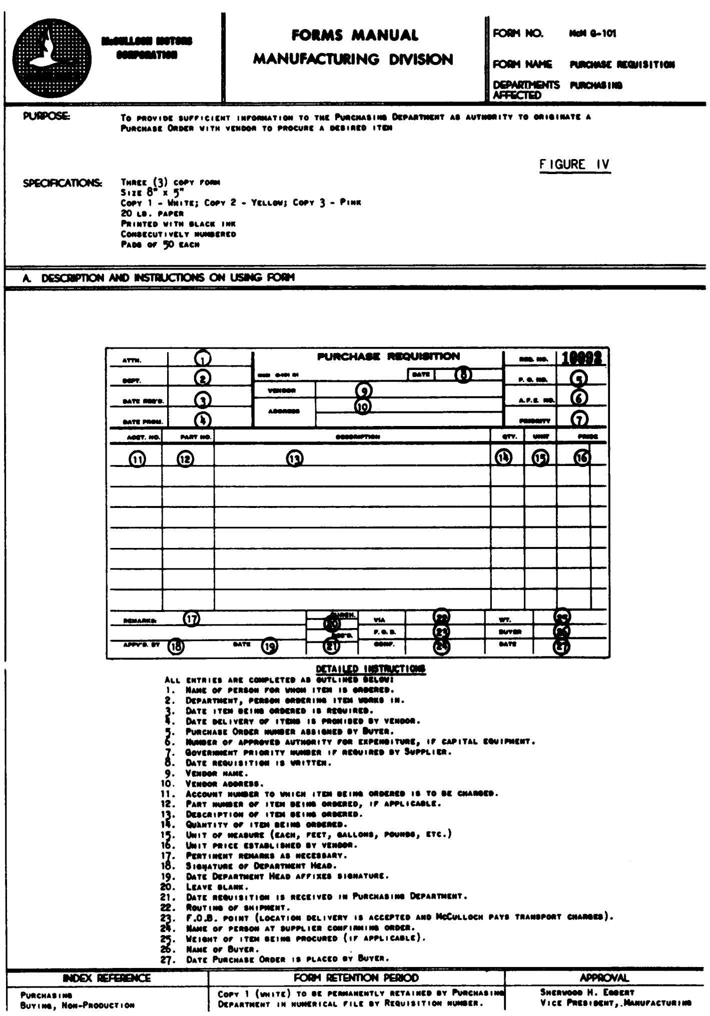


The second technique to be applied in purchasing is that of departmental methods, procedures and layout improvements. All of the department's procedures, forms and systems must be analyzed, improved upon and satisfactorily placed back into operation. The improvements from these investigations save countless hours of clerical work, eliminate red tape and duplication. The analysis of the procedures brought out the large quantity and variety of forms being used. The number of more important forms passing through the department every month are as follows:

Qty.	Form	Buying	Inv. Cont.	Rec.	Stores	Ship.
2,000	Purchase Requisition	x	x			
1,600	Purchase Orders	x	x	x		
3,800	Receiving Reports	x	x	x		
2,500	Stores Requisitions		x		x	
3,400	To-Stores Cards		x		x	
2,800	Sales Parts Orders		x		x	x
1,200	Shipping Reports		x			x
10	Bill of Materials Issues		x		x	
200	Engineering Changes & Deviations	x	x		x	
200	Invoices	x				

Approximately 50% of all of the corporation paperwork is processed through the Purchasing Department. It can therefore be readily seen how important the design, control and flow of procedures actually becomes. Standard practices and flow charts were set up to educate, standardize and follow a form through all of its stages of processing.

Figure 4


McCULLOCH MOTORS CORPORATION

FORMS MANUAL
MANUFACTURING DIVISION

FORM NO. McM G-101
FORM NAME PURCHASE REQUISITION
DEPARTMENTS AFFECTED PURCHASING

PURPOSE: To provide sufficient information to the Purchasing Department as authority to originate a Purchase Order with vendor to procure a desired item

FIGURE IV

SPECIFICATIONS: Three (3) copy form
Size 8" x 5"
Copy 1 - White; Copy 2 - Yellow; Copy 3 - Pink
20 lb. paper
Printed with black ink
Consecutively numbered
Pads of 50 each

A. DESCRIPTION AND INSTRUCTIONS ON USING FORM

DETAILED INSTRUCTIONS

All entries are completed as outlined below:

1. Name of person for whom item is ordered.
2. Department, person ordering item works in.
3. Date item being ordered is required.
4. Date delivery of items is promised by vendor.
5. Purchase Order number assigned by Buyer.
6. Number of approved authority for expenditure, if capital equipment.
7. Government priority number if required by Supplier.
8. Date requisition is written.
9. Vendor name.
10. Vendor address.
11. Account number to which item being ordered is to be charged.
12. Part number of item being ordered, if applicable.
13. Description of item being ordered.
14. Quantity of item being ordered.
15. Unit of measure (each, feet, gallons, pounds, etc.)
16. Unit price established by vendor.
17. Pertinent remarks as necessary.
18. Signature of Department Head.
19. Date Department Head affixes signature.
20. Leave blank.
21. Date requisition is received in Purchasing Department.
22. Routing of shipment.
23. F.O.B. point (location delivery is accepted and McCulloch pays transport charges).
24. Name of person at supplier confirming order.
25. Weight of item being procured (if applicable).
26. Name of Buyer.
27. Date Purchase Order is placed by Buyer.

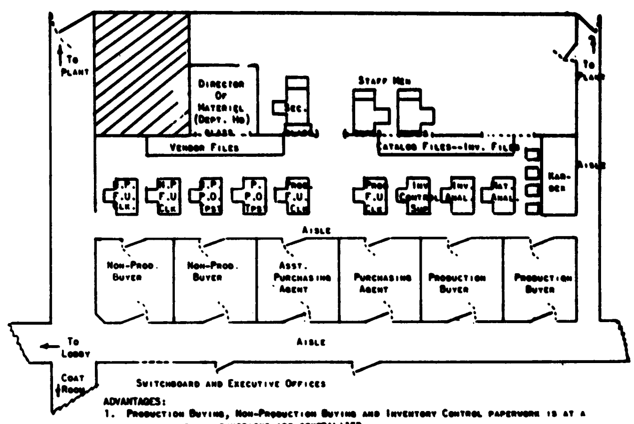
INDEX REFERENCE	FORM RETENTION PERIOD	APPROVAL
Purchasing Buying, Non-Production	Copy 1 (white) to be permanently retained by Purchasing Department in numerical file by Requisition number.	Sherwood H. Egbert Vice President, Manufacturing

Department Manuals of Forms, Responsibilities and Procedures were established for every section in the Purchasing Department. These Manuals were meant to be a permanent record of the department's operation. From these records, new personnel could be easily trained in department procedures, the existing methods improved and all personnel would have a common knowledge as to how the department operates.

Concurrent with the establishment of new and improved methods, forms and procedures, a new office layout is planned. This allows for the smooth flow of paperwork, better lighting, proper desk arrangement, centralization of certain functions and adequate work area. This reduces to a minimum the amount of confusion and errors that are made by the department's personnel in carrying out their everyday activities. In the following diagram is shown the proposed revision of the layout in the Purchasing Department.

Figure 5

BUYING AND INVENTORY CONTROL LAYOUT



ADVANTAGES:

1. Production Buying, Non-Production Buying and Inventory Control paperwork is at a minimum and all functions are centralized.
2. Buyers accessible to vendors and other department personnel.
3. Inventory Control adjacent to Production buying.
4. Production Follow-up Clerk and Typist are close to Production Buyers.
5. Non-Production Follow-up Clerks and Typist are close to Non-Production Buyers.
6. Purchasing Agent in charge of Production Buying, and Assistant Purchasing Agent in charge of Non-Production Buying, are next to each other.
7. Files are against walls, near pertinent user and away from traffic.
8. Director of Materiel has view of entire operations.
9. Staff men are isolated from traffic and are able to plan better.

The third technique is one which is synonymous with the term Industrial Engineering. That is, the field of work measurement, standards and wage incentives is the core of Industrial Engineering methods. In order to control the performance and analyze the effectiveness of the Purchasing Department, units of work measurement were set up in each section. Each section has approximately ten or more activities that are measured. A report is written monthly on these operations by the section supervisors. The compilation of this information in each section has accomplished the following purposes for its supervisors and personnel:

1. Exposed interesting job facts and given them new job knowledge.
2. Taught them to be more systematic and efficient in fulfilling their duties.
3. Has set work standards which will serve as a basis for comparison from which decisions will be made to improve the department's operations.
4. Aided in determining the manpower requirements.

Following are some examples of the important units of work measurement that are set up in each section of the Materiel Department:

Section

1. **Buying** (Production and Non-Production)
   - A. Number of Purchase Orders processed by buyers.
   - B. Number of Requisitions processed by buyers.
   - C. Dollar volume by purchase commodities and by buyers.
   - D. Purchase Price Variance from standard.
2. **Inventory Control**
   - A. Months of material on hand and on order.
   - B. Dollar value of material on hand and on order.
   - C. Number of postings to Kardex.
   - D. Number of engineering changes processed.
3. **Receiving**
   - A. Number of Receiving Reports written.
   - B. Pounds of material received.
   - C. Number of trucks handled at dock.
   - D. Number and dollar value of freight bills processed.
4. **Stores**
   - A. Number of orders filled.
   - B. Number of new and back orders on hand.
   - C. Number of requisitions and return to stores cards filled.
   - D. Number of bills of material processed.
5. **Shipping**
   - A. Number of orders shipped.
   - B. Pounds of material shipped.
   - C. Number of Shippers written.
   - D. Number of pickups and deliveries.

The operational statistical data just described is invaluable to the sectional supervisor. Figure 6 shows a typical report from the Buying Section.

Figure 6

McCulloch Motors Corporation

Division: Manufacturing
Dept.: Purchasing
Section: Buying
Date: 12-1-53 No. B-1358
Project or Product: General
Subject: Purchasing Dept. Work Measurement
Page 1 of 1

Title of Report: STATISTICAL ANALYSIS OF DEPARTMENTAL OPERATIONS

Item	Unit of Measurement	Quantities
1	Purchase Orders Issued by Buyer No. 1	115
2	Purchase Orders Issued by Buyer No. 2	200
3	Purchase Orders Issued by Buyer No. 3	175
4	Purchase Orders Issued by Buyer No. 4	475
5	Purchase Orders Issued by Buyer No. 5	400
6	Purchase Orders Issued by Buyer No. 6	250
7	Total number of Purchase Orders issued	1615
8	Total value of Purchase Orders placed by Buyer No. 1	$228,000
9	Total value of Purchase Orders placed by Buyer No. 2	165,000
10	Total value of Purchase Orders placed by Buyer No. 3	90,000
11	Total value of Purchase Orders placed by Buyer No. 4	110,000
12	Total value of Purchase Orders placed by Buyer No. 5	70,000
13	Total value of Purchase Orders placed by Buyer No. 6	180,000
14	Total value of all items purchased	$843,000
15	Dollar value of Production Blanket Orders	150,000
16	Dollar value of Non-Production Blanket Orders	25,000
17	Purchase Price Variations	10,000
18	Paid Purchases for month	1,600,000
19	Discounts taken	8,000
20	Obsolete costs	5,000
21	Number of Receivers posted to Production Purchase Orders	2,000
22	Number of Receivers posted to Non-Production Purchase Orders	2,200
23	Number of Salary Personnel - Exempt	6
24	Number of Salary Personnel - Non-exempt	7

We have found from experience that actually from two to five units of work measurement in each section are enough to give us a true picture of their performance. However, all of the units are measured, for it is hoped with the building of this statistical data that eventually indirect time standards will be set in these sections. If standards are not set, it would still be possible to statistically compare these units with various production figures and arrive at a ratio to be used in a wage incentive plan. That is, in a mass production type of manufacturing such as ours, there is a definite correlation between production labor hours (units and manpower) and the operations of the Purchasing Department Sections of Buying, Inventory Control, Receiving, Stores and Shipping.

As you know, it is relatively simple to calculate the efficiency of a manufacturing operation. This is not so of the indirect departments. They present a different problem because of the variety and non-repetitiveness of the work involved.

At the McCulloch Motors Corporation, upon the establishment of a plan, the Receiving, Stores and Shipping Sections would probably be tied in closely with the Production Department. The Production Buying and Inventory Control Sections might be calculated in the following manner. The assumptions and calculations used are not new, but the application is. The reason behind the method is sound and practical--and presents a relation between the costs and savings for which the Production Buying and Inventory Control Sections are responsible. It is an expression of the ultimate production purchasing cost in ratio tc the value of direct materials purchased.

Figure 7 presents a sample calculation for the performance of quarterly purchasing operations.

Figure 7

PURCHASING DEPARTMENT EFFICIENCY

I. CHARGES

A.	Prices paid above std. for material	$15,000
B.	Department Expense (Salaries, supplies, rent, lighting, phone, etc.)	27,000
C.	Freight Charges	10,000
D.	Discrepancies, Losses and Delays	5,000
E.	Expense of carrying Inventory ($2,000,000)	

Int.	.06
Obs.	.08
Det.	.01
Tax & Ins.	.005
Rent	.04
Clerical	.01
Handling	.02
Repairs	.01
Carrying Chgs	.20

.20 (2,000,000) 1/4 = 100,000

$157,000

I. CREDITS

A.	Prices paid below std. for material	$10,000
B.	Savings by substitution	2,000
C.	Salvage Sales	1,000

$13,000

II Net cost of purchasing = Charges - Credits (Per quarter)

Charges	157,000
Credits	13,000
Cost	144,000

III. Amount of material purchased (Per quarter) $1,800,000

IV. Deficiency Index = Total purchases divided by the net cost of purchasing (Also equals the amount of cents a company spends to buy a dollars worth of goods) $= \frac{142,000}{1,800,000} =$

= .08 or 8%

V. Performance Index = 100 - 8

= **92%**

NOTE: All figures are fictitious and are listed for the purpose of explaining the technique

The above efficiency would indicate that a considerable amount of buying is being done with a minimum of personnel. The above index serves as a measuring stick by which the department can analyze its effectiveness.

From the calculations it can be shown that the index will rise if the charges of such department expenses as inventories, losses, freight and manpower are reduced. At the same time, it is a challenge to increase the credit side of the ledger by doing more efficient buying and in engaging in a vigorous cost reduction program. The above technique may be refined and is presented to show the manner in which an indirect department performance can be measured.

The next item of importance is the application of some Industrial Engineering methods in the control of material inventories. With the amount of money being spent on production purchases, this is the area which is of the greatest importance to us. There is a need for a constant calculated and graphical analysis of the company's material inventories on hand and on order. A chart of material accounts by category has been drawn up for use between the Accounting and Purchasing Departments. All purchases, issues and withdrawals of materials are recorded by these account numbers. These account numbers enable us to analyze our inventories in more detail instead of by complete products. A series of reports on material transactions are issued monthly by the Accounting Department. These include reports on Inventories Charges and Credits, Purchase Price Variations, Dollar Value of Purchases, Cost of Sales, Scrap, Obsolete Costs, etc. Analyses are made of this accounting data of the past movement of materials. Important information is graphed to observe the trends, increases, decreases, minimums and maximums. Figure 8 presents some graphs on Inventory Data.

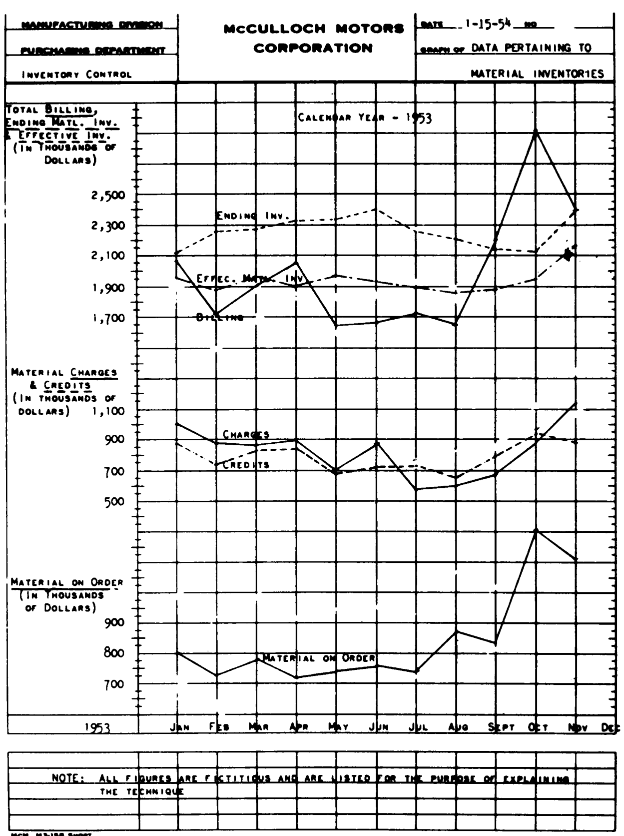


Figure 8

The most important report that is drawn up in the Purchasing Department is the analysis of the production purchase material inventory. The Accounting report lists by code number and by dollar value (1) the beginning inventory, (2) the charges for incoming purchased materials, (3) the credits for outgoing material in sales, and (4) the ending inventory. From these figures the Purchasing Department must analyze what took place in the past month and what, if any, action must be taken in the future. In one section of the report a new technique has been introduced to control the inventories.

A monthly analysis table of materials on hand and on order has been designed to gauge the effectiveness of inventory control. This table compares the actual inventory in terms of months of usage to that of a standard or desired months of usage. The following illustration describes this table.

Analysis of Purchase Production Material
On Hand and On Order

		Material on Hand Analysis							Material on Order					Total Inventory Analysis			
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	
Pdt. Code	Description	Actual Inv. Less Fin. Goods & Obsolete	Usage Avg. Mo. Based on Past 3 Mo.	Usage Avg. Mo. Based on 3 Mo. Forecast	Actual Usage Mo. in Inv.	Std. Usage Mo. in Inv.	Effectiveness Ratio	Inv. Turnover in 12 Mo.	Matl. on Order	Usage Avg. Mo. Less Outside Process & Exacto	Actual Usage Months on Order	Std. Usage Months for on Order	Effectiveness Ratio	Actual Total No. of Usage	Std. Total No. of Usage	Effectiveness Ratio	Remarks
10	Product A	$270,000	90,000	92,000	2.93	2.5	.85	4.09	135,000	73,000	1.85	1.70	.92	4.78	4.20	.88	Slightly heavy. Action being taken
20	Product B	- -	- -	- -	--		- -	- -	- -	- -	--		--	- -		--	
30	Product C	950,000	449,000	400,000	2.38		1.05	5.04	510,000	350,000	1.46		1.16	3.84		1.09	Satisfactory
40	Product D	1,000,000	227,000	380,000	2.63		.95	4.56	520,000	300,000	1.73		.98	4.36		.96	Satisfactory
50	Product E	150,000	90,000	60,000	2.50		1.00	4.80	87,500	50,000	1.75		.97	4.25		.99	Satisfactory
60	Product F	42,000	12,000	21,000	2.00		1.25	6.00	31,500	21,000	1.50		1.13	3.50		1.20	Light. Material ordered to increase
70	Product G	2,000	1,000	1,000	2.00		1.25	6.00	2,000	1,000	2.00		.85	4.00		1.05	Satisfactory
80	Product H	- -	- -	- -	--		- -	- -	4,000	2,000	2.00		.85	2.00		2.10	Too light. Model to be discontinued
90	Product I	600,000	180,000	267,000	2.25		1.11	5.33	321,000	190,000	1.69		1.01	3.94		1.07	Satisfactory
100	Product J	15,000	6,000	8,000	2.00		1.25	6.00	15,000	8,000	1.88		.90	3.88		1.08	Satisfactory
110	Product K	98,000	22,000	36,000	2.72		.92	4.41	58,000	30,000	1.93		.88	4.65		.90	Satisfactory
120	Product L	185,000	48,000	77,000	2.40		1.04	5.00	127,000	77,000	1.65		1.03	4.05		1.04	Satisfactory
	TOTAL	$3,312,000	1,085,000	1,342,000	2.47		1.01	4.92	1,811,000	1,102,000	1.64		1.04	4.11		1.02	Satisfactory

(1) Total purchased material per Accounting Inventory Report less finished goods computed by extending Shipping Report models in inventory against unit cost.
(2) Past total of three months credits divided by 3.
(3) Forecast three months requirements divided by 3.
(4) (1) ÷ (3)
(5) Policy Derived Standard
(6) (5) ÷ (4)
(7) Divide 12 months by months in column (4)
(8) Total of Material on Order Report B-109
(9) (2) less est. purchased outside processing and Exacto Manufacturing
(10) (8) ÷ (9)
(11) Policy decision established
(12) (11) ÷ (10)
(13) Sum of (4) and (10)
(14) Sum of (5) and (11)
(15) (14) ÷ (13)

NOTE: All figures are fictitious and are listed for the purpose of explaining the technique

Figure 9

The chart is broken down into three parts -- material on hand, material on order and total material. The material values are shown in dollars and by code number. Following is an explanation of the figures in each column.

A. Material on Hand Analysis

Column 1 - The actual material inventory on hand, excluding finished goods. Values taken from the Accounting Report.

Column 2 - Average Usage Per Month, Based on the Past Three Months. This information taken from past cost of sales data.

Column 3 - The Material Usage Per month, Based on the average of the next three months requirements. These values are calculated from the forecasted units on the manufacturing schedule.

Column 4 - Actual Months Usage of Materials in Inventory. Computed by dividing the inventory by the average month's usage. (Column 1 ÷ Column 2)

Column 5 - Standard Usage Months in Inventory. This standard is established through experience and analysis of desired inventory levels. May vary from two to five months, depending on the types, lead time, value, etc. of materials. This value is set by policy decision.

Column 6 - Number of Inventory Turnovers in Twelve Months. Should be from four to six months for the average light manufacturing firm.

Column 7 - Effectiveness Ratio. This is a performance index associated with control of the inventories. It is derived by dividing the standard months usage by the actual months usage. 1.00 is the desired rating--above indicates too high an inventory, and below indicates too low an inventory.

B. Material on Order Analysis

Column 8 - Material on Order. Calculated by the Inventory Analyst from the Kardex by code number.

Column 9 - Average Months Usage. Same as Column 2.

Column 10 - Actual Months of Usage of Material on Order. This value is arrived at by dividing the material on order by the average month's usage (Column 7 ÷ Column 8).

Column 11 - Standard Months of Usage on Order. This value is set by past analysis and is a policy decision. It may vary from one to three months.

Column 12 - Effectiveness Ratio. This rating is computed by dividing the standard months usage on order by the actual months usage on order. (Column 8 ÷ 9)

C. Total Material Analysis

Column 13 - Total Actual Months of Usage. This is calculated by adding the actual months of usage in inventory on hand to that on order. This gives the total inventory available to meet the next three months forecasted requirements.

Column 14 - Total Standard Months Usage. This is the combined desired months usage of inventory on hand and on order. These values have been set by current management policy decisions.

Column 15 - Grand Effectiveness Ratio. This ratio is derived by dividing Column 12 by Column 11. It is a relative measurement of efficiency of control exercised by the Purchasing Department to meet the requirements of the production schedule.

This table will prove to be a most useful tool in the control of material inventories. It presents the full picture of the position of the inventory. The inventory analyzed in this manner makes it possible to locate those sections which are not in a favorable position and the degree to which a correction to the condition should be applied.

In another section of the inventory report is an analysis of the variances of material cost from that forecast in the budget.

The Purchasing Department is responsible for the materials inventory budget. The budget material charges are calculated in accordance to a Manufacturing Forecast. The budget credits are prepared from the Sales Forecast. A master budget is prepared on an annual basis and biannual or quarterly revisions are prepared, if necessary.

The calculation of purchasing budget variances becomes quite involved. The causes of variances are due to:

1. Variation in scheduled units.
2. Variation in unit cost.
3. Service sales variation.
4. Scrap variance.

The subtraction of these variances from the total variance is that due to the performance of the Purchasing Department. That is, did we buy too much or too little in relation to that material which was budgeted.

Calculation of the economic lot size is another method to maintain the amount of investment in stores at a predetermined amount. Several methods, tables and formulas have been developed for making this computation of the different materials used. The problem would become very complex if all costs were considered. Actually only four factors need to be considered to arrive at a figure which is accurate enough for practical purposes. For purchased materials, these factors are:

1. Price discounts as the order quantity increases.
2. Cost of placing each order.
3. Cost of space used for storage purposes.
4. Inventory carrying charges, exclusive of space charges.

The first two factors deal with problems of preparation charges. The latter two factors are involved with carrying charges. The point at which these two costs equal each other is the economical ordering point. That is, for low inventories, the preparation charges of writing a purchase order are high because material is being continually ordered. In this case, a missed delivery or rejected lot can shut down the production line. However, if the reverse is true and one order is placed for six months of goods, the carrying costs are high because material may deteriorate, or become obsolete. In addition, it is subject to a space charge and ties up working capital.

So, as can be seen from the past calculations and explanations, the material inventories at our plant are kept under constant surveillance. Overextended inventories tying up working capital have more than once caused some companies financial embarrassment. We are endeavoring, through the use of our techniques for control, to maintain approximately a $2,000,000 material inventory. This is equivalent to a 2-1/2 months usage in relation to future production requirements. On a monthly basis, the amount of material coming in is balanced against the material going out in the cost of sales. The amount of material on order amounts to about 50 days usage.

The fifth tool that is jointly used by the Purchasing and Receiving Inspection Departments, is the science of statistical quality control. Purchasing is responsible for the procuring and receiving of material. It is up to the Inspection Department to judge as to its quality before routing the material into stores.

Material investigations are made into the sources of supply, type of vendor equipment, amount of past rejections, dimensions to be measured, class of part, etc. From these analyses the Purchasing and Inspection Departments are able to determine the type of quality control charts that are required to random accept different classes of materials.

The last technique that should be used in the Purchasing Department is the establishment and maintenance of a series of reports. These reports may be classified under separate categories -- operational and informational. The informational reports are those that are initiated to pass on interesting and general data to Purchasing and other department personnel. Material cost analyses of all kinds come under this type of report. The material cost analyses are made by commodities such as magnesium, aluminum, steel, forgings, castings, bearings, seals, machine parts, plastic and rubber parts, nuts, screws, springs, gaskets, etc. The trend of each of the purchasing categories is studied. Variations from standard are carefully analyzed and remedial action is taken. Some of the following reports could be placed in that category.

1. Dollar value and quantity of bearings used in 1952.

2. Material cost analysis by commodity for Model 33 saw.
3. Material price breaks for volume production of 1952 Ford Supercharger Kit.
4. Break even point of magnesium and aluminum die cast metal costs.

The operational reports are the most important and in most cases directly affect the department operation. All of the department figures on inventories, costs, manpower, purchases, operations are shown in these reports. A wealth of information is at your fingertips. These reports, when properly prepared and analyzed, are the strings from which are pulled most of the important decisions for running the department. In our particular type of operation the following reports come under this classification:

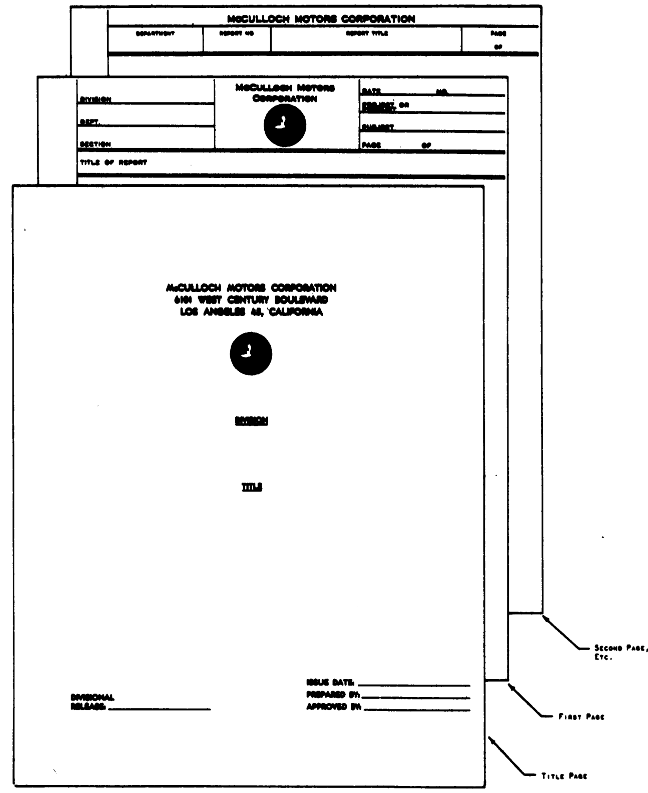
1. Budget Reconciliation
2. Material on Order
3. Analysis of the Material Inventories
4. Dollar Volume of Purchases
5. Purchase Price Variations
6. Obsolete Costs
7. Shipping, Receiving and Shortage Logs
8. Material Status (Blade, Chains, Magnesium, Aluminum, Bearings, Forgings)
9. Buying, Inventory Control, Receiving, Stores and Shipping Section Work Measurement of Operation

All of the reports are placed on a standardized report form. These forms have headings denoting division, department and section issuing report, report number, date, subject and report titles. Figure 10 is a sample of the type we use.

When we put into effect the series of reports as mentioned above, it was possible, with a minimum of confusion and errors, to effectively analyze and control the Purchasing Department operations.

In the past few minutes, the relationship of Industrial Engineering to the Purchasing field has been briefly discussed. There was a considerable amount of ground covered. Any one of the above Industrial Engineering techniques, as applied to Purchasing, would have been an important enough subject to have merited an hour of discussion alone. Please bear with me for not having gone into any one of the topics more deeply. However, it is hoped that the general discussion on the manner in which we at McCulloch Motors have applied the techniques of Industrial Engineering to purchasing will be of aid in solving some of your problems in the future.

Figure 10



There are many jobs open in Purchasing for Industrial Engineers. These classifications include such positions as Director of Materiel, Purchasing Agents, Buyers, Inventory Analysts, Material Analysts, Procedures Analysts, Statisticians, Material Follow-up, Material Forecasting, etc. Purchasing and Material Problems play a very important part in today's manufacturing operations. Its decisions commit the company financially and are therefore being accepted as an executive function.

Many companies in the United States, and a few locally, have made Purchasing Agents out of some of their industrial engineers. Their background of plant manufacturing methods and operations enables them to better understand material problems. Their techniques can be used to a great advantage in the procuring of materials. A new horizon has been opened to the Industrial Engineer and to the application of industrial engineering techniques in the field of industrial purchasing.

PRODUCTION ENGINEERING SESSION

Session Chairmen: At Berkeley - JAMES N. LANDIS, Chairman, San Francisco Section of ASME, and Vice-President, Bechtel Corp., San Francisco.
- DAVID A. GUSTAFSON, President of San Francisco Chapter, American Society of Tool Engineers.

At Los Angeles - FRANK BAEYERTZ, Chairman, Southern California Section, American Society of Mechanical Engineers; Chief Automotive Engineer, General Petroleum Corp., Los Angeles.

MANAGEMENT'S STAKE IN INDUSTRIAL RESEARCH

Max Kronenberg
Consulting Engineer
Cincinnati, Ohio

Once upon a time there was a machine manufacturing company so prosperous that its common stock dividend averaged more than $42.00 a share for many years. The company even paid an extra dividend of several hundred percent ... until a competitor came along with an invention cutting deeply into the sales of the machine company, which was now no longer in a position to pay any dividend!

What to do was the big problem. The management did a very sensible thing, and turned for help to research! Before long, the products and sales were so much improved that dividend payments could be resumed. This is a true story... it happened before the invention of the excess profit tax, the lack of which we are enjoying now again.

In several issues of the Wall Street Journal in 1949, you will find a resume of the financial aspects of industrial research winding up with a statement: "Take care of research and the dividends will take care of themselves."

It can readily be seen, then, that an investor nowadays does not base his estimate of the soundness of an industrial company on the financial statement alone - because it is often a record of past performance - but tries to ascertain whether and what management is doing in the way of forward-looking research to insure future development of the company.

It has been estimated that about 70% of the companies listed on the New York Stock Exchange - who might be expected to employ research - are making use of it. If Real Estate is disregarded, it may be assumed (Bichowsky) that at least 50% of the entire capital of the United States is invested in companies founded on inventions made in the last 150 years. Among them are our largest companies such as American Can, American Radiator, American Telephone and Telegraph, Baldwin Locomotive, Bethlehem Steel, Chrysler, DuPont, Eastman Kodak, General Electric, International Nickel, National Cash Register, Westinghouse, to name only a few.

These stories, gentlemen, give you - in a nutshell - the stake which management has in industrial research! The effectiveness of research can be judged best by the general condition of a company. Research is justified because it will keep an organization ahead of competition.

Karl T. Compton, the former president of M.I.T. has said:

"It is certain that a portion of experiments which are well worth trying will prove unsuccessful, whereas others will be successful and a few will be really great contributions. This is well understood by the directors of many industrial research laboratories... They know that some of the work might be unprofitable, but they realize that it is worth the effort because there will be some so successful as to more than justify the entire effort."

E. W. Rice, Jr. of the General Electric Company, whose company has more than one research laboratory, said many years ago:

"We have spent well over $100,000,000 within five years on our development work and we intend to continue at whatever rate of expenditure seems to be necessary. For we have found no other money so well invested."

Charles E. Wilson, in a recent article in American Scientist, supported this statement and recalled the contributions by Thompson, Steinmetz, Rice, Fish and Davis, which today stand out as having been sound and wise. Their decisions made 50 years ago must have been very difficult. At that time, the infant electrical industry was based on Faraday's research and on that of his associates and that was all. The machines and devices upon which the business was founded were few and not too efficient. The customers were few and skeptical. These men, however, saw that if their branch of engineering was to continue its growth, there must be a continuing supply of new scientific facts as a basis, since any kind of engineering is applied science.

Builders of ships are more practical, in Wilson's opinion, than the builders of machines, because they launch their craft at the earliest opportunity and make sure that it will float before they proceed with the expense of completing it.

Dr. Langmuir has called attention to the proficiency which the United States showed up to about 1910 in developing industries based on a foundation of pure science that had been developed in England, France, and Germany and he pointed out that since that time, Americans have been contributing much more than before in the field of pure science. The larger part was originally achieved in Universities, but gradually a tendency developed to carry out such research work in industry or with its financial support. This indicates that management is recognizing the significance of research to an ever-increasing extent.

FINANCING RESEARCH

As to how much money any given industrial enterprise ought to spend on research, it cannot be stated easily. That depends upon many conditions, such as the character of the business, its age, the nature of the products, and the life. Different companies spend on research anywhere from almost nothing up to 5 per cent and some even considerably more of their invested capital. The average expenditure on research of all those companies which maintain research laboratories, as indicated by a survey conducted by the National Research Council, is 1.3 per cent of the capital invested. Charles F. Kettering has suggested that a manufacturer ought to spend on research as much as he spends on advertising.

In 1951, according to a survey by the Business of Labor Statistics, the average expenditure for research was 2% of the total sales and services, although in some industries, such as aircraft 13% of sales were spent on research and 6% in the field of electrical machinery and instruments.

A survey of the cost of research broken down by industries is shown in Figure 1. In aircraft and electrical engineering, more than $400 million were spent on research in 1951, as against $100 million in mechanical engineering, a field where considerably more research is needed.

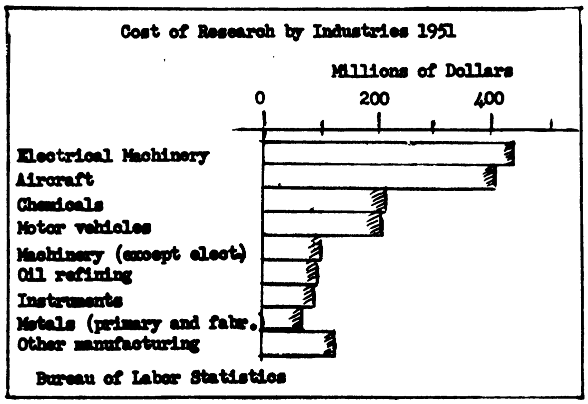


Figure 1

The average outlay for research per scientist varied from $16,000 in the chemical industries to $68,000 in motor vehicle manufacturing. This compares favorably with the investment of $75,000 required to make a job available in the steel industries according to an advertisement of January, 1954, by U. S. Steel.

Companies included in the survey employed 94,000 research engineers supported by 140,000 technicians and administrative personnel. More detailed information on a nationwide basis as to private industry's research activities is however still lacking. The number of American companies carrying out research has risen to about 2500.

PURE SCIENCE vs. APPLIED RESEARCH

The difference between research in pure and in applied science is often small, so far as ultimate results are concerned. In the opinion of T. B. Boyd of General Motors, the sole intention of the investigator in pure science is to advance human knowledge. Exploration in the field of pure science is thus an attempt to find out about something in nature for the simple sake of knowing. The intention of the applied science explorer is either to convert already discovered truth into practical usefulness, or to do both, namely, to discover new facts and to apply them in a practical way.

The investigator in applied science has, however, one distinct limitation which the pure science explorer does not have. This is the necessity that he produce a useful result or a practical solution of some definite problem, and as early as possible. It should be noted that, in order to be useful, research must have proper organization, adequate financing, and intelligent direction. The mere haphazard doing of research is no insurance of success at it. Essential to success in research is the element of time. "Too frequently", says W. A. Gibbons of the United States Rubber Company, "organizations have been willing to spend money on research, but have not been willing to spend time." There are many reasons why research moves slowly, such as failure to organize it properly, to use good judgment, to pursue the investigation in a concentrated and uninterrupted manner, and to eliminate the delays resulting from discouragement. The one outstanding reason why research takes time is the slowness with which new knowledge can be acquired at best. And enlarging the staff does not always hasten that process.

While one of the biggest problems in research is developing instruments, observation and measurement take considerable time.

Kettering, when once asked whether by doubling his research staff he could not cut the required time in half, said: "Maybe I can give you the best answer to that question by asking you another: Do you think that by putting two hens on a nest, a setting of eggs could be hatched out in less time than three weeks?"

Fringe benefits of research contribute often to its apparent slowness, but they are significant also. A man may not find what he is looking for but he would never find anything unless he is looking for something. It is usually the trained and alert observer who is able to recognize the importance of apparently accidental happenings, and to utilize the suggestions that they give.

Thus the most important contribution of alloy steels to the motor car industry was not their usefulness as materials of fabrication, but rather as cutting tools rendering it possible to machine the thousands of parts rapidly, with high precision and thereby reducing the cost of manufacturing so much that the development of the automotive industry became possible.

The word "research" has different uses. It covers, in general use, all processes whereby an invention is conceived and explored to the point where it can be turned over to production. Furthermore, the derivation of a theory needed for understanding and eliminating difficulties in the operation of machines, processes, manufacturing and leading to further development and sales belongs to the concept of research.

Important activities which are sometimes confused with research are engineering development, inspection and process control. Each of these activities touches, in some way, on research. Probably, the principal cause of so-called research failures has been the confusion of one or more of these functions with research.

Development and engineering are, in some respects, the antitheses of research. They are the brake and control mechanism for the car of progress - without it no business could be safely driven - too much and it never starts.

INITIATION OF RESEARCH

To find the right men who can run, supervise and evaluate research is another of the responsibilities of management. It is not always necessary - particularly not for the smaller companies - to have a full-time director of research but often more economical to employ an outside man or laboratory. The shortage of well-trained engineers and scientists is often a headache that can be overcome in this manner.

Top management must determine the problems to be investigated and how much to spend on them while the research director or consultant has to direct his efforts to determine how to go about them and how to present the facts later.

The selection of the projects is one of the most important stakes management has in research. No well-known technique has been developed and it is not possible to select "a winner" all of the time.

It is safe to say that the actual initiation of a research activity in an existing company is usually the result of the vision of one man, who may be a patent attorney, a service man, the chief engineer, or the president. From sales must come a substantial part of facts which suggest changes in the product or need of new products. This is because sales derives its knowledge from the great sources of dissatisfaction which promote industrial progress: 1) What is wrong with the product? 2) What improvements would the customer like to have? 3) What competitive products are on the market?

When Charles F. Kettering was developing the self-starter for the automobile, one of his great difficulties was to overcome the resistance set up by the expressed opinion of some of the country's outstanding electrical engineers that to crank an automobile engine with a storage battery would be a physical impossibility!

The greatest endurance contest in the world used to be getting a new idea into any factory. These conditions have changed in the past few years but it is well if management understands this and will constitute itself the sales department for the research organization!!

The small company that wants to be successful in research must keep equipment and sales cost low and stocks almost zero; it must be prepared to come out repeatedly with something new. This means that its research must be planned well in advance and must concern itself with a field where a steady output of new or improved products is possible. Very frequently this must be a field of its own devising and it must create not only new products but new needs.

More generally, if a small company wants to utilize research, research must be an intimate part of management that as new products develop the company is flexible enough to change and develop with these new products.

When research has been long established, it is usually well accepted, particularly when the head is technically trained and has advisers who can translate it into production and sales.

RETURNS FROM RESEARCH

All research work should reflect itself in the products which the company makes and sells. A research project should do one or more of the following things:

1) Improve a product
2) Produce a new product
3) Reduce the cost of manufacturing the product
4) Reduce operating cost to customer (increase efficiency)
5) Produce new business and good will
6) Provide technical data for other projects
7) Make older products obsolete

In large companies, the research department is usually credited for work done for other divisions of the company. It requires only an adequate bookkeeping system. Another source of income for the research department is outside royalties. It has become more and more of a practice to license other companies and to credit the royalties to the research. It is, however, difficult to allocate credit for new or improved products properly.

The publicity value of research can likewise not be translated into dollars and cents, but a properly promoted project is often worth a huge fortune to the company.

CASE HISTORIES

A few case histories of research work from my own practice are presented to illustrate the development in research in the field of engineering I have been working in for several decades, that is production methods, tool engineering, and machine tools. It includes also such research as the mathematics involved in grinding optical lenses and similar work which, however, cannot be discussed here.

Tool engineering research covers not only the scientific relationships of cutting speed, feed, work material, cutting force, tool geometry and many other quantities, but also the more recent type of research in this field such as deformation of machines, stresses, vibration, thermal expansion, etc. affecting accuracy and production. New and rapid developments are in the making since trial and error methods could be eliminated and their inefficiency and cost displaced by the results of the systematic research. They are worth the while of any management.

MACHINE TOOL DEVELOPMENT

About twenty-five years ago in a book which I had published on the laws of metal cutting derived from research carried out in the U. S. A., England, and Germany, it was said:

"The development in machine tools will follow the same trend as in other branches of engineering (such as aircraft), namely high speeds, low forces, and increased rigidity of the machines (which is <u>not</u> identical with increased weight)! In this way, deflections can be reduced, production increased and surface finish improved.

More research should be devoted to vibration problems in machine tools, because the high speeds to be expected will come into resonance with the natural frequencies of the structural design of machine tools."

The trend toward high cutting speeds has been increased ever since, due to the advent of sintered carbides which I have first observed at the Krupp Works in Germany. This company bought also a patent (long since expired) on an invention by C. Salamon, who made tests at cutting speeds as high as 55,000 feet per minute on non-ferrous metals.

In the patent of 1931, it was claimed:

"The method is characterized by the selection of cutting speeds in excess of about 2,000 feet to 2,500 feet per minute and by avoiding cutting speeds within the limits v_a and v_b a region where the work material is not machinable and which is critical for the tool material in cases where the cutting motion is executed by the tool."

This principle is illustrated in Figure 2, where the dotted curve for steel shows that we have not yet reached conclusive evidence in the machining of steel at high velocities.

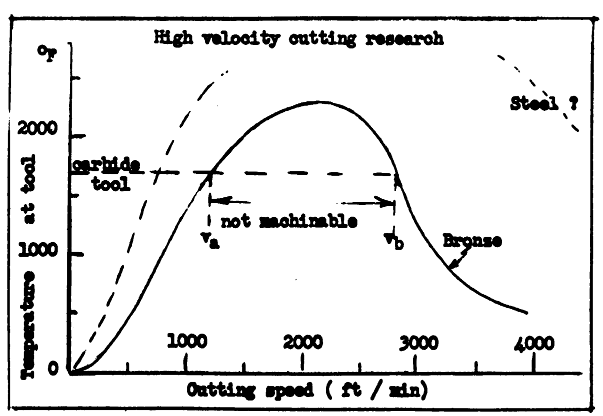


Figure 2

In a recent issue of "Iron Age", a report by the editor indicated that super high cutting speeds are employed to an increasing extent. In this connection an article by Tangemann in "American Machinist", 'Are We Slowpokes on Machining?', will also be of interest because more details on super high speed cutting, which I furnished, will be found there.

Some time ago, I found a note in a paper published in Switzerland reporting on tests carried out in the Russian Machine Tool Research Department in Moscow, indicating that the Russians have - of course - first done high speed cutting.

"Extensive tests, employing super high milling speeds of 20,000 to 28,000 feet per minute were successfully carried out - for the first time in the world in 1939 - at the Enims Institute in Moscow, proving that the milling cutter does not wear at these speeds when machining aluminum and bronze".

Up to now, we have ample practical evidence that the tools perform differently at very high speeds. However, any basis research into the reasons why and under what conditions these phenomena occur has, to my knowledge, not been carried out anywhere.

Here is a challenge to management! We ought to know what is happening at the cutting edge at these high speeds in order to be able to control and utilize this process instead of trying the "hit and miss" way.

RIGIDITY AND DEFLECTION OF MACHINE TOOLS

The rigidity and thermal expansion has a marked effect on tool life, working accuracy and maintenance of machine tools but relatively little was known about the underlying principles until a few years ago.

It is not necessarily the heavy chatter that causes destruction, but often light vibration in a machining operation, which can neither be seen nor heard.

A few examples taken from many tests should be sufficient here to illustrate these conditions. The tests were run on different types of machine tools, but the discussion shall be limited to milling machines. In all cases, temperature and thermal expansion were measured permitting the development of a relationship between them.

The thermal expansion between spindle and table of a vertical miller takes place in three major directors, as shown in Figure 3. The heat in the column causes an upward motion of the spindle, while the heat in the spindle carrier causes a downward motion.

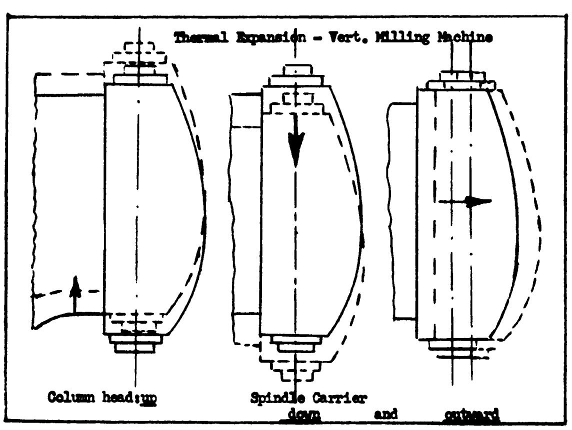


Figure 3

An erratic rise and fall of the spindle can thus be observed depending upon which of the two motions is the large one at any given instant.

In addition to these two movements, the spindle moves also toward the operator. Typical data are shown in Figure 4. In the upper portion, the temperature rise is shown, while in the lower portion the expansion is plotted that took place between table and spindle causing inaccuracy in milling operations. (See curves marked "before")

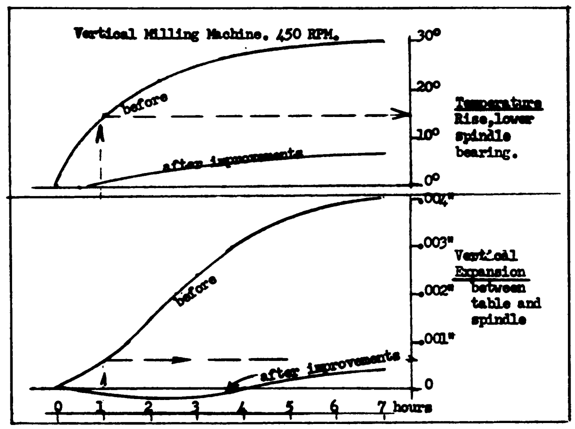


Figure 4

The improvements made (see curves marked "after") include: changing the type of bearings, readjusting them, replacing oil for grease, reducing the oil supply and similar factors.

Results were very satisfactory, reducing the vertical expansion by about 75% to 85%. We found, as a rule, that the temperature increase in a machine tool should not exceed 1/100° F. per RPM within the first hour of operation.

In the case of a boring mill trouble was experienced when trying to reduce thermal expansion. When the machine was cold, the accuracy of the produced holes was better than when the machine was warm. However, with the cold machine more trouble was experienced with vibration. The main reason was traced to the front bearing.

Investigation disclosed that during cold operation, insufficient lubrication permitted metal-to-metal contact over nearly 88% of the spindle bearing surface resulting in excessive vibration. When the machine was warm, metal-to-metal bearing contact was virtually eliminated and the associated vibration greatly reduced but accuracy was impaired because of spindle movement caused by thermal expansion. In order to remedy this condition, the lubrication system was modified.

VIBRATION

Vibration is often encountered in metal cutting operations which may sometimes become very violent. In shop language the term "chatter" is often used for vibrations leaving "chatter marks" on the workpiece or those which produce noise. In many cases, however, as indicated before - vibration is hardly perceptible, but is nevertheless often the cause for poor tool life, damage to machine parts, low production due to down time, poor surface finish, and so on.

Scientific literature on vibration in machine tools is almost non-existent. Although the principles of vibration are the same as in other fields of engineering, such as aircraft engines or automobiles, vibrations encountered in machine tools are often self-excited as compared with those encountered in other lines of engineering, namely forced vibrations.

It is necessary to differentiate between lateral vibration - such as the vibration of a string in a violin - and torsional vibration, which is the periodic twisting of a shaft about its axis of rotation.

Lateral vibrations in machine tools can be caused by a great number of reasons, such as unbalance in rotating parts (which is among the more simple cases of vibration), faulty bearings, excessive overhang of the tool, jerky movements of tables in reciprocating machines, and so on. The design of beds, knees, overarms, gear-boxes, headstocks, tailstocks, machine columns, tables, and so on, may also be a cause for vibration. We are still accustomed to consider the housings merely as covers for power transmitting elements, although they have to withstand forces, and are subjected to stress variation.

The most rapid and least costly method of dealing with detrimental vibrations is to study their nature and not to attempt expensive changes in the design before an analysis has been made. Such study should start with observation and measuring vibration and include a mathematical analysis of changes and their possible results.

Resonance with machine parts must be studied and many other items considered which can only be touched upon here. Vibration study in machine tools is a rather recent development, although an entire book could already be written on this subject.

Figure 5 illustrates the case of self-excited vibration of a cutting tool and of generating chatter marks on the work. The full lines indicate the neutral position of the tool. The dotted lines at "A" show the tool bent upward, while it is bent down in the case of position "B". The wavy path represents the chatter mark produced on the workpiece.

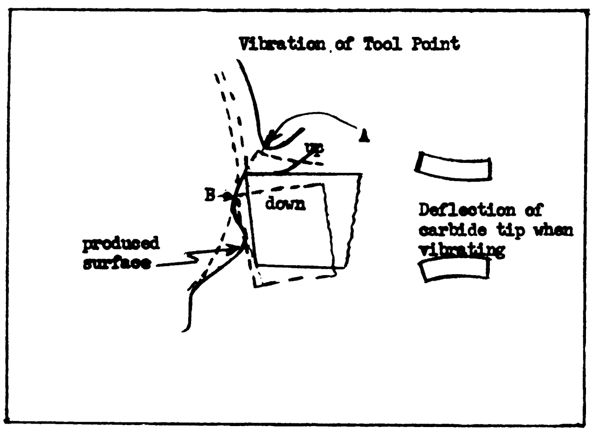


Figure 5

When the tool is in midposition while moving downwards, it is taken along by the work and the speed difference between work and tool is reduced. When the tool is again in mid-position, but moving upward, the speed difference will be increased. Hence in both directors, in the midway position, the friction force is high and energy is fed into the system which will therefore vibrate more and more. This is a criterion of a self-excited vibration.

Self-excited vibrations are often the cause for cracking of carbide tips, particularly at speeds below about 300 feet per minute. For this reason, carbide tools should not be used at lower speeds.

To obtain better data on the effect of vibration in machine tools, tests were conducted at R. K. LeBlond Machine Tool Company, Cincinnati. Vibratory strains were measured at various places on heavy-duty engine lathes having both conventional cast-iron and newly designed welded-steel beds developed by us on the basis of earlier cutting-force investigations. Numerous Baldwin SR-4 strain gages were attached to the carriage and bed. Twelve simultaneous strain readings were recorded by electronic equipment, including oscilographs and amplifiers.

In cutting tests, frequency and amplitude of vibration cannot be controlled. Therefore, additional vibration tests were run, in which controllable frequencies and amplitudes were applied to the machines.

Machines were loaded to 100% of the capacity in terms of cutting force, and the carriage was placed midway between centers. Vibratory strains measured near the bridge of the carriage were found to be associated with noticeable noise and chatter marks whenever the strain **reached a value of 40 microinches per inch** (0.000040 in. per in.). Therefore, we adopt this value as the arbitrary standard for comparing vibratory features of the same carriage mounted on differently designed beds.

The resonant range of vibration at a strain of this magnitude was found to be substantially less when the carriage was mounted on the special steel bed than when it was mounted on the standard cast-iron bed. Vibration range at "limit" intensity for the steel bed lay between frequencies of 90 and 120 cycles per sec. compared to the previous range of 60 to 180 cycles per sec.

Very likely, vibration that is hardly perceptible must be eliminated in the future in equipment, particularly for machining the new materials - titanium and high-temperature alloys.

INFRINGEMENT OF PATENTS AND RESEARCH

An item of vital importance to management is patent protection and infringements. Both require very often scientific research in order to protect patents or to prevent others from claiming too much. Here the research man cooperates often with the patent attorney.

As an example for the way in which research helps industry, a case may be presented dealing with a patent dispute between two tool manufacturers.

Company A had a patent on a tapping tool where the teeth were placed in such a manner (Figure 6) that they cut at first at the left side and with the following range of teeth at the right side, while a third range provided cutting in the middle of the thread being cut.

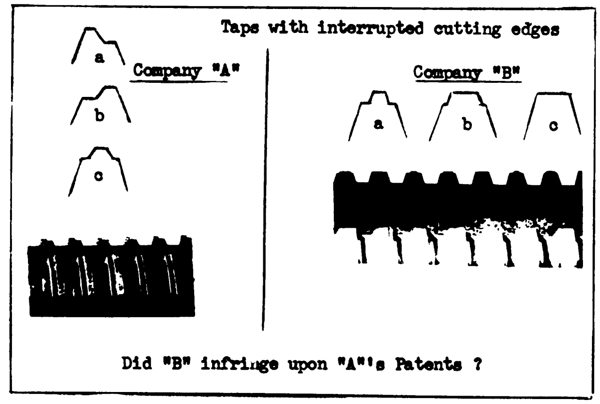


Figure 6

Company A claimed that Company B was using the idea of its patent. The matter was complicated by the fact that several patents were already known, which also made use of the idea of cutting the groove by means of "interrupted edges". Company B therefore claimed that it was only using that idea, thus not infringing on the rights of Company A.

It is naturally not possible to give here all the details of the opinion, which comprises more than 60 pages, but only to give some of the conclusions and the manner of obtaining them.

The main point was whether the cutting was done in such a manner that the cutting pressure, the wear of the teeth, the heat dissipation, etc., were equal on the teeth following one another on both tools or not.

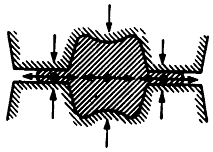
The investigation included also a study of the cutting capacity, comparison of the older tapping tools with the two tools in question, which proved that the "progress made by the patent in question" was considerably above all that was known before, and that this same progress was obtained by the tool of Company B by means of the same use of "interrupted cutting edges". Without scientific investigation the court would not have been able to decide whether Company B used only that which was known or that which was invented by Company A. Thus research helps industry.

SCHLEGEL PROCESS

One example may finally be discussed here on the recent progress in research carried out in Germany in the field of manufacturing methods. They succeeded for the first time in developing a method for forging cast iron blanks into finished articles, and thereby increasing the tensile strength threefold. The accuracy improved so much that machining operations can often be eliminated or substantially reduced.

Figure 7 represents - in a simplified way - the stresses set up in the workpiece in the case of a forging operation. Research carried out by Schlegel at the Aachen Institute of Technology indicated that stresses in the radial flash were the cause for cracking of cast iron when trying to press or forge it. He came to the conclusion that it ought to be possible to avoid cracking cast iron in the forging die if the radial flash could be eliminated, and he succeeded in developing a patented process which now is known by his name "Schlegel Process".

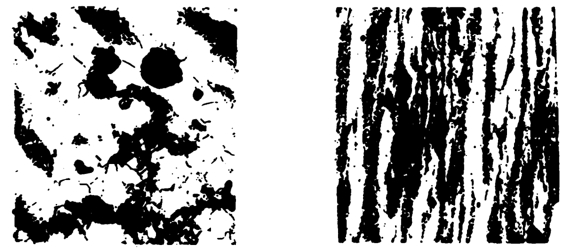
Forging of cast iron (Schlegel Process)



Research result: Eliminate the radial flash ... and forging of cast iron will be possible.

Figure 7

Figure 8 shows the microstructure of the pre-cast blank having a tensile strength of 50,000 per square inch (nodular iron) before forging and also the microstructure of the forged cast iron with the fibres arranged as in steel forgings.



Microstructure

Before (Precast blank)	After (Pressed Casting)
Tensile: 50 000 psi	145 000 psi

Figure 8

The tensile strength of the forged cast iron parts increased to 145,000 per square inch, exceeding that of a great number of steels. In other cases, cast iron parts were forged to 480 Brinell Hardness!!

An example of a mass produced hub is shown in Figure 9. In the upper row, the precast blank will be seen. It consists substantially of a cast iron ring and can thus easily be mass produced at low cost.

In the lower row, on the left hand side, the top view is shown of the forged part as it comes from the press with numerous diameters which need no further machining. A side view of the hub is shown in the center with the longitudinal flash which prevents the cracking of the cast iron. From the microstructure taken at a radius it will be seen that the fibers are continuous and thus provide great strength, while they would be cut in the case of a boring operation resulting in stress concentration.

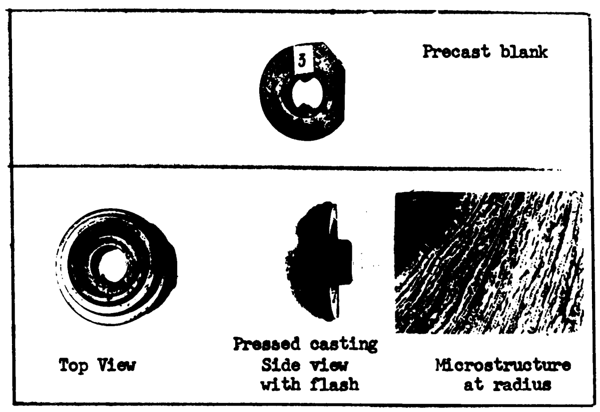


Figure 9

The temperatures of the Schlegel Process do not exceed 1500° F., its success depends on the observation of what is known as the "volumetric law" stating that a body when forged must not change its volume, but only its shape. The volume of the blank must therefore be carefully determined according to the volume of the forged part. Other details which are the result of extensive research must likewise be taken into consideration, such as the design of the die and the speed of the press. The forging operation requires only a single stroke and it is thus inexpensive and does not require great investments.

The Schlegel process can also be used for producing cast iron parts with close tolerances (0.004") comparable to those of metal powder parts. It will supplement the sinter processes where the less expensive cast iron is indicated.

Forged cast iron parts made abroad include piston rings, radiator parts, gears, valve bodies and numerous others.

CONCLUSION

Concluding, we may complete the cycle of thought by returning to the financial aspects involved in research. I would say that about 2% of gross sales is an appropriate amount to put into research in the field of mechanical engineering.

Management disregarding research might have a dead company in about five years hence. Someone once said that it is management's job to keep the customers reasonably dissatisfied with what they have and to see to it that research is able to present them with something better which they will want to have, as witnessed by our examples on vibration studies, rigid machine tools, high tool life, low production cost, new processes such as high velocity cutting, hot machining and forging of cast iron.

You may have heard or read the President's "Message on the State of the Union" three weeks ago where he made the following statement:

"For the business that wants to expand or modernize its plant, we propose liberalized tax treatment ... of research and development expenses ... "

From the standpoint of long term growth and research this policy is among the most promising reforms proposed by President Eisenhower and it will be up to management to utilize the technical changes in the corporation tax laws for the benefit of American industry.

MINIMIZING MANUFACTURING COSTS THROUGH EFFECTIVE DESIGN

George W. Papen
Department Manager
Production Engineering
Lockheed Aircraft Corporation
Burbank, California

The purpose of the Sixth Annual Industrial Engineering Institute is "To present fundamentals and recent practical applications in the field of industrial engineering and management. Special attention will be devoted to the problems of small business. New techniques and areas of application for industrial engineering will be featured."

Lockheed Aircraft Corporation and certainly the aircraft industry can hardly be classified as small business. However, from the standpoint of quantity of units produced, our problems are basically those of an overgrown job shop, with low production in terms of total units, rapid turnover of product design and tooling. Also, being a relatively new large industry, we are faced daily with the necessity for putting many industrial engineering and management principles into practice. As for new techniques and areas of application for these principles, we would like to recommend for your consideration that: The Design Engineer through his drawings and specifications, establishes the minimum cost of the product.(1) The degree of factory efficiency, tooling ingenuity and purchasing resourcefulness will determine how closely the factory approaches this minimum cost, but industrial engineering and management through the most efficient of factory methods, ingenious tooling and resourceful purchasing cannot reduce the cost of the product below the minimum established by the Design Engineer.

We recommend in view of the above which we most sincerely believe that you as students, devotees, and practitioners of the science of industrial engineering and management accept the design function as a vital-essential part of the industrial situation, not merely as a necessary evil.

An article to be manufactured must be capable of being produced, and an article to be capable of being produced must be so designed. Design Producibility then is the inherent attribute of a design which renders it capable of efficient production, the rate of which may be rapidly accelerated and maintained.

1. The designer's choice of materials, methods, processes, standard and commercial parts and articles of equipment and furnishings must insure efficient production.
2. Design producibility is revealed in the physical end results portrayed in engineering drawings of details, assemblies and installations.

We believe it is the designer's responsibility to design a product which can be sold competitively. To meet this requirement the product must be:

1. Functionally correct. It must meet whatever performance requirements have been established.
2. It must be of a quality level compatible with the market in which it is to be sold.
3. It must be capable of being produced at a cost which will permit a satisfactory profit.

Design engineering therefore encompasses more than the purely technical functional considerations. It extends into certain phases of every operation of a modern manufacturing organization; calling for close coordination and cooperation with all departments. Knowledge of current problems and activities, of purchasing, material control, tooling, production, inspection, sales and service is essential to the development of efficient design.

There is little room for argument relative to the designer's responsibility for function, nor can there be with that part of the product quality dealing with its function. The designer's responsibility for cost is the one area where there appears to exist a basic lack of realization of the designer's importance in establishing the cost of the product.

It is perhaps opportune to illustrate with some simple examples ways in which the designer effects the manufacturing cost. To bring a greater realization of this effect, to point out the importance of his every activity and to show that all parts, sections, areas or other criteria of his designs effect the manufacturing cost, let us pursue the effect of a design on the various elements which go to make up a breakdown of the costs of a commercial transport. Figure 1 illustrates the distribution of the costs of manufacturing a commercial transport.

The Design Engineer effects each of these cost segments to some extent. By his design he can expand or contract the total area of the chart or can change the ratio of one division to another. An uneconomical design which expands the total area will result in higher sales cost or lower margin of profit or both. A design which reduces the area will result in higher margin of profit or reduced sales price or both.

The shaded portion of the chart represents that portion of the costs which is under direct control of the Design Engineer and is effected by the designs he releases. These areas were arrived at by a study of detail cost estimates made over a period of several years during

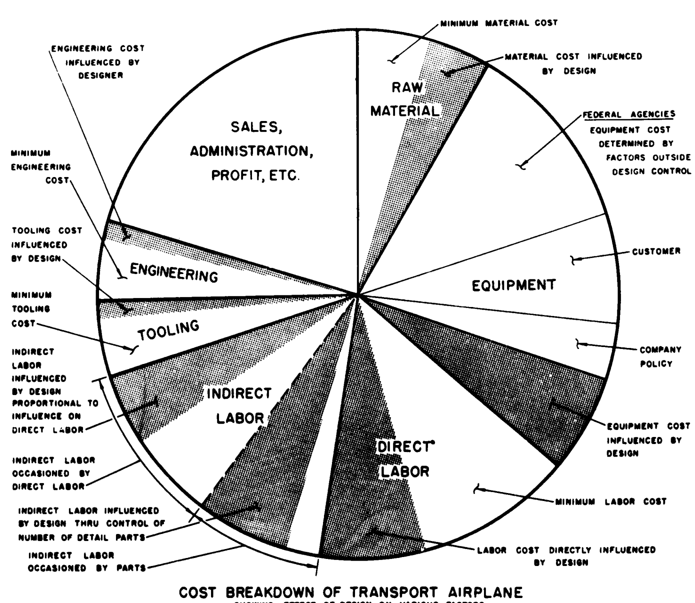


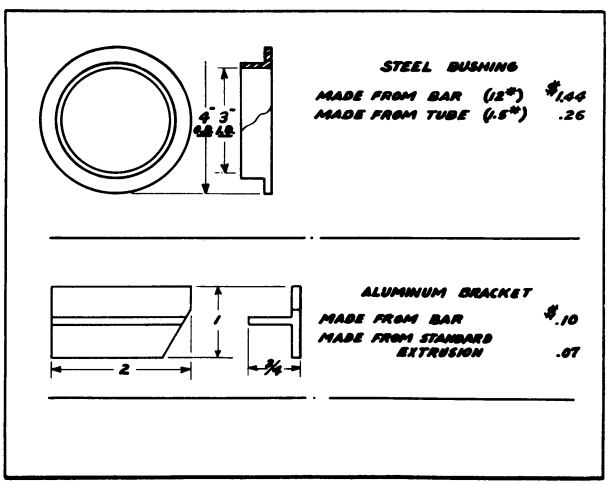
Figure 1

which many hundreds of designs were analyzed. By taking the difference in cost between two or more designs which were functionally acceptable, the difference in cost between the least and most expensive indicates the effect the Design Engineer had in determining the cost of the product. An examination of some of the individual segments will further demonstrate the point.

Raw Material: This part of the airplane cost is made up of sheet, bar, tube, forgings, castings, wire, fabric, wood, etc. For any given airplane, there is a minimum amount of material required to build it, to meet basic functional, structural, and performance requirements. The cost of this minimum amount of material can be said to be outside the control of the Design Engineer. However, whenever drawings call for material in excess of this minimum, for instance closer tolerances or special sizes, or to meet higher than necessary mechanical properties or chemical analysis requirements, then the cost exceeds the minimum and the extra is within the control of the Design Engineer. It is to be expected that in no case will the rockbottom minimum cost be met, but care is necessary to prevent the excesses from becoming unreasonably large.

The Design Engineer's effective control of material costs is tremendous. An example of this is shown in Figure 2. The choice of bar would make the part cost 5.5 times as much as the same part made from tube. A choice between extrusions at $0.07 and bar at $0.10 makes it possible to release a design costing 1.4 times more expensive than the minimum material cost.

Each of the two examples shown is typical of hundreds of similar parts and assemblies where the Design Engineer exercises control over the choice of material and thus affects the cost.



Effect of Design Choice on Material Cost
Figure 2

Direct Labor: Direct Labor consists of the manpower dollars spent in the actual manufacture of the design by the sheet metal worker, the welder, lathe operator, riveter, and the myriad of other skilled workmen required to build an airplane. The designer may reduce direct labor at the expense of material or tooling or may increase direct labor by designs which do not permit the use of economical tooling or factory methods. In any event a fine balance must be struck between labor, tooling, and material costs based on total quantity and schedule to achieve the most economical part. This is a responsibility of the designer.

Our industry is good at getting sharp downward slopes on our progress curves -- at making a rapid reduction in the number of manhours needed to product successive units. Designs which introduce unfamiliar materials or methods will add manhours to the first units produced because of the learning factor; as compared to tried and true methods, these designs will raise the starting point of the curves.[2]

Rapid increases in the performance demanded of airplanes make it easy to go overboard when introducing innovations. So do improvements in production methods. But even when the innovation will lead eventually to reduced production manhours, our budget may not be able to stand the effect of the manhour increase on the first units.

We have to maintain competitive airplane performance on the one hand and competitive production costs on the other. This means we must know how each proposed innovation will effect the projected manhour progress curve and then decide whether the improvement is worth it.

Figure 3 shows two examples of how labor cost is affected by design. It should be noted here that the examples shown are based on production quantities of only a few airplanes -- say 50 to 100 total.

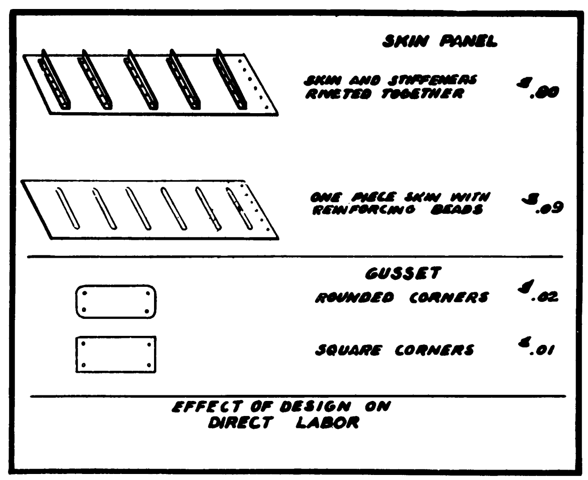


Figure 3

Indirect Labor: Indirect labor has been separated into two parts, (Figure 1) that part which is direct labor overhead, such as supervision, maintenance personnel service, etc., and that part of manufacturing overhead such as procurement, planning, scheduling, dispatching, order control, stocking, etc. The first division arises from the existence of the labor force, and is affected by design in the same manner as direct labor is affected. The second division arises from the existence of parts and details, and the design effect on this part of indirect labor is roughly proportionate to the number of parts required to build the airplane.

The example, Figure 4, shows a typical control surface assembly. The indirect cost for each design is based on those functions necessary to process parts through the paperwork system, and includes such items as planning, tool ordering, material procurement, fabrication and assembly order writing, stocking of material and parts, dispatching of material, tools and parts, order control, accounting, transportation, inspection, etc.

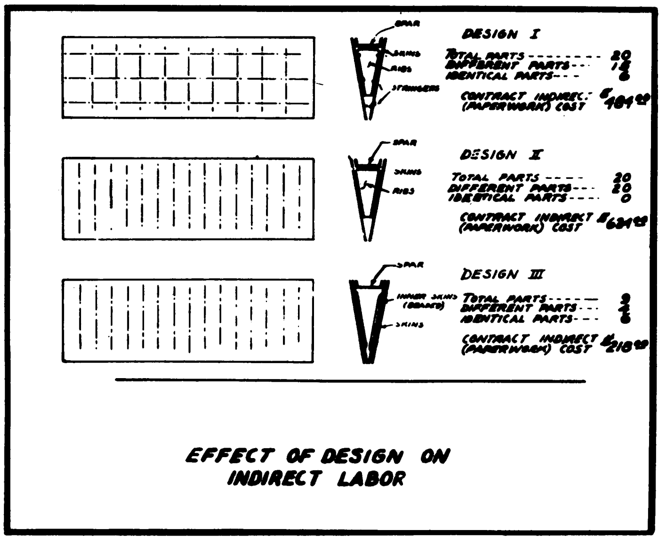


Figure 4

Tooling: As much as 30 per cent of the tooling cost of a typical transport airplane, as affected by design, is within the control of the designer. (Figure 1) Care in selecting structural breakdown, type of joints and design of details are requirements for good tooling, and are all directly tied in with the design of the parts and assemblies.

Uneconomical breakdown and joint or structural design may cost thousands of needless tooling dollars. Uneconomical design of one detail part or small assembly may not run into thousands of dollars, but uneconomical design of thousands of details and small assemblies will run into thousands of needless tooling dollars.

Figure 5 is a typical example for a part that was required for 25 airplanes.

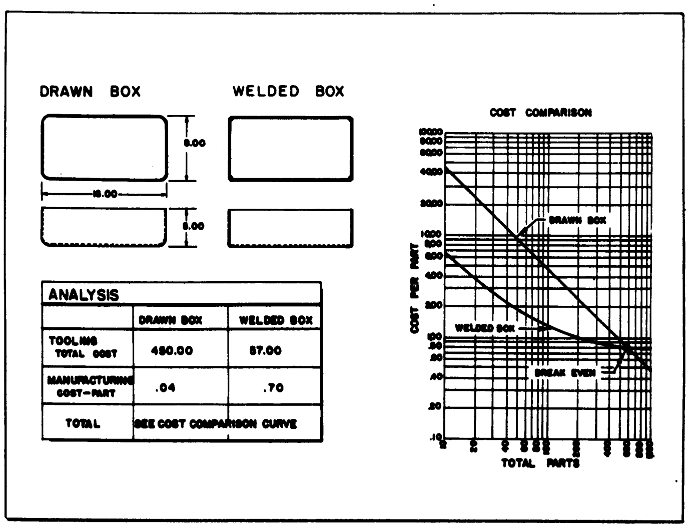


Figure 5
Effect of Design Choice on Tooling,
Also Shows Importance of Designer
Having Production Quantity Data

A more recent example of the range in which a design group's decisions may affect manufacturing costs is illustrated in Figure 6. As background information before studying this chart, we should mention that in the Engineering Branch at Lockheed we have a cost analysis group which is used primarily in making comparative cost analyses of different design proposals. These analyses do not represent the total cost of each design, but rather the difference in cost. In many instances, as many as five or six proposals for meeting the same design conditions may be analyzed. This cost data is then used by the responsible design personnel in arriving at a decision as to which design represents the optimum balance of all the design requirements.

All design studies which are still open for decision are plotted to indicate the total increase in cost if the most expensive design were chosen and another line representing the total decrease in cost if all of the least expensive proposals were selected. The spread then between the possible high value and the possible low value is an indication at any time of the magnitude of the effect on manufacturing costs of various design studies awaiting decision. Each month we also plot any decisions which had been made during that month and a comparison of this line with the previous month's is an indication of the trend of the design decisions of the department.

For the benefit of those who like to think in terms of units, we plot this information by airplane unit per model; and for those who like to think in large figures, we also plot the effect of design on manufacturing cost on a contract basis. Figure 6 illustrates the two charts through the month of October for the same model and shows that at the end of October we had design decisions pending which might increase the cost of the airplane by about $400, or if all of the least costly proposals were picked decrease the cost about $3000. The right-hand illustration shows the same data plotted on a contract basis. For this particular model as of the end of October, design decisions oould increase the manufacturing costs by contract to approximately $95, 000 or decrease them by approximately $500, 000.

From an observation of the trend line on both charts, it is evident that neither the most expensive nor least expensive proposals are being chosen and that there has been over the past year a preponderance toward choosing lower cost designs, which is indicated by the slope of the trend line. It must be remembered that this information

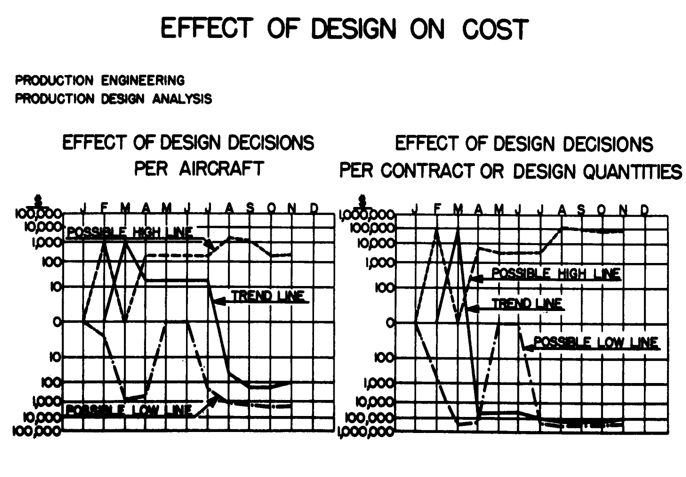


Figure 6

represents only those design studies on which a comparative cost analysis has been made. Also that each of the studies contains only designs which are acceptable and merely represent different compromises.

The design of a product establishes its minimum cost. Yet, all too often engineering has to develop designs without knowledge of the quoted price. As a result, production managers are often faced with planning production of a product within budgeted costs when they have no assurance that the design permits it.[2]

We are concerned about manufacturing cost when we design an airplane. We are constantly comparing alternate designs for cost and weighing the cost factors against weight and performance considerations. Where relative costs of different designs are not obvious, we make careful analyses to find out. But we still don't come up with total cost of a part or assembly -- all we know is which design is cheaper and how much.

It is, not in our opinion, advisable to expect to pick up design errors of either a functional or production nature after release. The cost in time, that is scheduled time, and dollars can be tremendous. Engineering is in a position where errors, regardless of type, can do great damage. After all, an engineering release starts the wheels turning and may activate dozens or hundreds of people on expensive operations, such as tool design, tool making, perhaps even parts manufacturing; for instance, a drawing released from engineering is followed then by planning and tooling, and finally by fabrication. If this complete sequence has been accomplished and then a new design or major correction is released, the entire sequence must be repeated. Since there would be some retention of learning, the second release might not double the cost in scheduled time or dollars, but would probably run in the neighborhood of 190 percent for cost and 180 percent for time.

On an operation involving a large quantity of parts to be made over a period of time, changes introduced into the manufacturing cycle become progressively more serious as more units are built. For instance, if the company were manufacturing a given model on an 80 percent learning curve and introduced at the tenth ship a 10 percent change in work, the tenth airplane would cost approximately 20 percent more in manhours than the ninth airplane. If the ten percent change were introduced at the 100th ship, the 100th airplane would cost 50 percent more in hours per unit than the 99th. If the change were made at the 1000th airplane, it would cost 110 percent greater than the 999th (Figure 7). With this condition, it is readily seen that the introduction of changes, even though on the surface the new

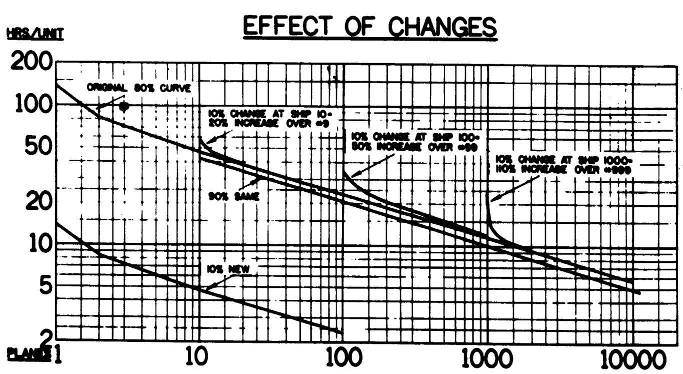


Figure 7

design is less expensive than the old, we do not get immediate results. It may be necessary to build a considerable number of aircraft before reaching even the same hours in production as the old design and, of course, a greatly increased number before the so-called "break even" point could be reached.

Changes in product design during production are probably inevitable. Maintaining one's competitive position necessitates the product always representing the latest desirable features. Changes caused by errors in original engineering are inevitable. Naturally, every effort must be made to keep changes of any type to a minimum, and the entire organization must be versatile, flexible enough to absorb the necessary changes.

We recently revised a major component of one of our models after 623 units had been produced. The first unit after the change required an increase of 6200 manhours. It was not until 170 units of a new configuration had been built that the manhours required equaled those of the old unit, and it was not until 630 units of the new design had been built that the cost of the change in manhours had been absorbed. From this point on, the new unit began to make a savings for the company.

This typifies the hazards lurking in changes made after one is in production. While it can be interpreted as a reason for not making changes, I believe it is better interpreted as showing the necessity for the engineering people to have the proper information relative to rates and quantities, and sufficient time to design the most economical unit in the first place.

We have attempted, up to this point, to establish the fact that design has a tremendous influence on manufacturing costs and that manufacturing costs must be considered one of the basis design criteria. Now let's discuss what engineering needs from management, both in information and organization, to meet this responsibility.

The important factors which comprise the ground rules which the Design Engineer must be familiar with and which management must supply are:

1. Function of the article.
2. Quality.
3. Quantity.
4. The resources of skill and experience that can be applied to the job.
5. Facilities.
6. Cost.

1. Function: Purpose for which the article is being manufactured establishes its functional requirements. The designer's first responsibility is to satisfy the functional requirements of the article.

2. Quality: Quality is an item that must be included in all discussions of design and manufacture for sale. Quality standards are indispensibly the responsibility of all parts of the organization.

3. Quantity and Rate: The number of articles to be produced and at what rate is generally based on market research, analysis of competitive product sales. Quantity and rate have a greater effect on the various operations that go to make up manufacturing costs than any other single item, and are therefore a fundamental consideration in the design.

4. Resources of Skill and Experience: Manufacturing plants are located in definite areas for a great variety of reasons. Each individual area has a certain pool of manpower which through years and years of training is capable of certain skills. The skills of this available pool must be considered in the design.

5. Facilities: It takes foresight to order modern production equipment with long span procurement time when there is no immediate need for it. On the other hand, Engineering can't base designs on equipment which won't be available when the design hits production. Our experience shows that this "chicken and egg" situation can be avoided by collaboration between manufacturing and engineering. Engineering keeps manufacturing informed of design trends which will affect manufacturing facilities, permitting purchase of equipment so it will be available when needed. Fears that the machines would not be fully utilized have proved groundless. Equipment and machinery purchased under this policy have been in full use almost since the day they were installed. And we've been able to base our designs on the most advanced manufacturing methods.

If design never called for greater capacity and ability than present production equipment can deliver, there would be no advancement of a material kind in the world. A manufacturing organization must maintain a progressive attitude toward the introduction of new and more efficient methods and techniques, the designers of the organization must be sufficiently cognizant of the best practices throughout the industry to be able to consider all of them in arriving at a solution which reflects maximum producibility.

6. Cost: The management must determine what the manufacturing cost of the article is to be in order to meet the selling price, which in turn has been established on a basis of market research. This manufacturing cost is the foundation for all design analyses. Why is this information generally hidden from the designer? It is very necessary, in fact a fundamental criteria to be considered in the design. All too often the designer working in the dark will come up with a design which cannot possibly be produced for cost sufficiently low enough to sell at a profit in the expected market. The product is dropped, or a painful period of redesign to reduce costs is required. This adds to the total costs and delays the placing of the article in the market.

With this information engineering must then have available a group of specialists in various fields of production. To guarantee that the basic production design principles are followed, Lockheed uses a specialized group of production design engineers on each project.(3) It is this group's responsibility in working with the designers to obtain the most economical design to fit function, strength, and airworthiness. As well as being competent designers, these men are also required to be competent production engineers and to know equipment and procurement limitations so that clean design within the limitations of available facilities will be realized. A further responsibility is the coordination of new material, process and equipment limitations with the manufacturing organization. Obviously the functions outlined must be carried by the designer himself when an engineering organization is relatively small. It is not practical to rely on the manufacturing organization alone to supply the type of assistance needed above.

The manufacturing organization seldom has a single group whose sole responsibility is least cost of manufacturing. Personnel from the various segments of manufacturing are primarily interested in reducing costs only in their own areas. It is therefore our belief that unless your specific organization has a single group covering cost that the engineering department should and must for its own protection establish a group to satisfy this requirement. It is, however, most efficiently handled in a large engineering organization by a special group of production design engineers. A quick method of obtaining cost analyses of comparative designs -- in other words, a cost estimating group within engineering or available at all times to supply the cost data in making design decisions. With the above two tools, specialists in overall manufacturing requirements, that is, the production design engineers and cost estimators, we should add a third - the Cost Target System.

The cost of the product which management has set for the goal in order to sell the product in the most favorable market must be made known to the engineers, and the engineers must have a method for measuring during the design stages the relation of manufacturing costs as affected by the design to the management established target or budget. We'll have to keep track of cost as the designs unfolds to make sure we meet the "target" cost. I'm not sure how far we should break down the target cost - whether we can establish it for major components or whether it should cover detail components - but I am sure that this kind of control is necessary.

We have been developing and experimenting with a cost target system for several years now along the following lines:

1. Breaking the total labor, material and tooling costs for a given project into the design elements such as wing, landing gear, empennage, etc., and assigning to each the amount of the total manufacturing cost which experience on previous models and judgment relative to the new model dictates. This establishes the cost target or cost criteria in sufficiently small increments that the group engineers would be able to utilize it in development of design.

2. Estimate the manufacturing cost as affected by the items included in the breakdown (material, equipment, labor, and tools) as the design progresses and supply such data to the designers at frequent intervals, thus indicating the trend of the design. With this information the designer is in a position to know whether the design is going to cost more or less than it should, relative to the target manufacturing cost. A summary of this information on a product basis would be available at the same intervals to management.

3. Follow-up production as a means of improving estimating techniques and assuring engineering that manufacturing is making optimum use of design features to meet manufacturing cost budget.

Designing to a target cost will give management the tool it needs to control costs in the design stage.

Cost control by a target system during design is not new and is well established in many industries. A thorough knowledge of predicted and actual cost are basic requirements in any profit motivated business. It is probably the most powerful tool management can have to assure an ultimate profit on its products. Needless to say, it is not enough that engineering do its job of assuring that the design represents the minimum in cost. After the minimum possible cost is established by engineering, it is up to manufacturing to achieve it. Manufacturing needs the detailed cost breakdown in order to have a target to shoot at. If at any stage in the manufacture of a part the cost estimate is exceeded, manufacturing management then knows where to expend effort to get costs back in line. The information should be put in a form directly usable by and coordinated with manufacturing in order to be of value outside of engineering.

The cost target system makes it possible at all times:

1. To know if a design can be built within it contract estimate. This is the first step in assuring a profit.
2. To determine areas that will yield the greatest reductions in costs within the limitations of contractual quantities and schedules. This work can serve as a strong guide in fixing production design trends.

To summarize this discussion, we have stated the proposition that the design engineer establishes the minimum cost of the product, and have presented data in its support. In addition, we have presented a program for making it possible for design engineering to carry this responsibility and assure management that the manufacturing cost of the product as affected by the design is within the limits of the manufacturing budget prior to release of the design.

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SELECTION OF THE MOST ECONOMICAL METHOD FOR PRODUCING PARTS ON PUNCH PRESS TOOLS

Otto McIntyre
Methods Engineer
Schlage Lock Company
San Francisco, California

I have been asked by the Industrial Engineering Institute to talk on the most economical method for producing parts on punch press tools. From my observation, it is impractical, or I would say, almost impossible to establish a hard fast rule for tooling a particular part. A great deal depends on the type of tooling required. I have been connected with punch press tooling in various plants in the area for some thirty odd years, fifteen of which are with the Schlage Lock Company in San Francisco, and find that it is almost impossible to establish a hard fast rule for tooling of the various parts in punch press tools since each item presents its own individual problems. Therefore, one must analyze the respective part carefully before proceeding with tooling method.

Schlage Lock Company has a wide variety of press working tools as well as automatic screw machine, broaching, swedging and impact extruding equipment, and a number of automatic drilling and milling machines. This all offers wonderful opportunity for the application of engineering skill, and since the production of lock parts is quite high it also affords excellent opportunities for multiple operation tools.

In first approaching a given problem of tooling selection, the technical design considerations must be clearly related to the economic aspects of the situation. First we must know the quantity required. Production estimates must be made or anticipated by the Sales Department. This will establish the type of tools that should be made for that particular part. When this is established, we should know, at this time, the tooling that would be required to produce the parts at a cost to suit the Sales Department or the cost of the item being tooled. This would determine the type of tool which should be made. Once this has been established, we can design the tool to suit. Should the part be of a complicated nature, we would determine whether to make dies to produce this part of multiple or single operation, whether the multiple dies would be more expensive to maintain or whether the single operations would be more expensive. All these factors must be weighed before a thorough estimate can be determined. Sometimes the limits specified on the part drawings are too close to maintain over secondary operation dies, since the part must be located in a nest, or by locating pins properly positioned for secondary operation. In a case of this kind, a nest with cam action must be provided to hold the parts rigid with no tolerances allowed for variation in material width, thicknesses or hardness and, whenever possible, all blanks must be located with pin holes provided for location of parts. It is very essential that these pilot holes be located to produce accuracy at all times.

It is often difficult to obtain the information necessary to afford an initial overview of the problem and to permit later comparison of various alternative solutions. As an example of such a general approach and to show the type of information desirable, a comparison of two alternate procedures is given in Figure 1. This comparison was developed to illustrate to the management the savings that can be brought about by combining in a single progressive die and press a number of operations which might otherwise be performed in several individual dies and presses as so-called secondary operations. In the example cited, six operations are involved and the comparison includes direct labor cost, tool maintenance cost, and floor space requirements.

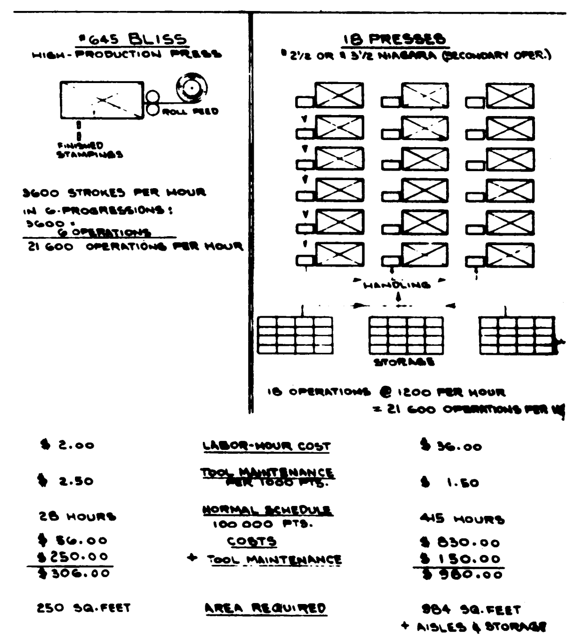


Figure 1
Comparison of Multiple Versus Single Oper. Presses

The comparison neglects the further cost factors of equipment investment, indirect labor for set-up, supervision, and materials handling, and the floor space required for temporary storage of material in process. The manufacturing cost differential favoring the single combination progressive die is considerable and for sufficiently large production could well warrant an increased investment in the required tooling.

Most all high production tools are designed to supplement secondary operation tools making tremendous savings in utilizing the press to the best advantage and to produce parts nearer to drawings, by this I mean that parts run over secondary dies are only partially completed while parts coming off the multiple die as a rule are completed in the die and parts inspection can be ascertained immediately. Secondly, there are less spoiled parts during a normal run.

Once the cost framework surrounding the tooling requirements has been established, the technical problems of the actual tooling design must be solved. I wish to offer a few remarks concerning this function. Quite often, I have been asked, "How does any one person know just exactly how to design a particular die?" That is not too hard to realize after a person has worked with tools very long since any idea is not new, it is generally picked up from a similar idea of some kind. First, the ideas and the past experience of the designer and the chief designer are all combined and the ideas are drawn as a rough sketch of the various operations as they progress through the particular tool. This sketch is classed as a work sheet. Next the tool committee analyzes the function of this tool as they see it working on the layout and, quite often, this sketch or layout is returned to the designer two or three times before a satisfactory design is completed. Finally, the designer proceeds with a complete layout or a side view of the tool; and in this way, the designer and the chief designer have an opportunity to see the working parts of the tool. "If it works on paper, it should work in a press." Quite often a particular function that we plan on incorporating in the tool is made up of a paper model and operated on a drawing board just the same as a person would make a model pattern or some other paper cutouts and quite often they pay off very well. Therefore, the little extra time spent with the designer to help him work out his problem is well worthwhile. Recently a designer came to me and told me that he had worked for nearly three days trying to design a particular function in a die and was unable to put it into the space allowed. After checking the design with him, I suggested doing it in an entirely different way. He looked at it for a minute and said, "I don't think this will work". However, after he spent a little time on it, he came back and said, "How did you see it so quickly?" It's probably because he was working too close to see new ideas. Sometimes designers get into a position where they can't see a new idea. They work hard to develop ideas and their mind is cluttered with these ideas, no new ones coming into their thoughts. Quite often a person who has no thought at all about that particular application, from thereon in can very readily see a new method, a new way, of producing the same function. Therefore, when the designer is in trouble, it is always well to have somebody who can offer a suggestion, whether the suggestion is any good or not. He can screen that himself and quite often obtain the information that he needs from a suggestion - opening a different train of thought; therefore, he would be able to complete the design and so on through any tool.

We all have thoughts that are picked up from observing, or working with, or trouble shooting and straightening out other tools that are giving trouble or have given trouble and this experience is valuable to anyone properly using it.

The technical ability of the tool design group further bears an important relationship to economic production through tooling simplification to reduce initial die construction cost and through design directed toward decreased maintenance requirements. Also, by ingenious design, it is sometime possible to extend the scope to press working to include new or unusual operations. In this way, appreciable savings can often be realized through the elimination of subsequent separate operations.

Figure 2 shows an enlarged photograph of a part formed from sheet metal on a press by piercing and blanking. The item is a detent 0.093 in. thick, approximately 1/2 in. long, and requiring tolerances of 0.001 in. The diameter of the smaller hole is less than the material thickness and both holes are located very near the edge of the part. Normally, production of this part on a press would be considered poor practice because of the part shape and size requirements. However, a die was designed to produce the part with but little maintenance trouble in operation and, as a result, the necessity for a subsequent drilling operation was eliminated.

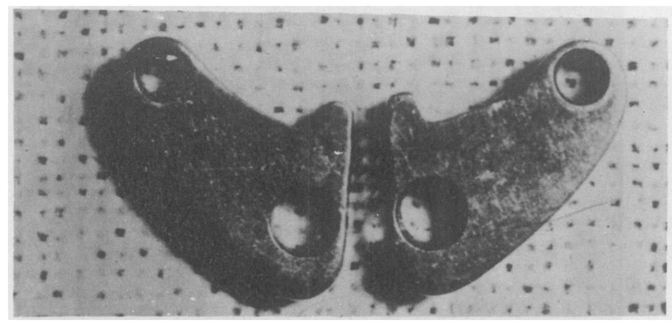


Figure 2

A case history presented in some detail of a tooling change recently carried out at Schlage Lock Company might be of interest and also serve to tie together the earlier remarks. Since the change to be considered involved the design of a single die to replace a total of three separate dies previously required for production, it also will be possible to obtain a cost comparison between the two alternate methods.

The item concerned, shown with dimensions in Figure 3, is a fairly typical lock part.

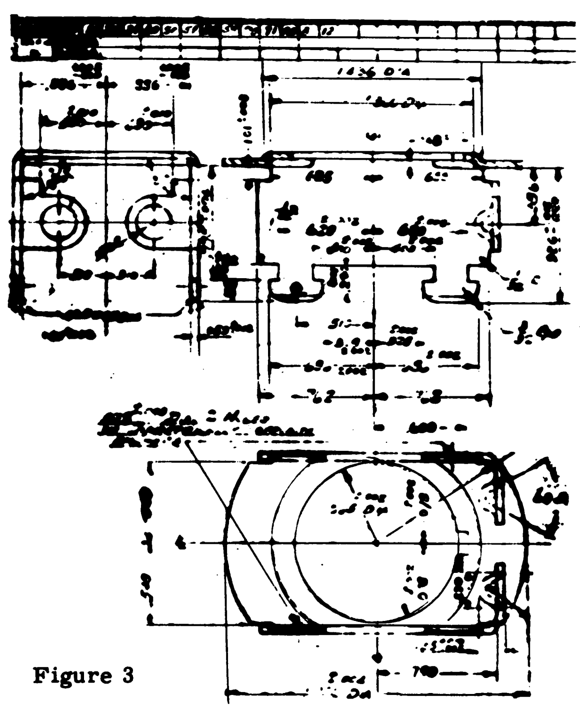


Figure 3

separate dies previously required for production, it also will be possible to obtain a cost comparison between the two alternate methods.

The item concerned, shown with dimensions in Figure 3, is a fairly typical lock part. Our first tooling for this part involved several separate dies -- a progressive blanking and piercing die, a second forming die, and a final piercing die -- three dies in all to form and complete the part. Photographs of this initial tooling are shown in

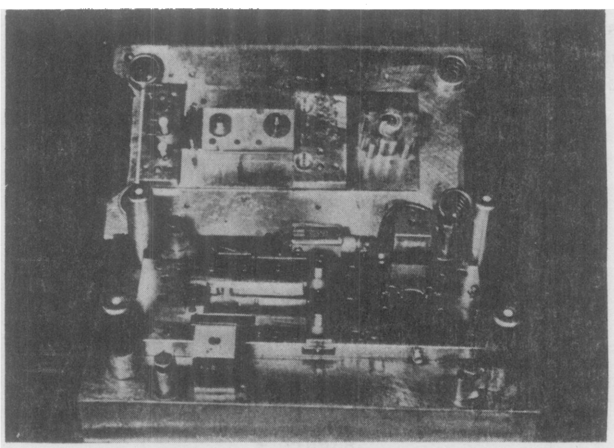


Figure 4

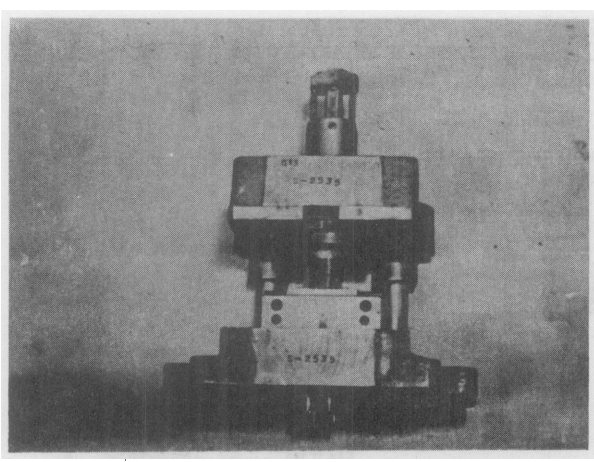


Figure 5

Figures 4, 5, and 6. The first die, Figure 4, is a progressive blanking die incorporating five operations performed in sequence as the stock strip is fed through the

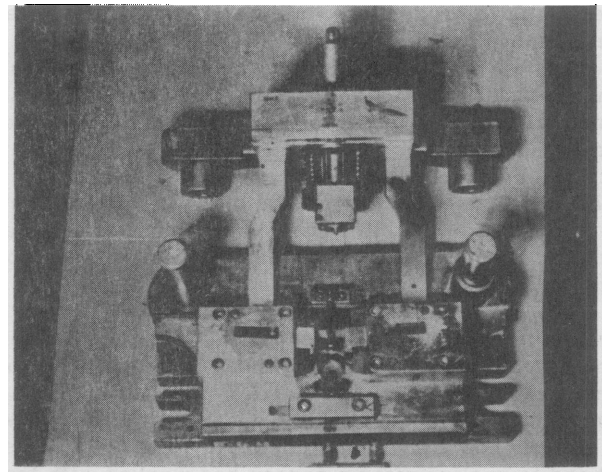


Figure 6

die. The intermediate die, Figure 5, is a form die for bending the blank from the first die into the "U" - shape. The final die, Figure 6, is a combination pierce-and-form die which completes the part. These dies, of course, were built when production was low and the cost of more complex tooling not warranted. All of the production required could be run on this type of tooling.

As time went on, the problem arose of producing accurate parts for increased production at lower cost and with less tool maintenance. After analysis of the problem, we chose as a better method the tooling which is next described. A single progressive die was designed to replace the original three separate dies. This die, mounted in a Minster press, is shown in Figure 7. The

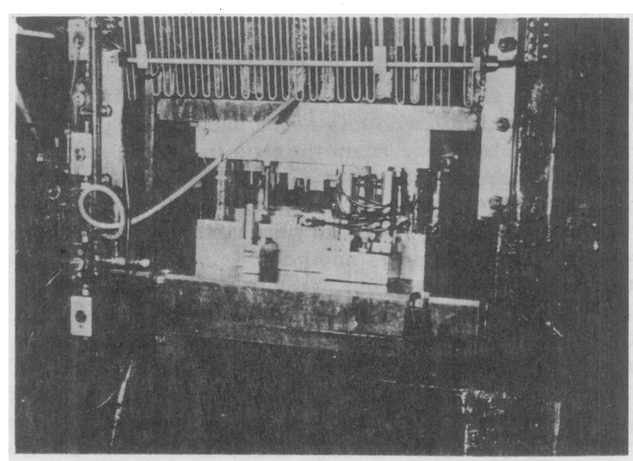


Figure 7

skeleton produced in the die, Figure 8, clearly shows the sequential action of the tooling in progressively forming the part. Details of the die construction can be seen in Figure 9, in which the stripper plate has been removed for greater clarity. Figure 10 shows the mating punch holder with its operating mechanism.

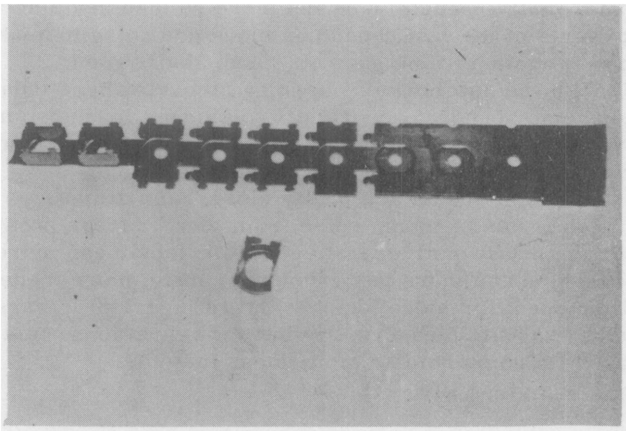


Figure 8

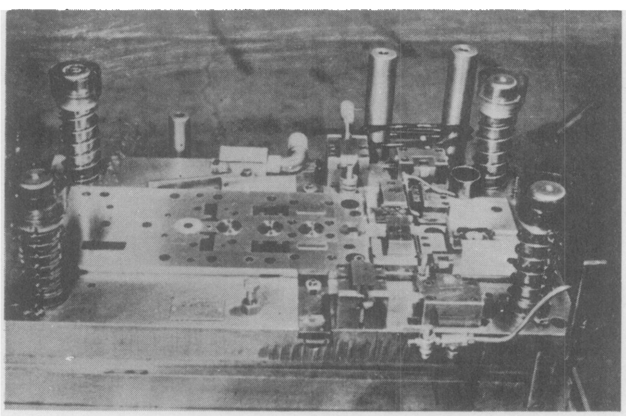


Figure 9

Before considering the production cost comparison between the two alternate methods, a few comments concerning the tooling and operation features of the new design might be in order. The single die replacing the prior three individual dies and incorporating their various functions is obviously larger, more complex, and more expensive. However, it is usually true that the experience gained in the design, construction, and operation of the initial tool-

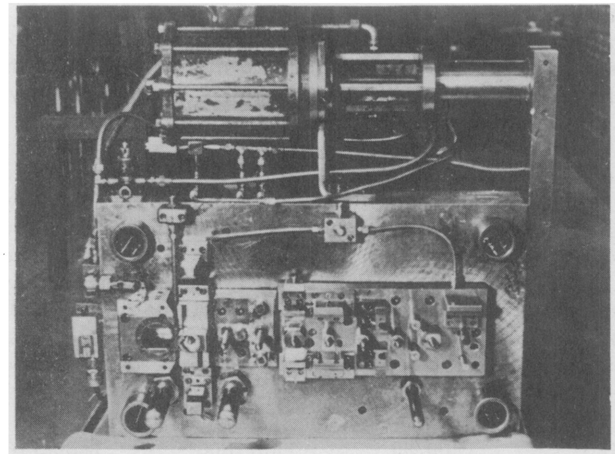


Figure 10

ing benefits a subsequent re-design by indicating functional and technical improvements, modifications, and desirable adjustment features. It comes to our attention that we probably build a very expensive die and, of course, that can only happen when the production will warrant the cost of expensive tooling. All tools have to be paid for in some way or another; the time, labor, and equipment saving provided by the faster operating dies will save the cost of the tools being built in this manner.

As can be seen from Figures 9 and 10, built-up construction has been used for both the punch and die. This design feature simplifies reconditioning and repair and also makes possible easy individual adjustment for each of the several tooling stations. As a precaution in the event of tool damage, it is well to have spare parts on hand that are rough machined and kept in readiness for an emergency repair and the built-up type of construction favors this procedure.

To date this die has produced approximately eight million pieces and has given very little trouble. We have set the die into the press and started production, made our final adjustments to suit gage requirements, and have operated the die as much as 120,000 pieces before removal for sharpening. We figured that sharpening after 100,000 parts will remove less die life and maintain better parts free from burrs than by running a die until it is actually dull. It is very possible to operate a die of this type for possibly 150,000 or more pieces but the rate of dulling after a die starts to dull is very fast and requires much more grinding to bring the die back into condition. It has been proven to us many times that a few thousands removed from the cutting edges prolongs the total die life.

Production experience with the new tooling shows a considerable decrease in rejects, largely the result of pilot location throughout the entire operation sequence which provides greater accuracy. At the same time, if any discrepancies creep in, the toolmaker is in a position to make adjustments immediately and to check such corrections as soon as the part has passed through all of the operations of the die. Sometimes we find material that will not operate properly through the dies and we must lay it to one side. It may be thickness, or material hardness that is giving trouble; but in any event, we must produce accurate parts. There are cases where we have made alterations in the tooling; that is, minor adjustments to accommodate oversize or undersize material. When this is done, the parts can be checked immediately and only such material run as will produce acceptable parts.

An economic comparison between the two production methods is made in Figure 11 on the basis of direct labor cost. Additional information on production rate is shown to indicate the need for temporary storage of nearly 6000 parts as in-process material in the case of the initial tooling. On the basis of the labor cost alone, it can readily be seen that tremendous savings are obtainable through the use of multiple operation tools when the production is sufficiently high to justify the cost of the more complex tooling.

DIES	PROD/HR	HRS/1000	LABOR/1000
1	3,360	.2976	.5208
2	1,440	.6944	1.215
3	1,200	.8333	1.458
		1.8253	3.1938
PART STORAGE	6,000		
ONE DIE	2,078	.4812	.8422

Figure 11

When we speak of the creative phenomena known as repetitive manufacturing, interchangeability of parts, and mass production - the very special and exclusive forte of tool design - it can well be said that "It had to happen in our time".

A hundred years ago, few of our countrymen realized that a new kind of freedom was in the making. Benjamin Franklin realized it when he said that he wished that he could be preserved in a tun of wine for a century and then be revived in order to see his country in all its glory. Franklin must have known then, as it has been so unmistakably demonstrated since, that Americans are essentially an inventive people; perhaps more so than any others, but events of the last decade or more are going to make us prove it again as time goes on - and, that's good.

With the new horizons opening up everywhere today, we have an abundant opportunity to pioneer in fields and in ways undreamed of - even a few short years ago. Time to again prove the ideals of this country.

Ideas and ideals are pretty close, sometimes.

Jobs, lots of them, come from ideas. Ideas prosper when the profit motive is alive. More jobs mean more workers, mean more pay envelopes, mean more money will be spent for more ideas - like refrigerators, cars and trucks, vacuum cleaners, radios and televisions, telephones (to communicate more ideas faster).

It's a great life.

SMALL BUSINESS SESSION

Session Chairmen: At Berkeley - WILLIAM R. WILLARD, President, San Francisco Chapter of SAM, and Director of Organization Planning, Columbia-Geneva Division, U.S. Steel Corp., San Francisco.

At Los Angeles - ELMER F. SPROULE, President, Los Angeles Chapter, Society of Applied Industrial Engineering; Training Manager, Hughes Aircraft Co., Culver City.

EVALUATION OF THE INDUSTRIAL ENGINEERING PROGRAM IN SMALL PLANT MANAGEMENT

Martin S. Meyers
Chief Industrial Engineer
Baby Line Furniture Company
Los Angeles, California

Several weeks ago, a manufacturing friend was relating his experiences and difficulties in establishing the actual costs of his products. Seemingly, he had allowed sufficient labor dollars in his sales price, but his accountant was now reporting a loss on labor. Naturally, I asked him what basis he had used in predetermining his labor costs, and received an answer to the effect that he had been in business for twenty years, and should know his labor costs by now. No doubt you have heard the same answer.

When I suggested that it would be to his advantage to hire an industrial engineer to make time studies, and tell him on a scientific basis what his labor costs should be, he gave the following answer: "Martin, I know I should, and I want to. As a matter of fact, I have had several, but they're all over my head. I can't understand them."

Gentlemen, we could overlook this if it were an isolated instance, but it isn't. During the past year I have heard the same words at least four times. Today in small plants there is a growing tendency to feel that the industrial engineer is a theorist and a luxury. And frankly, I can not blame them. Furthermore, I place the responsibility for this attitude on us -- the practicing industrial engineers and the university staff members.

It is time we stopped getting ahead of ourselves if we are to benefit the small plant. We must act in terms of what is practical today and think in terms of plans for tomorrow.... not proceed with future developments before we have utilized the tools available today. This is the basic difference between the application of industrial engineering in large industry and in small plants. The principles are the same, but the application and the responsibilities are different.

In a large operation, management is willing and can afford to invest for future returns, but small plants have small budgets, and must make each dollar pay for itself today. The industrial engineer, by the same reasoning, must show results today. We cannot wait for tomorrow. It is perhaps because this has not been done that the industrial engineer in small industry is not considered a success.

Much of the failure is our fault for starting on too high a plane; but equally to blame is the fact that we have never taken the time to explain to management what may be expected. If no measure of success is established, who is to say that a program has failed; or more important: How is the engineer to know if he has succeeded?

Thus, the subject of the evaluation of the industrial engineering program in small plant management becomes of paramount importance in these proceedings, and I feel deeply honored that I have been selected to deliver the paper on this subject. I, personally, feel that there is no facet of this program of greater importance.

Yet, the entire subject could be encompassed in just one sentence: "Give management lower costs--thereby implying better profits--with less headaches". Greater profits alone is no longer enough. The desire on the part of ownership to have high profits regardless of the physical and moral consequences is obsolete. Progressive ownership or management (and I use the terms interchangeably) is evidenced by a smooth-flowing operation and by a normal ratio of profit. And this is where the industrial engineer can prove his value.

One point before we progress further: To those of you in the audience who may be ownership or management above the engineer, while this paper is written to the engineer as to what he must give and can expect, it equally applies to what you should expect and must give. Always remember that the road to success in any program is a two-way street. It can lead to success and it can lead to failure. At the same time, it is paved with giving as well as receiving.

No doubt much of what is said here today will sound very elementary to many of you, but it is important when a program is conceived to start with the basic steps, and not at too high a level for plant management to understand. All too often, the industrial engineer will not bring his thinking down to the basic problems that beset the small operation with the result that the program is beyond the ken of the owner. He cannot understand it, so he wants no part of it; and the whole program is discarded.

The first thing, and probably the hardest for an industrial engineer to realize when he first enters a new and small organization is that he must first record what is happening; not try to change what he sees. The fastest way for an industrial engineer to start wrong is to start telling other people what they are doing wrong. As was once told to me: Tell me later how it should be done; right now tell how it is being done. In other words, gentlemen: Consider that the first phase of an industrial engineering program in small plant management is to let them know what is happening today. When you have done this, you have performed your first major service.

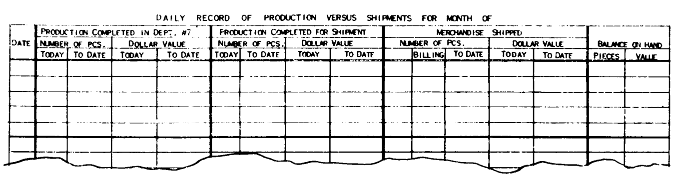
To be specific: When a new man enters an organization, he should know what is expected of him. In the case of the industrial engineer, it is not only important that he know what is expected of him, but that he should know what is expected of each member of the organization as well. In small plant management, this is sadly neglected. Very few small plants have a written organization chart. It thereby becomes important that the engineer consider it one of his first responsibilities to establish such a chart, with adequate descriptions of what each person and function is today, not what it should be according to the textbook.

Remember two points: The small plant owner does not want a "young upstart" (regardless of his age) to come in, and immediately start to tell him how to run his business. Secondly, the small plant owner wants to understand every move that every man in his organization makes so that he can evaluate it. It is a general conception that understanding is an indication of success, and rightfully so.

A typical small plant organization chart very often will divide the staff functions among a six man executive staff as we have done at the Baby Line Furniture Company. These are: the sales manager, who is also responsible for the inside order desk and all outside warehouses; the engineering and inspection manager, who is responsible for issuing all specification sheets and setting quality standards; the plant superintendent, who is responsible for production and plant maintenance; the purchasing agent, who is also responsible for the receiving and stores department; the comptroller, who is responsible for all office procedures including accounts receivable, payable and billing; and the industrial engineer, who is also responsible for the personnel, production control, and factory cost accounting functions.

In establishing the organization chart, it is also important that the lines of communication be delineated, and that each line officer be aware of the reports he is to make, when he is to make them, and to whom. At Baby Line, every foreman turns in a production report to the plant superintendent, who in turn gives it to the industrial engineer. These reports cover the overall operation of each department, as well as the performance of each individual operator in the department. These are the basis for several operating reports given to management, and help to give management tangible evidence of the program being established.

One such report is "Production versus Shipments", shown in Figure 1. Department #7 in this case is the assembly department, where the product first assumes an identity either as a crib, chair, play-yard or case. Under the third major division, "Merchandise Shipped", there are two daily unit columns. The first is to record the synopsis of the report from the shipping department, and the second is to record the units actually billed to the customer. This is a cross-check between the two, and is important for proper inventory control when tied in to the factory cost ledger. The dollar value in each case is dollars at sales price.



DAILY RECORD OF PRODUCTION VERSUS SHIPMENTS FOR MONTH OF

DATE	PRODUCTION COMPLETED IN DEPT. #7				PRODUCTION COMPLETED FOR SHIPMENT				MERCHANDISE SHIPPED					BALANCE ON HAND	
	NUMBER OF PCS.		DOLLAR VALUE		NUMBER OF PCS.		DOLLAR VALUE		NUMBER OF PCS.			DOLLAR VALUE			
	TODAY	TO DATE	TODAY	TO DATE	TODAY	TO DATE	TODAY	TO DATE		BILLING	TO DATE	TODAY	TO DATE	PIECES	VALUE

Figure 1

From this report, which is placed on the desks of top management each day, it is easy to sight the comparison of sales to production, as well as the progress of production between the two departments shown. It also gives management an immediate answer to the status of finished goods inventory, and to many other problems that arise in the daily routine of material anticipation and personnel requirements.

Incidentally, if you will notice, every fifth line is a heavy one and is used to indicate the end of the work-day week. The days of the month are so placed that management can tell how many work days remain in the month. This is a small detail, but helps to convince management that every small detail has been attended for the ease of analysis of the report.

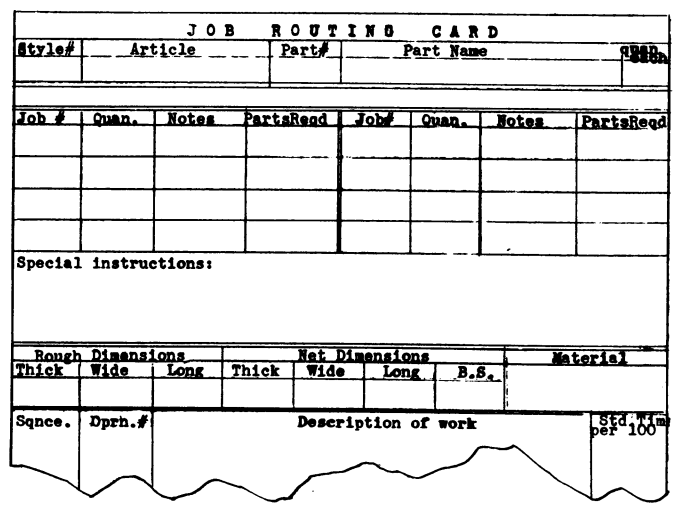
A second report compiled from the same information plus the payroll department's record of payroll dollars per pay period in one designed to give the comparison of labor efficiency where time standards have yet to be established.

The payroll is divided according to the actual dollars of payroll consumed by each department after proper adjustments for inter-departmental transfer. Then, the dollars are stated as a percentage of production in sales dollars, and as a percentage of actual shipments in sales dollars. The same report can cite the increases and decreases in these percentages each pay period.

While this type of report can be considered contrary to all good standards of industrial engineering, it nevertheless enables the industrial engineer to give management the facts immediately. Small plant management does not want an industrial engineer to say that the standards have not been set, so no report at all can be made. If the program is to succeed, the industrial engineer must establish an immediate measure by which to gauge conditions as they currently exist; and the dollar is the easiest ruler by which a small plant owner can measure his success. If he is spoken to in terms of the dollar, he understands immediately. (This could be said for all of us, actually.) More important, it allows you, as an industrial engineer, to start showing results at an earlier stage in the program.

Actually, speaking of rulers, we still do not know that an inch is really an inch, nor a minute really a minute. We only know that the term "inch" was set to indicate a certain amount of distance. As long as it is accepted by everyone as being the same, then it becomes a standard measure. Today, the dollar is accepted by everyone as being the same, so the industrial engineer can use it until his time studies are taken, and standard time data established.

Another basic item very often overlooked in small plants is the shop routing card, an example of which is shown in Figure 2. To most of you, there is nothing unusual about this form. The card is placed in a plastic envelope, and moves with the work through the shop.



JOB ROUTING CARD

Style# | Article | Part# | Part Name

Job # | Quan. | Notes | PartsReqd | Job# | Quan. | Notes | PartsReqd

Special instructions:

Rough Dimensions: Thick | Wide | Long — Net Dimensions: Thick | Wide | Long | B.S. — Material

Sqnce. | Oprn.# | Description of work | Std. Time per 100

Figure 2

Each machine in the shop has been given an operation number according to an over-all plan, and the machine to be used for a particular operation is indicated on the routing card by this number. On the extreme right hand side of the card, there is provision for the standard machine time expressed in time per hundred pieces.

The top of the card has been designed so that it can be used for eight different jobs through the shop. This was done to save making new cards for each production run of the same style number. The column headed "notes" in this section is used to advise the operator of the standard time for the number of parts required.

When all operations are complete, the load is transferred from the mill-room to the assembly department. The foreman there is responsible to check the number of pieces on the load against the number of parts required according to the parts routing card, and then to return the card to the industrial engineer's office.

Here again, it would surprise you to know that many small shops do not have these basic routing cards. In all too many shops, the management is completely dependent upon the foremen to determine how a part is to be made, and then to tell the individual machine operators orally about it. This is another of the basic steps that must not be overlooked by the industrial engineer in showing management the value of the program in recording current conditions.

And more important for the eventual success of the program, the routing cards are the basis upon which the time standards are set, and the basis upon which the standard cost of the product is established.

Another big headache to small plant management that the industrial engineer can relieve is the lack of knowledge relating to anticipated shipping dates. All too often, the sales manager or order desk will be forced to ask the owner, the plant manager, the foreman, or anyone else who is handy when a certain item will be ready for shipment. Undoubtedly if the same question were asked of each, there would be as many different answers as there were people asked.

Thus, it is necessary for the industrial engineer to prepare a written completion schedule. This should not be an elaborate chart, and should not even list dates when first issued. The first step is to get the proper sequence established. Then, add tentative dates. After time study data are established, it is possible to proceed with standard completion schedules.

Here, again, it is important that the industrial engineer should not be alone in establishing these schedules at first. Much of the success in meeting the dates can be assured in the early stages of the industrial engineering program by letting the foremen of the individual departments feel they are establishing the dates to be met. Again, it is an instance of the engineer recording the facts as he finds them. Later, the principles of proper scheduling to standards can be explained and used.

There are many other management engineering and production engineering functions that could be indicated to stress the point that the first responsibility of the industrial engineer--and the first indication of his value to management--is to establish written records of what is happening in the organization when he first joins it.

But in so doing, it is not my intention to minimize the importance of the long range program of proper organization, of proper time standards and of proper scheduling. These are all very important and will come; but they will not come until management has gained confidence in the program. Even some of the larger consulting organizations often make the mistake of walking into an organization cold, and before learning how the company operates, proceed to tell the owners how the plant should be organized and should operate.

One of the most important books I own is a diary which I started during my early days of industrial engineering. In it is recorded all the myriad of ideas for changes that I felt vital during the time of service with the particular company. In retrospective reading, it is amazing how ridiculous some of the ideas are in view of what I later learned about the company. Repetitive reading of such is conducive to more earnest contemplation of frivolous suggestions, I assure you.

If the industrial engineering program is properly organized, staff meetings will be held to discuss problems of each division individually. This is necessary even if the staff consists of two or three men. Meetings are important to air gripes properly and to exchange ideas. During these meetings, the subject of organization is injected to the point where each man realizes what work he has been doing that could be performed more adequately--notice that the word efficiently is not used in suggesting changes--by another man in the organization.

The direct result of these meetings is a good organization chart where each man knows what he should do, not what he has been doing, for the overall benefit of the company rather than according to his individual personality and desires.

Thus, the industrial engineer has started on the second phase of his work; to record for management what should be happening. In so doing, you must remember that all industrial engineers are basically egotists. After all, we do believe that we can solve the particular problem at hand better than anyone else. The important thing is that we recognize this fact before anyone else, and conduct ourselves so that the others do not resent it.

In recording for management what should be happening in regards to production, the tool most often used by the industrial engineer is time study. As fast as the new standards are set, then the previous reports to management on labor efficiency using the dollar as the measure should be changed to reflect the new basis for comparing actual to standard.

A simple form used for this purpose is Figure 3, showing top management the standard cost hours of production of each department for each day of the week as a

DAILY SHOP EFFICIENCY REPORT FOR WEEK ENDING ________ 19__

		MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	TOTAL
DEPT. # 1	Std.						
	% of						
	Act.						
DEPT. # 2	Std.						
	% of						
	Act.						
DEPT. # 3	Std.						
	% of						
DEPT. # 13	% of						
	Act.						
TOTAL	Std.						
	% of						
	Act.						

Figure 3

percentage of the actual hours consumed for the same production. As long as this percentage is 100% or better, management knows there is a profit on labor. If the figure is below 100, then there is a loss on labor.

This particular form, as described, is used when standard labor is in cost hours rather than standard production hours. Standard production hours meaning the amount of work that should be performed and cost hours meaning the same standard modified by the operating efficiency of the shop. Many small plants are showing a loss on labor on their operating statements because they are using standard production hours in computing sales prices, rather than using cost hours.

It is important that you, as the industrial engineer, assume the responsibility for making this delineation and preventing your company from making the same mistake.

If this report were intended for the executive in charge of production, then it should be shown as standard production hours as a percentage of actual production hours. In this case, provision should be made on the report to show the percentage of efficiency used for each department to determine the cost hours.

A more detailed report of the same information is shown in Figure 4. This report shows the actual hours and actual units of production in the particular department according to the product line, as a comparison to the standard production hours of work performed. This report not only serves to show the efficiency of the department, but is used by the factory cost office for recording actual cost and labor variances on the month end operating statement.

DAILY REPORT OF ACTUAL VERSUS STANDARD HOURS IN DEPT. # ____________

MONTH OF ____________, 1953

DATE	CRIBS		CASES		CHAIRS		YARDS		MISC	TOTAL		TRANSFERS		PAYROLL
	ACT'L	STD.	ACT'L	STD.	ACT'L	STD.	ACT'L	STD.	REF.	ACT'L	STD.	IN	OUT	HOURS
TOTAL ACT'L														
TOTAL STD.														
ACT'L PCT. OF STD.														

Figure 4

Thus, due to the necessities of small plant operation, a single report is used for multiple purposes to give better control of the operation with a minimum of clerical detail and expense.

By the time that the industrial engineer has made time studies sufficiently to make these reports, he is also sufficiently familiar with the product, with the materials, with the machines, and with the men that he should be able to discuss their problems on a common ground--no longer as a newcomer or stranger to the organization.

And that is the start of the third phase of the industrial engineering program: Suggest changes to improve the standards already established. Here again, you are only telling the production division what could be done to make your standards show less man hours or more efficient operation. You are still not interfering with the sacred area of the other man's domain. The entire approach is that you are concerned with your job, not with telling the other man what to do.

Of course, some of the more idealistic of us may believe that the foremen or production managers are going to welcome us with open arms to come in and show them how to do their jobs better. Maybe in some shops this is true, but I don't believe I would enjoy working in them. I cannot believe that any man with any ability who is in a responsible position will welcome anyone coming in to tell him in effect how bad a job he is doing. All of us feel that what we are doing is good--not perfect--but at least good enough to warrant an occasional pat on the back.

On the other hand, remember that in everyone there is a feeling of wanting to help the other fellow. I cannot tell you how often I have used the trick of showing someone where I needed help on an idea I had in order to get him to change what he was doing. Think about it, and you'll remember when you have done the same.

Some of the improvements that can be effected by a properly organized industrial engineering program are illustrated in the before and after pictures shown.

Figure 5 shows the before and after method of receiving and stock-piling lumber as delivered via freight car. Originally, the lumber was piled into the car piecemeal and removed from the car one board at a time. A current supplier is shipping the lumber palletized and strapped as shown. The resultant savings in unloading alone was roughly four man days versus five man hours. Further, the shipper advises that his savings in labor of loading more than offset the additional cost of strapping materials and labor.

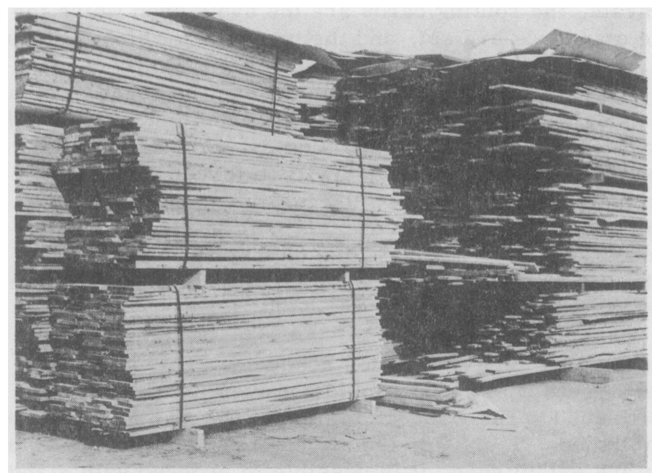


Figure 5

Another good illustration is Figure 6 of the conveyor belt used in the shipping department. This belt is approximately 600 feet long, making a complete circle of the

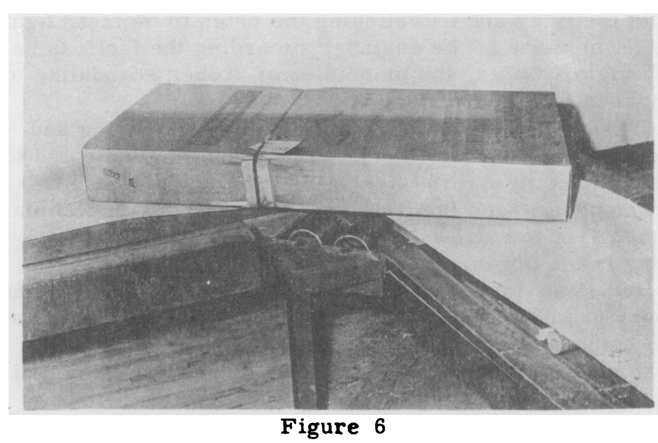


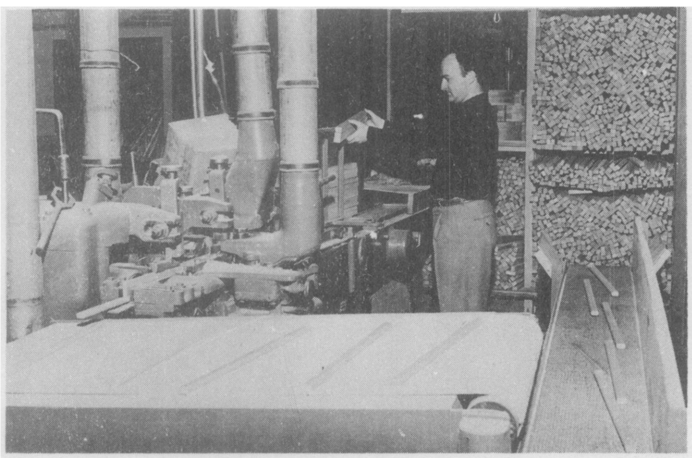
Figure 6

of the second floor in addition to going down to the first floor and back up again. While the photo does not show too well, it can be seen that there is no return belt underneath. The belt is 100% usable surface at all times. To our knowledge, there is no similar installation on the west coast.

In the same photo can be seen a method of finished goods inventory control through an identification card on each package entering the warehouse.

Figure 7 shows a conveyor belt used to replace the off-bearer at a moulder. In the background can be seen another development to save floor space. The truck shown is divided into four sections, but only three of the areas are used for material in transit. The fourth is used to place the machined parts as they come from the machine. This was developed due to the constant complaint that machine operators could not find empty factory trucks, and were constantly away from their machines.

At the present time, and since these photos were taken, the conveyor belt shown has been rebuilt so that it now carries the parts directly to the machine performing the next operation, thereby eliminating the need for material handling between the operations altogether.



. Figure 7

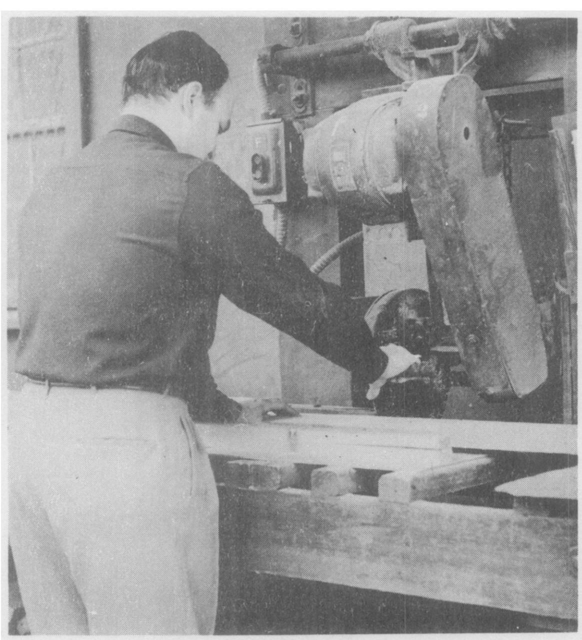


Figure 8

Figure 9

Figure 8 shows the before and Figure 9 the after method of a cutting operation in the rough mill. Originally, it was necessary that each operator have a helper to remove cut material, or that he stop his own productive cycle to remove the cut-piece to a pallet. The photo also shows the safety hazard in the operation. Currently, the operator operates the saw through a control button at his right hand as shown in the photo while feeding the stock with his left hand. A guard directly in front of the saw blade prevents his left hand from contact by a margin of two inches. As the piece is cut, it drops onto a conveyor belt and is carried to the off-bearer, who is simultaneously working with other machines. The scrap is carried by the conveyor directly to the incinerator without further handling. The resultant savings were a helper for each operator versus a helper for each three operators. Plus the safety factors.

In the final analysis, there is a saying very often repeated, "Having ideas is easy, but putting the ideas into effect takes hard work". We say that ideas are a dime a dozen, but following through to put an idea into practice is what pays off. Management expects reports from the industrial engineer for methods improvements and for other betterments. But at the same time, he expects the industrial engineer to conduct himself and to prepare his reports so that they will be used, not just read. More bluntly stated: the final evaluation of the industrial engineer to small plant management is "how much of his program can he have put into effect with a minimum of commotion and turmoil".

One point: It is much better if you, as the engineer, can have the changes made without going to the owner. Show that you are part of the team, and not a "Tattle-tale" telling teacher all the bad things there are.

On the other hand, it is equally important that you do not find yourself becoming a line officer doing the work, instead of a staff officer recommending the improvements. Tact is important at that point, as is the organization chart showing who is responsible to do the line function, and the staff meetings setting the schedule of changes to be incorporated.

To summarize then: What are some of the things that small plant management can use as an ultimate result in evaluating your program:

1. Adequate time standards to establish costs and to establish operating efficiency

2. Current daily information on operating efficiency
3. Constant methods improvements based on new ideas and equipment as well as plant lay-out reflecting lower time standards
4. Proper production planning as evidenced by schedules that can be relied upon
5. Not previously mentioned, but equally important, a quality control program
6. Budgetary control of factory overhead
7. Intangible, but necessary, an improved safety record and certainly many other intangible benefits that warrant the "less headaches" phrase.

But to obtain all this, it is necessary that you first show management what is happening before the program starts. Build up his confidence in you, warrant his cooperation and faith.

I am reminded of one factory manager who once said to me, "What do you mean I didn't cooperate with the man. I backed him all the way. Why I even backed him up when I knew he was wrong." Don't expect that type of cooperation. If you are wrong, expect to be told so. If you are right, this doesn't mean you are going to be made vice-president the next day.

Management and the industrial engineer must be compatible -- both working toward a common goal of less headaches and better profits, with tangible evidence in both directions that a fair evaluation of the program is being made.

TEAMWORK: THE KEY TO INCREASED PRODUCTIVITY

Peter C. Jurs
Partner and Production Manager
Shand & Jurs Company
Berkeley, California

If you were to define the term "Small Business", unless you worked for a company employing many, many thousands, you would probably use as an element of such a definition a company up to and including approximately the number of employees in your company. On that basis, my definition would have to be one employing approximately 115 individuals. But regardless of the definition, these comments should be appropriate. If they seem impertinent, they are certainly said in good faith and not meant rudely. If they seem brash, you might brush them off just as a biased criticism by an unpolished Stanford graduate, trying desperately to find a basis for criticizing something about the University of California.

At previous Industrial Engineering Institutes here, it has frequently seemed that the emphasis was on tools and methods applicable only in G. E., Westinghouse, Lockheed, Eastman Kodak, General Motors, etc. If it is claimed that the tools and methods are the same and the differences in application are only quantitative, not qualitative, I say it also works in reverse. Those engaged in industrial engineering in long run operations and in big business could amost certainly profit by knowing the essential short cuts practiced in small and short run operations. It was very encouraging to see the greater emphasis on the problems of small business at last year's Institute and again here this morning.

Since our manufacturing plant started in 1922, the only use we have ever had for a stopwatch is timing flow rates of the valves we manufacture. Honestly, almost before a carefully tutored industrial engineer could get out his stopwatch, clipboard, and pencil, or his tripod, lights and movie camera, or other properties, a particular operation on a particular machine in our shop would be finished. And it would rarely repeat again for four months or more. During the interval it might remain the same or it might be changed radically. Any elaborate study of any kind would be next to worthless too often to merit taking the necessary time in the first place.

Since provision must be made for efficient and economical manufacture and since we feel that we cannot afford the luxury of the elaborate techniques already developed and being constantly improved, we must make provisions elsewhere. This is where our teamwork comes in.

Somewhat more time is usually consumed in the original design stage to try to foresee bugs. No design ever hits the shop proper without the superintendent and the foreman, if necessary, having gone over it piece by piece. Questions of holding or machining or tolerances, or gauging, from the production point of view, are decided as far as possible before it leaves the drawing board. By the time our team finishes the design is something that we feel certain will do the job and fits our production pattern. It has taken a little longer, but usually the time is very well

When it comes right down to the components themselves, how do we know whether the individual pieces are being made at a satisfactory rate? The answer there lies most often with the foreman and the machine operator himself. The foreman must be able to walk by a drill press or turret lathe and determine with just a moment's visual observation that the speeds, feeds, and finishes are essentially correct. But oddly enough, he has the help of the man performing the operation. Why? Because of the teamwork created by our bonus system. Every man is anxious to do the job as rapidly as possible, consistent with good work, but not to a point of killing himself in the process. You may say that's putting an enormous amount of dependence on a foreman. We agree. He is one of the key men on the team.

It almost goes without saying that we have what we consider to be a satisfactory cost system so that we are not dependent exclusively on casual glances from time to time to know whether our costs are staying in line.

Perhaps we seem to have strayed from my point for emphasis on industrial engineering training for small business. Actually, we have not. If less time were spent in studying how to knock a few seconds off of an operation by using a different finger or by using a circular motion instead of an up and down motion and more time were spent instead on fundamentals, the men produced would be only slightly less valuable to the industrial giants and very much more valuable to smaller businesses. A balanced approach to the application of the principles of industrial engineering to short run jobs and short term operations would produce men better able to take over such positions as superintendent or production manager sooner than if they had not gained that balance.

Why do some of us continue to dwell upon the subject of small business? Why did the questionnaires at the end of the Fourth and Fifth Industrial Engineering Institutes result in replies by 74% of those attending that they wanted more emphasis on problems of small business? I have only a fragmentary statistical basis for statements, but we have reason to believe that this geographical area contains a higher percentage of small businesses than the industrial centers of the East.

Even though the elements leading to a preference for small business may not be easy to analyze, let's try for a minute. Many organizational differences are clearly evident. The individuals comprising top management are only a few rungs up the ladder from the wage earners. Incidentally, notice we carefully avoid words differentiating "management" from "workers". Chances are that if you are a part of management, you don't enjoy any more than we do being excluded by implication from those who work.

In small business the differences between line men and staff men practically disappear. Assignments to committees and task forces are unknown. The only true committee in our plant is the Safety Committee with two permanent members and the other four places revolving through the entire plant personnel from top management clear to the bottom. We do have three periodic conferences, but as they are described you will see that it is not committee work. They are more like a football half-time huddle in the dressing room. They discuss, "What has happened lately, where are we, and what do we do next?"

The line of communications is so simple that we must re-examine it from time to time to insure that we are not handling too much on a verbal basis. Normally it takes about a day or two for incoming purchase orders to get retyped into sales orders and for the various copies to work their way through production control and inventory to the shop, assembly, and shipping departments. For emergency conditions communications can be very rapid. If some customer calls in a lather and if the item is in stock, we can very often have it addressed and on the way in ten or fifteen minutes. Even if it has to be assembled from components on hand, it can sometimes be completed in an hour or two instead of a day or two, because of a simple line of communications. This also means much less red tape.

There are many other aspects of business procedure in which the progress from the inception of an idea or the recognition of necessity can be translated into immediate action. Examples are company policy changes, production programming, priority changes, material substitutions, changes in engineering or sales emphasis. This operational flexibility can be the trump card if played correctly. It can also be a trap of confusion if carelessly handled. That is where real teamwork spells the difference.

We would take hours relating examples of the speed with which an integrated small business can move. Possibly the most spectacular differences, and the ones so often contributing in large measure to the development of customer good will, occur upon the receipt of a customer's complaint relayed from the field. Oftener than not, the progress from complaint to repaired equipment in the field is a fait acompli in the time a big company might take to debate whose responsibility it was and who would foot the bill.

We could not terminate this subject without mentioning the downright fun of being in a small company. One gets to know practically everyone else, his hobbies, pet peeves, skills, his family. There's a feeling of belonging to a team when passing the drill press operator or assembblyman or crater. He is not just a number on a time card, but instead he is Dick, the guy who would rather fish for trout than eat, whose golf game has suffered since trout season opened. His little girl has just recovered from the mumps; he just bought a brand new Ford. And you really know a lot more about Dick's ability and a great deal about almost everyone in the plant. In return, they know you well enough that when they call you mister instead of by your first name, you know at once something is wrong. A man doing graduate work in the engineering school at Cal right now who had been in the Navy was talking to us about employment the other day and drew a good analogy. He wanted to work in a small company because it was like serving on a destroyer contrasted with a carrier or a battle wagon. On the tin can he found the advantages we have listed. On the carrier he could do a good job or a poor one and never really get the feeling that anyone who counted knew the difference.

Another comment or two and we will turn to specific examples of how we have our team organized. The first is simply an elaboration of the closeness of individuals. This means not only the closeness of top management to the machinists and assembly men, but the very close liaison between the engineers in the engineering room, between them and the order desk, or between them and the purchasing department, or between the purchasing department and the order desk. It means that at almost any time of day any engineer or one of the buyers or almost anyone else in the office can confer with one of the partners and discuss any problem while it is hot instead of having to make appointments or depend upon inter-department correspondence or memos. The chain of command is just too short for decisions to be passed rung by rung up the ladder to higher and higher authority trying to find someone who will accept the responsibility of making a decision. And it's also harder to pass the buck down because the line is so short.

We interrupt now long enough to describe our company and products sufficiently to show that in this specialized business it would be almost hopeless simply to follow the conventional patterns. We manufacture a highly specialized line of fittings principally for the oil industry and to an increasing extent the petro-chemical industry. These consist mostly of special valves, fittings, and appurtenances for the very large storage tanks holding crudes, refining intermediates and finished products, running the gamut from asphalt and heavy oils on one end to propane on the other. The individual items most often fall into a category of safety and conservation equipment and are of such a highly specialized nature and the volume so relatively small for any particular item that it is of little or no interest to the truly large valve manufacturing concerns. This whole line of specialty fittings is pretty well standardized and cataloged and, in general, acceptable to most of the companies in the oil industry.

Along with the standard or almost standard items, we handle special requests every day for very special assemblies. For instance, a naive inquiry will ask for a price and delivery on a gage that is designed for use on a steel storage tank containing ordinary motor fuel. A little incidental footnote might say that the product to be gaged will be concentrated hydrochloric acid, or hot slop ends containing high percentages of sulphuric acid.

Figure 1 shows the number of people in the various departments in our company and from most points of view it would seem to be extraordinarily heavy on overhead. You can see that over half of the total personnel are so-called non-producers, those who do not physically help transform the raw material into the finished product or assemble it or test it in the manufacturing sense. It is probably a little unusual that it takes twelve men full time on sales and sales engineering on a volume of business that can be produced by only 56 men in the shop and the assembly room proper.

FIGURE I

NON PRODUCTIVE	PARTNERS (GEN. MNGMT, SALES, ENG., PRODN)	4	59
	SUPT., ASST., TOOL DESIGN, PRODN CONTROL	4	
	FOREMEN	3	
	OFFICE PERSONNEL & ENG. STAFF	22	
	SHIPPING, RECEIVING & MISC.	12	
	OUTSIDE SALES (N.Y., CHI., L.A., HSTN, TULSA)	14	
PROD.	MACHINE SHOP PROPER	32	56
	ASSEMBLY & CLEANING ROOM	24	
		TOTAL	115

Figure 2 illustrates for such a small business the tremendous number of different assemblies we produce as well as the very much larger number of components we have to produce in our own shop to put with those things we buy in order to produce those assemblies. The large number of factory orders, the relatively small number of assemblies per factory order illustrate vividly what we means by short run operations. The large number of sales orders and the small number of items per sales order follow the same pattern.

This background is provided partly because we must bear in mind that there is a real difference between the small business producing a relatively large volume of only a few things and the small business whose volume is attained by producing a great many different things but each one in relatively short runs.

FIGURE 2
1953

EQUIPMENT PRODUCED

DIFFERENT ITEMS	APPROX 135
DIFFERENTIATED FURTHER BY SIZES	OVER 400
DIFFERENT COMPONENTS MANUFACTURED,	OVER 3700

PRODUCTION ORDERS TO SHOP

FACTORY PRODUCTION ORDERS	958
IDENTICAL ASSYS PER FACTORY ORDER (AVERAGE)	90

SALES

SALES ORDERS FOR 1953	6270
ITEMS PER TYPICAL SALES ORDER	5.8
DIFFERENT ITEMS PER TYPICAL SALES ORDER	2.3

Consequently, let me describe our bi-weekly executive conference as one of the fundamentals of our teamwork. Prior to its use the many small and frequent conferences and discussion groups which were held often left one or more of the partners or perhaps another department head ignorant of some important decision or worse yet possibly we failed to benefit from what he or they could have contributed to the decision. Realizing that considerable time was lost in reviewing such matters with those not at first included, and realizing further that benefits could be derived from frequent full meetings of top management, we started the executive meetings early in World War II. Actually, when we first started, it was held as a daily conference and consisted of the four active partners, the plant superintendent, and the purchasing agent. You will remember that during World War II the confusion of rapidly changing priorities, the colossal problems of procurement, rapidly changing material specifications, and the unpredictable pattern of prohibitions on the uses of certain metals put a high premium on flexibility and rapid decisions.

After the war ended, the five conferences per week were cut down to three, and now are at a level of two, which seems to be the optimum under more normal business conditions for us. These meetings convene for as long or as short a time as may be necessary to discuss the problems that each may be facing and where the most efficient action will be determined by the evaluation of influences and factors from the other departments.

Problems of manufacturing, purchasing, engineering, research, and sales policy are discussed as they are introduced and a course of action is determined which is the best from the viewpoint of the whole group.

Most matters of company policy are settled at these meetings. Employee and public relations, major equipment investments, new developments, customer relation and service problems, the general catalog and other allied problems receive frequent attention at these meetings.

Another problem that comes up time and time again and will continue to as long as we are in business is the question of specials. Just how far can we afford to go in accommodating a potential customer who needs a piece of equipment much like a piece we already make but wants a modification in materials or design? A decision can be reached in a relatively few minutes where no one of the individual departments could have enough information at its fingertips to make nearly as good a decision.

A perpetual inventory system of stock on hand is a responsibility of production control under the superintendent. The clerk who manages the actual inventory figures provides the superintendent with notices of items nearing depletion and a rerun of such items is automatically in order. The superintendent invariably brings these notices to the attention of our conferences. This permits improvements under way in the engineering or research departments to be incorporated with the standard line at the earliest possible moment. It also permits advance information in the hands of the sales department to influence the quantity which would normally be made on this next run.

Mutual problems of our outside sales offices and agencies are integrated with plant problems and production methods in these meetings, and department heads who would not otherwise be acquainted with such problems obtain a broader picture of the entire company operation.

Differences of opinion naturally arise as frequently as spontaneous agreements, but in the event of serious disagreement strictly engineering phases are decided upon by the partner in charge of engineering, sales problems finally by the partner in charge of sales, and so forth. Inter-departmental problems are decided by the group.

You can well imagine that some of our conferences are apt to last several hours, but just as often they are over within 20 minutes to half an hour. We are jealous of the time spent in these sessions and permit only the most important of telephone or other calls to interrupt them. As it is today, it starts promptly at 9 o'clock on Tuesdays and Thursdays, and only very rarely does one of the participants allow any other engagement to encroach on that time. An atmosphere of informality permits anyone to speak when the spirit moves, and it has been known to permit time for a story or a joke if the one telling it believes it good enough to get away with.

An additional, though perhaps less tangible, benefit derived from the use of this conference as a tool of management lies in the fact that through constant close attention in our bi-weekly conferences, the various executives are more able to step at least temporarily into another position should an unexpected absence, emergency, or vacation require it. In a business with so few in real top management, an inability to be flexible in this respect could conceivably work a serious hardship.

This frequent but regular executive conference would have to be tailored to the particular type of business. And we don't mean that where similar conferences of essentially all the representatives of top management are not in use that they should immediately be employed. We do mean to say that it has proven to be a most successful tool in developing the necessary teamwork in our manufacturing business.

Our bi-weekly conference of top management is supplemented by weekly conferences between the superintendent and the three plant foremen. The three foremen are from the machine shop, the assembly department, and the shipping department. Their conference is for the purpose of better integration of the work in progress. This conference is held at the same time each week, and every single unshipped sales order or uncompleted factory order is examined. The assembly foreman learns about the anticipated flow to him of components during the coming week. He can be very helpful to the machine shop foreman by indicating which components are needed soon and which may be delayed somewhat to correlate the flow of manufactured components with the arrival of components purchased outside and with his anticipated pattern of available assembly time during the coming week. This is obviously a help to the machine shop foreman in scheduling his over all work load and individual machine loading.

Anticipated shipping dates were set up for the sales orders when they were first received, but during these meetings of the foremen and the superintendent special emphasis can be put on orders requiring it, and plans laid for the most efficient use of time remaining to finish a job. The shipping room foreman gets a very clear picture of what he will doubtless be receiving during the course of the following week and can prepare his department accordingly.

The superintendent acts as liaison man from each conference to the other.

The third and last type of formal conference contributing to coordinated team action is held once a month with the partner in charge of production, the superintendent, his assistant, and the three foremen. This is for quite a different but a very important purpose. In it the questions of company policy as they relate to employer-employee relations and union problems are thoroughly discussed. Company policy with regard to hiring and firing, time off by individuals for personal business, discipline for such infractions as chronically punching in late in the morning, re-evaluation of job classifications, individual merit raises beyond the union scale, handling of union grievances, etc., are all discussed at this monthly meeting. The foremen have sufficient advice concerning company policy and the desires of top management that most of the problems arising at the employee-foreman level can be handled at once by the foreman with little worry as to whether he is handling it the way management would want him to.

An example of how effectively this helps is that our shop was unionized for almost eight years before we ever had our first formal written grievance handed to a foreman by a union steward.

The last tool of management which I would like to describe is probably the most important in developing a full spirit of teamwork in the entire company. This is our bonus plan. It is in its thirteenth year now, and in order to describe it we should start back some months prior to Pearl Harbor in 1941. If you were in the metal working business or possibly it was true in all businesses, you will remember that for a while there wages started to go up at a very rapid rate. Labor pirating became rampant and workmen were being lost right and left to companies who would give them fictitiously high classifications in order to pay higher wages and the problem of holding one's crew together was getting to be colossal. It became evident that trying to keep pace with the bidding for machinists and mechanics was something we couldn't afford so we decided to institute a wage incentive plan.

Prior to that we had considered a number of benefit plans such as pension systems, insurance plans, etc., but they had all been discarded as being too bulky and expensive for our small company, which employed at that time only about 50 people. You will remember also that the emphasis at that time was on take-home pay; earnings that could be felt fondly and spent rapidly.

Needless to say, much thought went into the formulation of our plan for we knew that it would have to compensate each participant individually to a worthwhile extent or it would be a dud. Also it would have to give a higher return to the most valuable men and still an adequate return to the least valuable. In addition, we wanted at that time to encourage overtime, and you will remember that ten and eleven hour shifts were pretty commonplace during World War II. In addition, it had to be simple, for again in our type of business it was out of the question to consider such things as piece-work rates or setting up norms for the thousands of components that went into the hundreds of assemblies that we made. It became evident that the end we desired would be best attained by paying the bonus as a percentage of each individual's gross earnings each month. Everyone would get exactly the same percentage bonus. Obviously, the highest paid men got the biggest bonus in dollars, even though the percentage was alike for everyone. Also, those who worked the longest hours had the highest gross earnings and therefore got more bonus. And that's the way it was set up, a monthly bonus of a certain percentage of gross earnings with the same per cent applying to everyone.

The reason that the partners did not participate is obvious. The superintendent was already being paid an annual bonus as a per cent of company profits for the year; therefore he did not participate. Nor did the salesmen in our outside sales offices who were working on salary plus commission. But everybody else in the factory (office, engineering, shop, and shipping) got the same bonus percentage.

The next important question, of course, was what element of performance should be used as a yardstick in setting up the bonus. It appeared to us that if the workmen in the shop took the blueprints and the raw material and converted them into finished goods at a faster than normal rate and maintained good quality, they were doing everything that could be expected of them. If the assembly department worked efficiently and the shipping department got the assemblies out with dispatch, they were doing all that could be expected of them. If the engineering department and the office personnel stayed abreast of the requirements for a rate of production higher than average, they too were doing a good job. But if in spite of this, the operations did not turn out to be profitable, there was nothing any of them could do to change a loss to a profit. Profit is management's responsibility; consequently, it seemed logical to use as a yardstick the rate of production measured in dollars per month of shipments in relation to the number of employees, leaving profit clear out of the calculation.

An analysis of audits for five years preceding 1941 led to the determination of an average amount of billing or gross sales required per employee per month to net a moderate and reasonable return to the company.

The datum was determined at that time to be $750 per participating employee per month. Then it was determined that on the basis of the average number of employees at that time and the existing level of business, a bonus of 1/2 or 1% of gross earnings could be paid to each participating employee for every $1000 of shipments that month beyond the datum or base. It appeared to be a level at which the employees would be generously repaid for extra effort and at the same time the company would still retain a fair share of the extra profit that would be realized by the increased rate of production.

Said in words this may seem slightly involved, but an example as shown in Figure 3 will help to illustrate its complete simplicity.

FIGURE 3

SAMPLE MONTHLY BONUS CALCULATION

SHIPMENTS —————— $ 100,000

BONUS BASE (100 EMPLOYEES a $ 750.00 EACH)— 75,000

BONUS SHIPMENTS —————— 25,000

AT $\frac{1}{2}$% PER $ 1000.00, BONUS = 12$\frac{1}{2}$%

It is perfectly obvious that while all the employees are striving for a maximum rate of production, the over all operations have to be profitable. As a consequence, the superintendent in responsible charge of all of the production operations gets his bonus not from rate of production but from company profits.

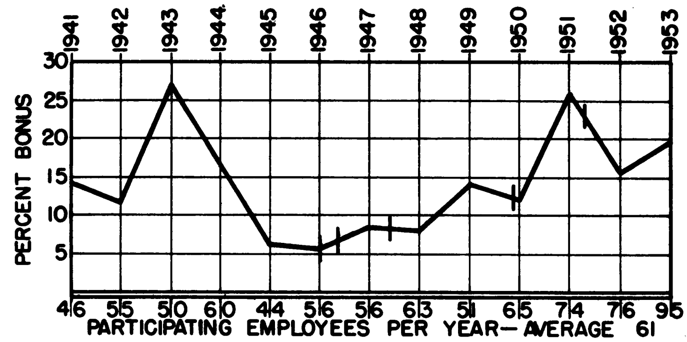
The next most important individual upon whom a high rate of production depends is the foreman of the machine shop proper. He is responsible for the activities of his men and to a limited degree for the activities of the two other foremen. Consequently, he occupies a particularly important position in the general set up, and his compensation therefore must fall somewhere in between that of his men and the superintendent. Without being paid an abnormally high salary for this job, he enjoys double the regular bonus, thus giving him the added incentive to see to it that the work under him is effectively and efficiently performed. However, he always has the brake on him of his superintendent so that techniques are not used in order to increase production that are inconsistent with profitable operations.

In our business, advancing prices have been very slow in keeping pace with increasing costs of production, both laborwise and materialwise. Since 1941 our base beyond which the bonus is paid has had to be increased to keep pace with the higher costs and higher prices that we have had to charge consistent with the periods of time during which price ceilings were in effect. However, we think that Figure 4 which shows the bonus percentages over the years will also show that our management has not deliberately held the base high to keep the bonus low. The five short vertical lines along the curve show where the method of calculating the base had to be changed.

Figure 5 shows how the base of the bonus was changed.

Even during the course of one year the bonus fluctuates substantially as illustrated by Figure 6 based on the year just past. Our business shows very little reflection of

FIGURE 4



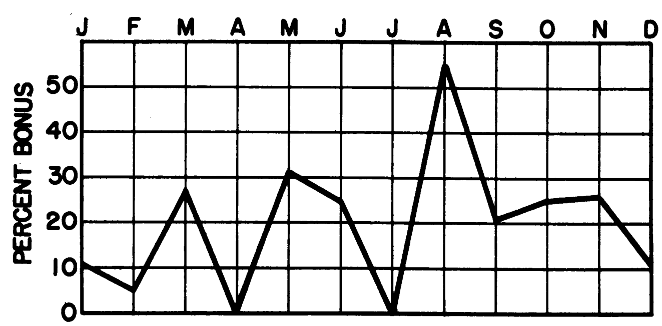
MONTHLY AVERAGE, 149 MONTHS —————— 14.2%
TOTAL DOLLARS PAID IN BONUS, 149 MONTHS—$ 440,897.00
APPROX. AVERAGE PER EMPLOYEE PER YEAR——$ 556.00

FIGURE 5

	BASE FOR 0% BONUS $/MONTH/EMPLOYEE	$ BEYOND BASE TO EARN ½% BONUS
AUG. 1941	750.00	1000.00
DEC. 1946	1000.00	1000.00
MAY 1947	1200.00	1000.00
JUNE 1948	1300.00	1000.00
OCT. 1950	1500.00	1000.00
FEB. 1952	1500.00	1500.00

FIGURE 6

1953



AVERAGE 19.7%

seasonal activity so explanation of these variations would consume more time than we have available.

What does this plan accomplish? The benefits to the employees are clear from the figures just shown. The benefits to the company are almost as obvious.

What else has this plan accomplished?

We can assure you that it has helped keep our crew intact and has reduced turnover among employees. We know from having lived with it for over twelve years and from the balance sheets and profit and loss statements that it has helped produce economical and profitable production.

Since it is paid monthly, and we close our book on the 25th of every month, we have eleven big pushes each year. Right after the 25th of each month there is a slight relaxation, but it isn't more than a couple of days until the relaxation is over. Around the 20th of each month everyone starts scurrying around to make sure that there are no loose ends left dangling and that all possible orders are filled and shipped on or before the 25th. Figures for each month's billing together with the bonus percentage are posted on the bulletin boards each month and it is positively incredible how close some of the guesses come to the correct figure. Most of the guessing actually is based on the weight of goods shipped which the boys in the shipping department seem to have pretty well correlated now with dollar value.

You may wonder why we say eleven big pushes instead of twelve. July never produces a bonus because we have a complete shutdown during the first two weeks of July for a plantwide vacation. Obviously, enough can't be produced and shipped during the remaining two weeks ever to reach the bonus base. Actually, when the men return from vacation they work just as hard as they do the balance of the year, but it seems that the actual shipment of finished goods during July is always lower than one would expect, and a strong suspicion exists that, where it is really not harmful to the business itself, some of the orders that could be completed and shipped before the 25th day of July for reasons best known to the men themselves don't get shipped until the 26th or the 27th of July so that they count on the August bonus. Needless to say, we are aware of this and shipments that management knows must and can go out do go out. You may have noticed on the slide showing the amounts of the bonus by months during 1953 that July had a 0 bonus and August had a 54% bonus.

How can we keep a running measure of productivity in this bonus system without work standards? Probably by precise industrial engineering standards we are a little loose in this respect. But the very closeness of the supervisors to the men keeps a down-to-earth running check. Even though it is out of the question to examine every job for costs, the analyses we do run alert us before things can get badly out of hand. For the over all picture we have a good estimated monthly profit and loss sheet and an audited P & L every six months.

Another factor enters to a surprisingly large extent, but honestly not in a manner to cause friction and unpleasantness. This is a real awareness in our workmen if anyone is soldiering or just plain slow. The slowness is sometimes to be expected in new men who may never have worked under a reasonable incentive system or may just take a little time to get into the spirit of our teamwork until they have enjoyed a month or two of a good bonus. But if it is evident that a new man needs help, the others offer it without simultaneously insisting that the union claim lead man pay for them. Normally, new men get into the spirit of things. If not, they start getting gentle barbs. If they are really hopeless, they usually quit or are discharged.

We hired a new engine lathe operator not long ago, and after about a month he stated to the foreman that he felt that "he was not cutting the mustard." The foreman was sympathetic and suggested that in the course of a little more time he would get into the swing of things. Nevertheless, after another month this machinist volunteered in a perfectly friendly way that he was going to quit. He said that it was because the rate of production in our shop was at such a relatively high rate that he thought he would never make the grade and was fearful that he would always have a feeling of somehow riding the tail-gate and dragging his heels. So he quit.

Last month we had occasion to discharge a turret lathe hand who after six months was still so slow that we simply could not tolerate him. He was slower than average by a substantial margin on almost all the jobs that he did. The particular job that finally resulted in his discharge was one in which it took him over 29 hours to make 1200 of a certain piece whereas the average of three other men who had done the same job was around 15 hours and the fastest one had been able to make 1200 pieces in 12.9 hours. You can see that we are not haggling over seconds. Actually, the foreman was well aware of this miserable performance, but before we got around to discharging him three of the other men had complained rather bitterly about our retaining the turret lathe operator. In fact, one of the most forthright complaints came from the individual's own union shop steward.

Quality control is maintained by the same general techniques as productivity. Everyone in the shop knows who machined a batch of rejected pieces, and the offender realizes everyone knows it. He knows it is hurting the bonus right at the top cream level where the bonus is being skimmed off. A certain datum has to be passed to get any bonus, but once passed the bonus piles up rapidly. Consequently, a relatively small percent of spoiled work may have a relatively large effect on that month's bonus.

We still have foreman control, inspection, testing, and last, but least pleasant, returns from the field or customer complaints. Material returned for any reason is deducted from next month's shipments before calculation of the bonus, and the men know that, too.

Have our relationships with the union been impaired by the presence of the bonus? To the best of our knowledge never. There are a great many other factors besides the bonus which go into determining this relationship, but our bonus plan was in effect before we signed our first contract with the union in 1946. After just one year's experience with it, on the first contract renewal, they tried to insist that it should be written into the contract as an addendum. Needless to say, that did not work, and really the only complaint they have with our bonus is that they do not have primary control.

You might well ask what bugs have developed in this plan. The first to be mentioned is not a real bug but just a cautionary comment. When costs and consequently prices went up, we needed to change the bonus base and found that a very careful explanation had to be made. Consider any particular assembly on which the price had to be doubled, exactly twice as much would be shipped, measured in dollars, for exactly the same number of hours of work; therefore, the base or datum must be adjusted in a direct correspondence to increase in prices. In our plant it was found that the easiest way to make this explanation was by word of mouth at a full meeting of all plant personnel. This was made abundantly clear and plenty of time allowed for questions. Finally, we might add that the experience of the next few months better bear out what was said!

By the same token if prices go down, one would expect to have to lower the bonus base. We think the men would accept that with considerably less explanation.

One real bug is connected with growth. The bonus base, of course, keeps pace with the increased number of personnel; but adjusted as it is now for us the 1/2% bonus per $1500 beyond the base does not keep pace. If the crew got large enough, 1/2% of the monthly payroll could in theory absorb all of the profit, and more, of the $1500. So this must be watched. It could be put on some sliding scale depending upon the number of employees participating in that month.

Why have I been justified in taking so much time without complex slides, graphs, and tabulations in discussing what seemed to me to be essentially human problems? The guide came from the results of the interest questionnaire from the Fourth and Fifth Industrial Engineering Institutes, At the end of the Fourth Institute the questionnaire asked, "What topics would you prefer at the next Institute?" Out of nineteen different listed categories the one that got by far the most preference checks was "Human Problems." At the end of the Fifth Institute out of seventeen categories, again the one checked most often by an overwhelming margin was "Human Problems," the runner up being "Work Simplification." I would feel very badly indeed if I did not feel that this hour may have contributed a little bit to a better understanding of human problems and work simplification, as they pertain to small business.

AUTOMATION IN SMALL PLANTS

Frank K. Shallenberger
Associate Professor of Industrial Management
Graduate School of Business, Stanford University
President, Shalco Engineering Corporation
Palo Alto, California

This is the second year I have had the pleasure of talking to the Industrial Engineering Conference on the subject of "Automation in Small Plants". Perhaps I am no better than the Professor who announced that he was going to give the same examination as last year, but was going to change the answers. In a sense, that's what I'd like to do today, to bring last year's discussion up to date in the light of developments which have taken place since that time, to offer some new thoughts, ideas and examples and to modify some of my former conclusions.

I will readily admit that there are many more important things in our personal lives than this business of automation. But I know of no other single development which will bring about such radical changes in our way of industrial life. It is natural that with such a potential impact on industry, automation has received a great deal of attention -- both technical and philosophical. It is not static, and, like the budget or market forecast, warrants a periodic reappraisal of earlier conclusions and predictions.

In a narrower sense, automation is the process of making production processes automatic. In its broader concept, it includes the application of similar techniques and devices to the office, the home, agriculture, distribution, transportation, and even to the making of management decisions.

There has been a tendency to regard automation as a new phenomenon, a technique borne of the wartime development of fabulous electronic devices which controlled gunfire, the flight of aircraft and the path of guided missiles. It is true that these developments -- along with high labor costs, increasing volumes, tighter tolerances and greater appreciation of the benefits of mechanization -- have spurred the current interest in automation and will accelerate its application in the future.

And yet automation is not really new. Its origins will be found in the Industrial Revolution, and its current development is nothing more than an extension and refinement of the mechanization which began at that time. The purists will draw a distinction between mechanization, which is the substitution of mechanical or electrical power for the worker's physical labor, and often his skill; and automation, in which photo-electric cells, magnetic tapes, punched cards, computers and servo-mechanisms provide automatic control or direction, of production operations. The distinction is valid, and perhaps we stand now on the threshold of a second industrial revolution, in which automation will relieve the worker of mental effort in the same manner as mechanization relieved him of physical effort. The industrial revolution of the 19th century was characterized by the application of energy to production processes. The industrial revolution of the 20th century will be characterized by the application of information or instructions, to production processes.

I am not sure just how important the distinction between automation and mechanization is for the purposes of this paper. It is important that we recognize that automation opens up broad new fields for the industrial engineer to conquer. It gives him fabulous tools to work with. He can now do things which were impossible in the past or which could be accomplished only through very elaborate, costly means. For now he has not only the motor, the cylinder, the lever, and the cam to replace the worker's muscle. He now has devices which can observe, and think, and make decisions -- and, as one person suggested, even dream -- devices to replace or relieve man's mental effort in the control of industrial or other processes.

But in many cases there is a very thin line between mechanization and automation. And automation must be recognized for what it is, merely extension and a refinement of mechanization, if we are to avoid losing perspective and being carried away in Buck Rogers fantasy. Automation is primarily a device for saving or relieving labor, and we might argue that it makes little difference to the practical businessman, the plant manager, or the industrial engineer whether the worker is replaced by a motor, an air cylinder, a conveyor, a magnetic tape, or a servo-mechanism except as these latter devices may provide greater speed, accuracy, flexibility, or decreased initial cost. And with this further and tremendously significant exception -- automation may have in it the means for remedying the major evil which mechanization is said to have created, the subordination of man to the machine. Mechanization brought with it many benefits, but it also transferred to the machine and its jigs and fixtures, the skills of the journeyman craftsman. It thus created, for better or worse, many routine, monotonous, repetitive, unskilled and unchallenging jobs. It has been truly stated that today "an unskilled job is a mistake in engineering," a concept that is borne out by the fact that the routine, repetitive, unskilled jobs are exactly those which automation can most readily replace. To me, the possibilities for mankind which lie in this fact are of equal significance to the more publicized possibilities of higher standards of living, shorter work week, greater leisure and so forth.

At any rate, for purposes of this talk, I would like to think of automation primarily as advanced, mature mechanization. Automation is also, in a very real sense, the logical outgrowth of imaginative, uninhibited industrial engineering, as you have heard it discussed in this conference, and particularly of work simplification, as pioneered by Taylor and the Gilbreths and brought to the high level it has attained today by the notable contributions of such leaders as Ralph Barnes. For any good methods engineer will tell you, will he not, that the best improvement you can make in any job is to eliminate it.

For those who still regard automation as something new, let me point out that in 1784, an entirely automatic plant was built in Philadelphia, a flour mill in which grain was processed into flour on a continuous basis without human labor. In 1797 Maudsley gave the lathe a lead screw to control automatically the movement of the tool along the work. In 1801, the Jacquard automatic loom, which actually was controlled by punched paper cards similar to those used in present day automatic office equipment, was developed and widely adopted in Europe. In 1833 the "victualling office" of the British Navy automatized the manufacture of biscuits. Conveyors incorporating automatic weighing and other devices were introduced into the meat packing industry in 1869. The famous A. O. Smith automatic factory in which strip steel was automatically blanked, formed, assembled, riveted, and painted to form a complete automobile chassis every 8 seconds, was built in 1920.

We have many virtually automatic factories today -- refineries, chemical plants, food processing plants. Commodities such as lamp bulbs, tin cans, bottles, cigarettes, and the like are produced in virtually automatic plants. We have the transfer type machine, which combines automatic machining and materials handling, really a number of machines automatically coupled together and centrally controlled. We have machines guided automatically by cams, templates and even by a line on a blueprint. We have automatic machines which paint, assemble, inspect, count, sort and package the finished product. We have fully automatic telephone systems and even automatic parking lots. In our private lives we have automatic washing machines, driers, and dishwashers, which operate through a predetermined sequence without human guidance. We have automatic headlight dimmers, traffic lights and elevator systems which adjust themselves to changing conditions. The common household thermostat is an excellent example of "closed-loop" automatic control. For more than 20 years, photo-electric cells have been counting, sorting, detecting conveyor jams, weighing, filling, measuring, and performing thousands of other useful tasks throughout industry. In 1946 two machines were built in England to produce radio sets automatically. The Ford Motor Company has had an Automation Department since 1947; in fact the word "automation" was coined at Ford. To Ford, automation means automatic materials handling into, out of, and between machines, and one has only to look at the "iron hands" which load and unload giant presses, the conveyors which carry cylinder blocks through more than 40 machines and 500 different operations, the chutes and the transfer machines, to realize the effectiveness of this department's efforts.

Many of these devices are really examples of mechanization, and not automation, at least in terms of its narrower definition. They are programmed and operated by cams, stops, levers, limit switches, solenoids and air and hydraulic cylinders. They have mechanical, electrical and hydraulic interlocks to assure proper sequencing. But only a few of them can monitor their own actions. Only recently have we seen widespread use of the tremendously valuable technique of "feed back", a "built-in supervision" which assures that the machine performs exactly as instructed. Only recently have we had control devices which can observe, think, remember, make decisions and take appropriate corrective action, as do Ford's and De Soto's crankshaft balancing machines, for example, which check out-of-balance condition, then drill the right amount of metal from the right spot to bring the crankshaft into balance.

The great dream of the future, of course, lies in electronic controls, highly versatile devices which can direct their own actions in the light of changing conditions and thus provide full and complete automatic control over complex industrial processes. Many of these are already in widespread industrial use. They can see and hear and measure better than any human can do. They are faster, more reliable, and more precise, than human operators. They never tire, don't make mistakes, don't talk back, are fully predictable, have few personal problems and don't go out on strike! It is the ability of such devices to think and choose, to accept and remember and use information or instructions fed in on a tape or card, and to move accurately and with great speed, that makes them the key to the factory of the future. Their versatility is almost without limit and there are few if any production jobs which they could not perform if economically justified.

What about the small plant and automation? Will the need for highly skilled technicians, for large capital investments, for large volumes, for product re-design, for elaborate sales and production planning tend to concentrate industry to the hands of the large concerns? Will the big get bigger and the rich get richer?

First of all, it should be noted that in some fields there is already a considerable degree of small plant automation, especially in the food processing industry. And we see automatic screw machines, cut-off saws, plastic presses, grinders, color sorting, painting, plating, heat treating and so forth, in many small plants.

Nevertheless, as I pointed out in Berkeley last year, the striking thing about automation is not what can be done in the future but rather how little has been done in the past. In spite of the examples we have quoted, there are thousands and thousands of jobs now performed by human workers in both large and small plants that could be performed more accurately, more efficiently and much more cheaply by automatic means, using devices which have long been available.

In the case of the small plant, one of the most important reasons for this failure to take advantage of available techniques, is lack of capital, the chronic problem of small business. In many small plants, funds are simply not available, even for the simplest automatic devices. Whatever the potential payoff, there always seems to be some other need more acute, some other project with a greater payoff. Small plants are notoriously catchalls for antiquated production equipment. I fully appreciate the dangers of generalization, but let me quote a few examples. A plant with which I once had the dubious pleasure of association in the East is still operating machine tools which were purchased when the company was founded in 1902! Here is a company with know-how, skills, goodwill, a fine reputation and a good product, but it cannot compete unless it replaces its equipment, and with the handicap these antiquated machines place on plant operations, it cannot earn the capital to replace them.

Ask any machine tool dealer to whom he sells his used equipment -- to small plants. I discussed this matter with a San Francisco dealer recently and he emphasized the point by showing me a home-made turret lathe made by a small plant operator who felt he could not afford to buy a new machine. It had a bed made of machined railroad rails and other similar improvisations -- a fine tribute to the builder's ingenuity and craftsmanship, but certainly little credit to his knowledge of costs. Apparently the dealer had no trouble in finding another small plant to take it off his hands.

Even the better managed small plants may not be able to afford the equipment which any industrial engineer would insist they should have. I think, for example, of one of our most efficient small shops in the Bay Area, a shop which employs about 15 workers. Until recently, they actually had shut down a new $10,000 lathe every half hour or so while their undersized compressor built up enough pressure to operate both the chuck on the lathe and the air vise on an adjoining milling machine. This same mill had to be shut down periodically for several days at a time, whenever its special form cutters had to be sent out for grinding. The company clearly recognized these wastes and would have liked to replace the compressor with a larger unit and to buy an extra set of cutters. But it was a growing concern which simply did not feel they could afford such expenditures when the same amount of money would yield an even greater payoff elsewhere.

It should be noted at the same time that many small (and large) plants who do have adequate funds available still fail to replace obsolete equipment. Surveys of machine tool age in industry show an astonishing and almost disgraceful failure to replace productive equipment on a sound, economic basis. The Eastern plant I described had many opportunities to modernize in the past. Unfortunately we often let our decisions in this area be made by owners pressing for dividends, or by accountants with a reverence for book value, technicians who have not always learned that the wisdom of equipment replacement depends upon comparative performance in the future, not on bookkeeping entries of the past. It is a sad commentary that by 1955, in this the most industrialized nation in the world, if the present replacement trend continues, more than three-fourths of our machine tools will be over ten years old. More than 20 per cent are already 20 years old. Automation will clearly come slowly unless we revise our thinking on equipment obsolescence and replacement.

There are other factors which will delay the automation of the small plant. One is our strange thinking on business conditions. When business activity is high, competition offers little incentive to modernization. When business is low, we feel we cannot afford it. Last year, in trying to sell a new technology to the foundry industry, I actually had a number of small foundries say to me "Why should I invest in a new process when I already have more business than I can handle?" And this year, I am frequently told that no new equipment can be purchased until the future becomes more certain.

Labor groups have retarded modernization and automation by their successful insistence on maintenance of former piece rates, or by prohibiting the assignment of workers to more than one machine. In one Western plant, the company has been forced to mount several machines on a single base to permit operation by one employee and thus realize the benefit of partial automation. Of course it should be recognized the same time that the increased cost and unpredictability of labor is without doubt one of the greatest incentives to automation. The ratio between equipment costs and wages is now 23 per cent lower than in 1940. Certainly horsepower is now, more than ever, cheaper than manpower.

One of the most important deterrents to automation from the small plant standpoint is the relative flexibility of automatic equipment. Even with the necessary capital, the small plant which competes in a market of short runs, unpredictable demands, changing products, non-repetitive operations would find transfer machines, custom-built conveyors or elaborate automatic loading and unloading equipment ill suited to its needs. For by investment in such equipment, it would thereby lose the flexibility which gives it its strongest competitive advantage.

Before speculating further on the automation of small plants, we should attempt to visualize the automatic factory of the future. There will be no machine tenders in the fully automated plant. The only workers will be highly trained technicians whose function it will be to develop, install, tool and maintain the equipment.

The automatic plant will be relatively inflexible both as to volume and product. It will, in most cases, have a relatively high break-even point, for fixed costs will be high relative to variable costs. However, since the automatic plant need not accommodate itself to the convenience of the work force, it will probably operate on a 24 hour basis. Thus, its fixed costs per unit of output may actually be lower than the non-automatic plant. But flexibility will have been lost for cutbacks will be costly and there will be little opportunity for expanding production in a plant already operating around the clock.

Likewise it appears that the automatic factory will be relatively inflexible as to product. The popular concept of a plant equipped with versatile general-purpose tools operated by robots, able to shift rapidly from one product to another by a little rearrangement and changing of tapes or punched cards, is unrealistic. Although electronic controls offer a much higher degree of versatility than the mechanical controls of the past, nevertheless the automatic plant will still be engineered, equipped and tooled for the production of a specific product, and design and product changes will always be costly.

The automatic plant will be a closely integrated unit from incoming material to finished product, and vulnerable at any point. Emphasis will be on high utilization. Preventive maintenance will be a must. Administrative breakdowns, such as materials shortages or faulty planning will be as serious as mechanical breakdowns. Added premium will be placed on management competence, upon precise planning, scheduling and follow-up. Relations with suppliers will take on added importance.

Automation may well elevate the sales department to an even higher responsibility than it now enjoys. For the sales group will have to develop and maintain the market necessary to keep the automatic plant operating at a profitable level. A much greater premium will be placed upon sound market forecasts prior to plant construction. Full automation will be practicable only in plants producing a standard product in large quantities and the public must be persuaded to accept such standardization. In many cases, products will be completely redesigned of new materials which lend themselves to automation and extra sales effort will be required to overcome the buyer's resistance to these radically new products. It is clear that the competence with which the sales department can meet this challenge will determine the future of the automatic plant in many industries.

In summary, the managerial problems loom as large as the engineering and financial problems, and I pose the question as to whether the small plant can attract high caliber management necessary to meet this challenge. Perhaps it can, for the attractions of small business are very great. Certainly big business has no monopoly on managerial ability. I often feel that small plant operators, as a matter of fact, have to have a higher level of management competence than their counterparts in large plants.

Let us now consider some of the positive aspects for automation in small plants. In the first place, it should be pointed out that we already have a high degree of automation in many small plants -- food and dairy products, beverages, screw machine products, chemicals, paint, toys, paper products, hardware, plastics, specialty consumer items. I am associated with a new company about to go into production of wooden crates on automatic equipment. We anticipate that with a crew of 10 we will be able to produce 1,000 crates a day; yet our plant investment will be less than $30,000. The equipment for this plant is highly flexible, even though automatic, and with such a low investment, we will also have a very low break-even point. Because the equipment has been designed largely around standard parts, its cost and maintenance will also be low. To a large extent, automation in small plants will depend upon the development of such equipment.

It is reassuring to know that there is considerable activity of this nature now underway. One can always talk more concretely from his own experience, and I trust you will excuse me if I tell you of our own experiences in trying to develop and promote a piece of equipment specifically designed for small plants. Two years ago a group of students at Stanford developed a shell molding machine for small foundries. Shell molding is a process developed in Germany during the war. It consists of dropping a mixture of sand and thermosetting resin onto a heated metal pattern, then dumping off the excess to leave a thin layer of resin-bonded sand adhering to the pattern. This shell is cured by heating into a smooth, rigid, accurate duplicate of the pattern. Two shells placed together form the mold into which the metal is poured to produce the casting.

The primary benefits are extreme smoothness of surface and accuracy of dimension. There is little comparison between the roughness of the ordinary green sand casting and the beautiful smooth finish produced by shell molding. As-cast tolerances can be held to $\pm$ .003 inches per inch, so subsequently machining can be greatly reduced and in many cases eliminated altogether. The shells are porous so that gases escape readily and such common foundry defects as blow holes, mold shifts, flash, fins, or sand inclusions are virtually eliminated and clean-up is greatly reduced. Because of the smooth walls and insulating effect of the shells, very thin sections, impossible in green sand casting, can be readily cast. Materials handling is greatly reduced, for a few pounds of shell replace 50 - 100 pounds of green sand mold. Likewise floor space requirements can be substantially reduced. Little skill is required and the process of making shells can be readily automatized.

FORTUNE Magazine described the shell molding process as the first major revision in foundry technology in several thousand years. At the time the students tackled the problem, the only shell molding machines available were elaborate, fully automatic monstrosities costing upwards of $15,000 to $30,000. Obviously the typical small foundry could not afford to invest that kind of money in a new and relatively unproven process.

The machine developed by the students was manual in its operation, but highly efficient. Even more important, it could be made to sell for less than $2,000. It created such interest that a new company was formed to conduct further research and to develop a machine for the commercial market. The first prototype was produced a little over a year ago. The machine's acceptance has been very good, and although it has been copied extensively, American foundries today are using more of this machine than any other. Although designed principally for small foundries, the machine has also found ready acceptance in large plants and foundries as well.

The machine is basically very simple. The pattern is hinged to the dump box and brought into position by simple rotation of a capstan. Continued rotation of the capstan inverts the box, depositing the sand-resin mix on the pattern. After an investment of 10 - 15 seconds, the box is merely reverted to its original position, the pattern opened onto the frame and the oven rolled over the half-cured shell to complete the curing. While the first shell is curing, the operator steps to the other end of the machine to repeat the operation on the second pattern, thus almost doubling the production rate of the conventional single-station machine. Upon completion of the curing, the shell is pneumatically stripped from the pattern and the cycle repeated. Foundries report productivity as high as one complete mold every minute, or about 3 times that of the jolt-squeeze molding machine commonly used in the conventional foundry.

I would like to emphasize that the benefits of shell molding are not, as commonly supposed, limited to large volume production. We are currently shell molding twenty-one parts of the machine itself, replacing parts formerly sand cast, flame cut, machined from solid bar stock, or fabricated by welding. We are enjoying cost savings ranging from 20 to 80 per cent. In some cases these savings are as high as $25 on each mold poured, and we have amortized our pattern cost on as little as 12 machines.

Last year at Berkeley I presented our thinking on automatizing this machine. Today, a full year later, it is still not automatic. Why? Primarily because we have not found the demand for an automatic unit large enough to offset the added cost. The automatic machines on the market have been plagued by repeated breakdowns. Making the machine automatic would not increase its production rate, nor would it reduce the skill required. Admittedly, automation would make for more consistent production by forcing adherence to ideal times. It would reduce fatigue and give the operator time to operate two machines or to perform auxiliary duties such as cementing or clamping shells for pouring. But it would add about 70 per cent to the cost of the machine, an increase we have at least thus far felt unwarranted. We have made two concessions to automation -- automatic clamps to hold the pattern to the dump box during inversion and an electric timer. But the timer only signals the operator when inversion or curing are completed. It does not actuate other phases of the cycle.

At every stage in the development of the manual machine, it has been borne in mind that at a later date we might wish to automatize it, so before we froze the design of any movement or any mechanism, we gave considerable thought to how it might later be automatized. Whenever the market indicates the desire for an automatic machine we will be ready to produce it. As a matter of fact we are now offering a kit with which the customer can automatize his present machine if he wishes.

We now have under construction two large machines in which much of the work will be done hydraulically. But even these machines will be only semi-automatic; only the heavy work, the rotation of the pattern and the dump box will be done by power.

Perhaps it should be noted parenthetically that new processes such as shell molding, investment casting, powder metallurgy and plastics, are not only well suited to automation themselves but to the extent they eliminate later machining operations, they have an economic effect similar to the actual automation of the subsequent finishing processes.

I also described last year another new machine which, while not specifically designed for small plants, is nevertheless ideally suited to small plant use and to automation. Called the Magna Drill, it represents an entirely new approach to an age-old production operation -- drilling. It is predicated on the assumption that since little can be done to speed up the drilling cycle itself, the greatest opportunities lie in shortening or eliminating the load and unload elements and in drilling more than one hole at a time.

The outcome of this thinking is a highly flexible, highly productive drilling machine. As many drilling heads as desired can be mounted in such a way that they can be quickly arranged for simultaneous automatic multiple drilling in any plane. Thus it can perform operations similar to the elaborate and expensive single-purpose

Excello, Kingsbury, or other automatic index type drilling machines, but with a low initial cost and complete flexibility for rapid changeover to other jobs. The manufacturer calls the technique "fleximation" rather than automation.

There is not enough time here to quote more than a few examples of the economies which this machine provides. On the first of these, as originally set up, the job took 2-1/2 minutes per piece; now it takes 1/2 minute. Previously there were 5 set-ups, including 4 jigs; now there is 1 set-up and $185 worth of tooling, plus a $265 index table. In the first station, the set screw hole is drilled, in the second the axial hole is drilled and in the third, the set screw hole is tapped. Loading and unloading is so rapid that the operator has time to assemble this part to three mating parts -- in other words production time has been cut to one-fifth and the assembly operation is thrown in "for free."

Let me quote several additional examples: The electronics industry, which has such a large stake in automation and which has seen the successful rise of so many small companies, lends itself very well to automation of its own operations through such techniques as printed circuits and modular assembly of components. It is reported that with the fabrication techniques developed under Project Tinkertoy, now available to industry, 35 workers can turn out as much as 1200 could produce by conventional wiring and assembly methods.

To return to the metalworking industry, General Electric has developed an automatic lathe equipped with what is called "playback control." As the machinist makes the first piece, his operations are recorded on a magnetic tape. Then in the same manner as a tape recorder plays back your voice, this device "plays back" the operation, automatically repeats the operation on that lathe, or any number of other lathes so equipped. Hesitations, gaging and trial cuts made by the machinist are not recorded. The same control is now being applied to skin milling in the aircraft industry. As yet there is no indication that this technique will be developed in a form suitable for use in small plants.

The Arma Corporation has developed an automatic lathe directed by a punched paper tape similar to a player piano roll. This lathe reportedly was set up in 15 minutes and turned out in 4 minutes a piece that it took a skilled machinist 30 minutes to produce. In other words, it was set up and turned out the first piece in about two-thirds the time required by the conventional lathe to turn out one piece. Thereafter it turned them out about 8 times as fast as the conventional lathe! And the small plant would not have to mortgage the shop to get such a control unit. It was coupled to a standard engine lathe at an estimated cost of only $1500.

What is even more startling is the accuracy of such control. Utilizing the principle of "feed back," the unit monitors itself, assures itself that it has done exactly what the tape told it to do. The tolerances on this operation were held to $\pm$ .0003!

These controls, I hope, are only the start. With techniques now under development up to 10 or 15 channels of information can be recorded, so that all phases of the machine operation -- loading, unloading, movement of the cutting tool, speed and feed changes, and so forth, can be controlled. One of the big problems will be the cost of "taping;" that is, of putting the information onto the tape in such a form that the machine can "understand" the instructions. Thus far, this requires a skilled technician and in most cases expensive equipment.

Several companies are working on techniques for "taping" by the use of computers. Their objective is a typewriter-like device through which the technician would prepare the tape directly from the blueprint or operation sheet. A "taping service" might be set up in each industrial area. Small plants which could not afford to own such equipment would send their prints into the taping office and receive a processed tape ready for use, in much the same manner as drawings are sent out to have patterns or dies made. The control mechanisms which would mount on the machine to translate the taped information into movements of the work and cutting tools could be highly standardized and relatively inexpensive.

Significantly, devices such as these would find as much application in certain types of "one-off," highly skilled operations as in volume production, -- for example, in die-sinking, pattern making, jig boring or contour milling -- where the geometric and dimensional formulae would be processed onto the tape and in turn fed into the machine.

The whole process is not quite so simple as it sounds, for shifting from one job to another will never be just a matter of inserting a different tape or card into the control mechanism. Any machine is necessarily limited in the functions it can perform, and even on the most versatile equipment, cutting tools, chucks, and so forth, must be changed for each job. Moreover, a group of automatic machines is a far cry from an automatic plant.

At the same time all these examples are significant in that they indicate that partial automation is already practicable in many small plant operations, and that at least some equipment manufacturers are carrying on constructive work which can lead to further automation of intermittent production comparable to that already achieved in process type industry. There will be more when they appreciate the potential of the small plant market. The examples indicate also that automation of the future will not necessarily require a large capital investment and high priced application engineering for each specific job, or long run continuous production. And it will not necessarily inhibit flexibility.

It should be emphasized that the small plant need not wait for low-cost electronic controls. The Magna Drill uses no electronics. Nor will our shell molding machine when we automatize it. Standard, off-the-shelf components such as pneumatic and hydraulic cylinders, solenoids and limit switches are readily available and widely used in progressive plants, both large and small. There are also package units such as drill press feeds, index tables, air vises and hydraulic systems. Some electronic devices such as high speed color sorting equipment, are also available at a cost which the small plant can well afford. In one application recently the worker was replaced by a photo-electric installation costing only $130!

It should be further emphasized that there is nothing sacred or necessarily desirable in 100 per cent automation. The payoff is proportionately as great even in partial automation. You don't buy automation for automation's sake. Automation is just like any other type of work simplification. You go only as far as your pocketbook permits or the potential payoff warrants. If the stakes are high, you go "first class," use all the techniques and devices available to you, make the job 100 per cent automatic. But if circumstances only warrant making it 30 per cent or 10 per cent automatic, that is as far as you go.

The determination of when to automatize is strictly a matter of dollars and cents, evaluating the investment against the anticipated payoff. But automation must not be sold short. Nine times out of ten you can be liberal in estimating the returns, for the intangibles and unpredictables in the form of quality, consistency, safety, morale and reduced fatigue and skill requirements usually mean a much faster payoff than anticipated.

There may be many small plants and perhaps some large plants which will never enjoy a high degree of automation. In our own shop, which is devoted to relatively low volume assembly work, we have no automatic operations and I don't believe we ever would have many. Our subcontractors who are much like most of the small metalworking shops throughout the country, have only a few pieces of semi-automatic equipment -- automatic cutoff saws, punch presses, and grinders. I am sure that highly flexible control devices such as I have described will tap a tremendous market when and if they become available at a reasonable price.

Automation will not squeeze the small plant out of the picture. There will always be a demand for the goods and services which only the small plant can economically fill and so long as we have a technologically fermenting economy, you will have small plants successfully experimenting, innovating, pioneering. During a period of rapid industrial mechanization we have also seen the most widespread industrial decentralization. Automation, I believe, will accelerate that movement for no longer will availability of a large supply of labor be a determining factor in plant location.

The trend in automation equipment appears to be toward greater flexibility broader standardization and decreased cost. But automation will not encourage the large company to invade the field of the small plant. Flexibility, which gives the small plant its greatest competitive advantage, is more than a matter of flexible equipment; it is flexibility of management, of procedures and paperwork. Automation may actually give many small plants new opportunity to compete on the same footing as the large plant.

Will the small plant have the managerial and technical competence to take advantage of the opportunities which automation offers? I believe so. Conferences such as this are contributing much to a broader dissemination of know-how among small plants. Large plants certainly have no monopoly on managerial or technical competence. In spite of the tremendous concentrations of resources, facilities, and technical abilities in large companies, still small plants seem to contribute their share of new ideas, innovations, new knowledges. And they compete successfully in many fields. "Automation engineers" will be available to assist the small plant in meeting the technical problems of automation. This is a new and expanding profession and I would encourage students to consider seriously the opportunities which this new field offers for challenging, satisfying profitable careers.

In summary, I believe that the small plants has more to gain than to lose in automation, more to hope than to fear, so long as it keeps informed and open-minded and continues to demonstrate the imagination, ingenuity and resourcefulness small plants have demonstrated in the past.

HUMAN ENGINEERING SESSION

Session Chairmen: At Berkeley - PHIL WAGNER, President, San Francisco-Oakland Chapter of AIIE, and Manager, Properties Division, East Bay Municipal Utilities District, Oakland.
At Los Angeles - GEORGE W. ROBBINS, Acting Dean of the School of Business Administration, University of California, Los Angeles.
HAYLETT B. SHAW, President, Los Angeles Chapter, Society for Advancement of Management; President, Graphik Circuits, Inc., Pasadena.

HUMAN FACTORS IN ENGINEERING DESIGN

Alphonse Chapanis
Research Scientist
Institute for Cooperative Research
The Johns Hopkins University
Chevy Chase, Maryland

During World War II there was a great need for and production of many complex and intricate machines. But oftentimes these machines did not do what was expected of them because they exceeded the capabilities of the human beings who had to operate them. So I and many other people like me were called in to do consulting and to do basic research on people and their capabilities for operating machines. The question we were asked was, "How can we best design machines so that people can use them effectively, safely, quickly?" There are many other groups who have been interested in this problem, of course, and we are certainly not the first in the field. But I think that because of our somewhat different outlook on these problems, the experimental psychologists have been able to make a few contributions to the older work in this area.

Much of what I have to say today is concerned with machines of war, with radar, aircraft, and fighting ships. The primary reason for this emphasis is that I know this area best. However, I shall also bring in some industrial examples as I go along. In any event, I should like you to keep your eyes open for basic principles, because I believe that the basic principles of designing machines for human use are the same whether we talk about machines of war, automobiles, agricultural equipment, or egg beaters.

One of our most fruitful sources of ideas for research has been the Combat Information Center in a modern warship. The Combat Information Center is a complex aggregation of men and machines which has much to do with the operational effectiveness of the ship. Into this Center comes information by telephone, teletype, television, telegraph, radar, sonar, sonobuoy, and infrared viewing devices. All this information must somehow be co-ordinated, filtered and displayed, so that men can act on it efficiently and effectively. The man in CIC also has to keep in mind a lot of supplementary information: gunnery status orders, command orders, information from radar pickets and airborne CIC's, and intelligence information. Finally, all of his work has to be done under conditions which are far from ideal. I am sure you will recognize many types of human problems in this situation.

Those of you who have seen the bewildering barrage of dials, controls, switches and indicators on the instrument panel of a modern aircraft, undoubtedly can understand why it is that the largest single source of aircraft accidents is human error.

The research we have done has ranged from the very simple to the very complex. Some of our simplest experiments have been concerned with the design of dials and related machine indicators. One of the most troublesome types of aircraft indicators is the altimeter. It is a multi-revolution indicator, that is, it makes use of three pointers. The smallest pointer indicates altitude in tens of thousands of feet. The next larger one indicates altitude in thousands of feet, and the largest one in hundreds and fractions of hundreds of feet. During the war many annoying errors were made in reading this altimeter by both experienced and inexperienced pilots. This kind of error, incidentally, occurs not only in the altimeter, but also in the tachometer, which is also a multi-revolution dial and, believe it or not, in the clock as well (see Fitts and Jones).

A persistent problem in complicated man-machine systems has been the problem of check reading; of somehow simplifying the task of watching and monitoring groups of dials so that malfunction in the equipment can be located very rapidly. Fortunately, we can do something about this since some of our tests have been directed toward the reading of groups of dials. For some types of operations there is a safe or normal operating range. In aircraft this range is usually shown by a small colored segment along the outer edge of the dial. When the needle

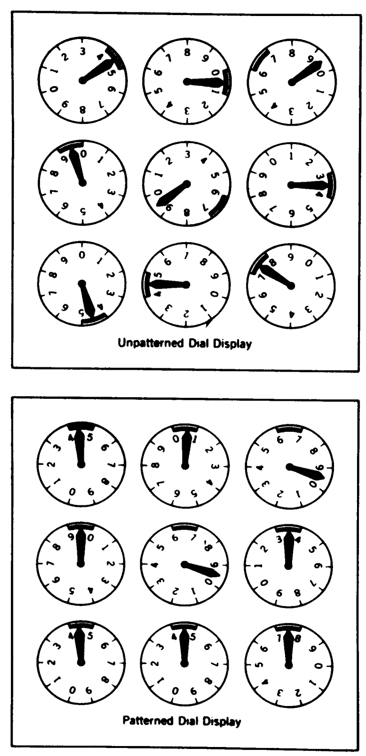


Figure 1

is pointing to this area you know that the corresponding machine function is O. K. In conventional aircraft these dials are now unpatterned as shown in the upper section of Figure 1. I think you will agree that it takes a little while to locate the two instruments here that indicate malfunction. Experiments have shown that patterning, as in the lower section of Figure 1, reduces by a very considerable margin the time required to find malfunctioning equipment. The essential idea behind patterning consists of aligning the safe, or normal operating, ranges so that they all point to the right or to the left.

Actually, we have used a great many other numbering systems, and on the basis of our own research and the research of many other psychologists we have come up with what we think are some good and bad numbering systems for dials. An excellent one is one in which the major divisions are numbered in tens, there are ten small divisions between the numbered ones, and the fives are marked by elongated lines.

To show you that this is not just abstract laboratory experimentation, but that you can find practical illustrations of these, I had our photographer follow me around our laboratory one day to take some pictures of what we have there. Figure 2 shows four that we found. The one in the upper left hand corner has a numbering system which has been proven excellent. The major divisions are

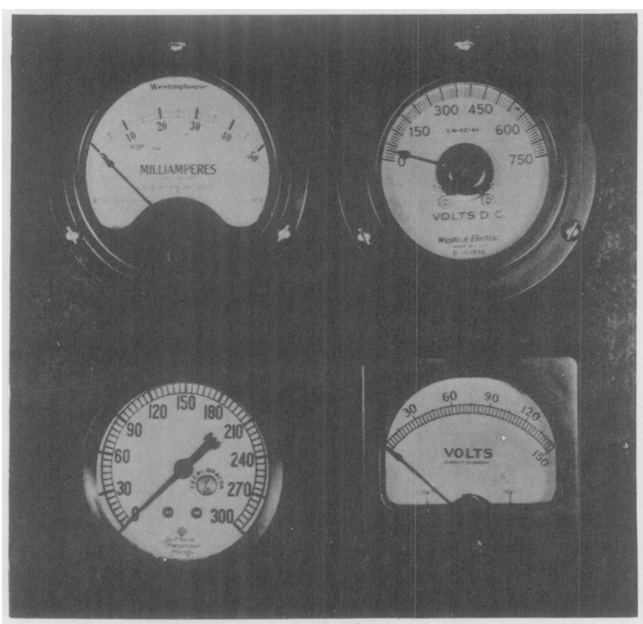


Figure 2

numbered by tens and there are ten small divisions between the numbered ones. And now let us take a look at the one below it. The major numbered divisions go 0, 30, 60, 90. Now let me see - there are 1, 2, 3, 4, 5, 6 spaces between the numbered marks. That means that when the pointer is here .... Well, I think you can see that I would have a great deal of difficulty in reading this dial.

There are still other illustrations which perhaps you can find in your own home. As you know, during the war there was a shortage of meter readers and some of the power companies in the East asked householders to read their own meters. Well, they tried this for a month and then had such a shambles in their accounting offices that they gave that plan up. After that they stamped pictures of the dials on cards and asked the householder simply to draw in where the pointers were. Figure 3 illustrates two meter dials. Both are poor and the lower one is especially bad. This dial violates two important perceptual principles of dial design. The first of these is that you get best results if your scales increase in a clockwise direction. The second is that if you can't make them increase clockwise, at least make them increase in the same direction.

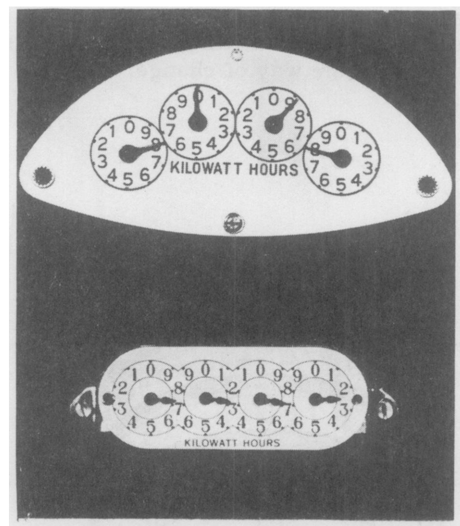


Figure 3

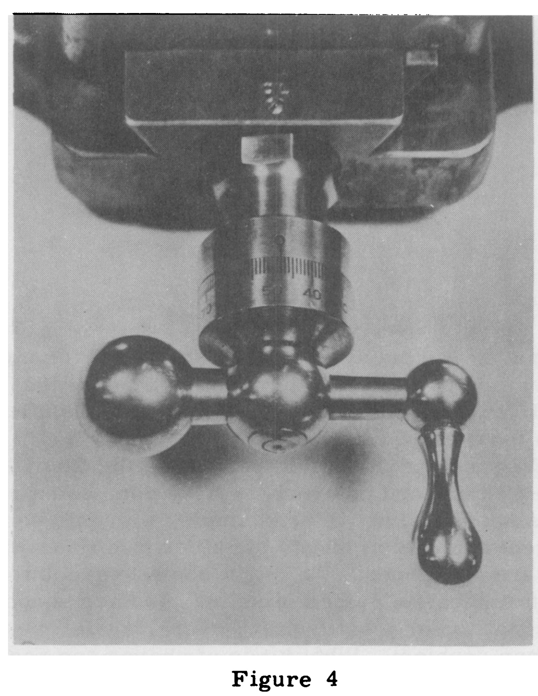


Figure 4

These results of dial design and research have been put to use in industry. In Figure 4 you see an indicator which I am sure most of you are familiar with. The small divisions represent thousandths of an inch, and there are 125 of them around the circumference of the indicator. If the operator of this machine has to move it more than an eighth of an inch, he must note the beginning and end points, count the number of revolutions, and then do some very simple arithmetic. Although the arithmetic is simple, to be sure, it is a good general rule to eliminate mental computations whenever possible. An experimental psychologist in England (Gibbs) asked the question: "Would it be any better if we substituted a direct reading device for this kind of indicator?" Figure 5 shows a device developed as the result of his research. I think you will not be surprised to know that when indicators such as these were attached to milling machines in a typical industrial situation, operators were able to turn out work faster and with fewer errors. I understand that they are now being developed commercially by an English firm. It will be designed, I believe, so that it can be applied directly to English lathes and milling machines without requiring very much in the way of change.

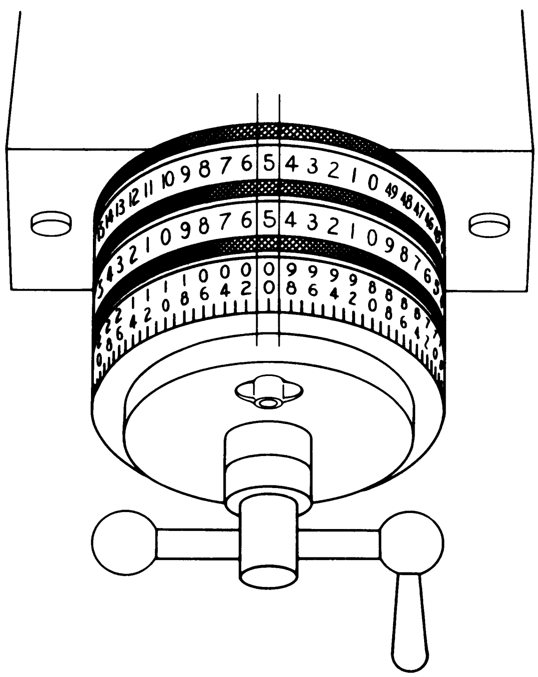


Figure 5

In Figure 6 we see the counter substituted for a dial on a kilowatt hour meter. I think you will agree that you can read kilowatt hours faster from this type of indication than from those shown in Figure 3.

A coding method that could be used in the Combat Information Center, and on which we have done some research, is shape coding. For example, we could perhaps use different shapes to identify the kinds of targets with which we are concerned. We might use a long pointed type of arrow to indicate a guided missile. Another shape to indicate a flat top or a battleship. Here, again, we run into a human problem. What kinds of shapes can people readily distinguish under conditions when the lighting is not good, and when they are rushed? Let us take the case of arrows. Everyone has seen arrows and you might think there is virtually nothing to be done here in the way of research, yet I can assure you there is. The two arrows which you see in the top of Figure 7 are arrows which you have undoubtedly seen many times in your everyday life. These are conventional types of arrows. But one of our Hopkins research psychologists, Sleight, found that arrows like the two lower ones are much more legible and can be seen at much greater distances than the conventional types of arrow.

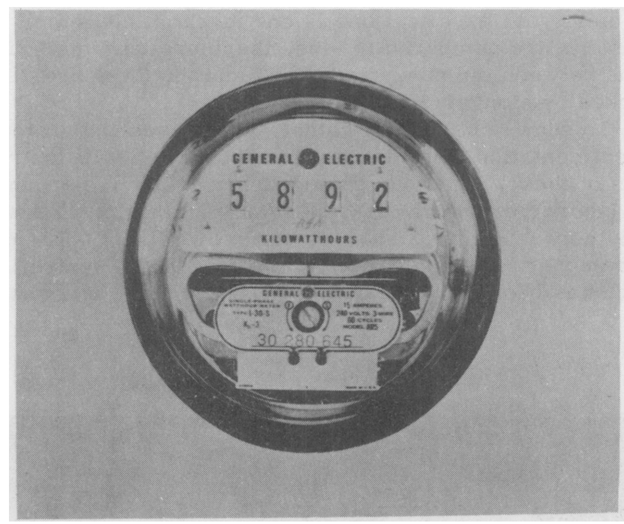


Figure 6

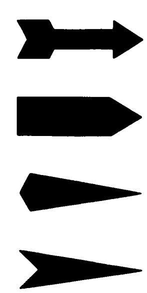


Figure 7

Well, again, does this have any practical application? Yes, I think it does and as an illustration let me show you a puzzle, or kind of game, which the New Jersey State Highway Commission plays with the motorists in New Jersey. Figure 8 is a highway sign not very far from the Bell Telephone Laboratories. The question for the motorist is: "What way to Summit?" I'm sure you will agree that, considering the speeds at which cars travel today, there is no excuse for this kind of engineering design.

Among the kinds of shapes that one could use for shape coding there are, of course, the numbers and the letters. These are familiar shapes which are used for coding information in one way or another all the time. We might ask the question: "What are the most legible numbers and letters which one could design?" There has been quite a bit of research on this question since people in the printing business have been concerned with the legibility of numbers and letters for a long time. The trouble with much of this research is that it has been concerned with type faces which are now in existence - with the kinds of fonts that you can find if you go into the stockroom of a large printing house. This is, I think, not quite the correct approach. We should, rather, take a bold new look at this problem. Suppose we were to forget everything that we now know about letters and numbers, destroy the shapes that we now see used for numbers and letters and try to design the best set, the most legible numbers and letters that we can. What would we end up with?

Our attack at Hopkins (again by Dr. Sleight) on this problem has been unconventional and it has given us a rather unusual result. I don't think that any printing house will adopt our numbers, but let me tell you about it anyway. The way Dr. Sleight approached this problem was to chop out various parts of numbers and see what happened to their legibility. For example, he masked out everything except the top fourth of the numbers, showed the remnants to people and asked them to tell us what they thought the numbers originally were. Following this procedure gives you some interesting results. For example, when the top left half of numbers is masked off leaving only the bottom right, people make about 27 percent errors in trying to guess what the numbers were. Now let us look at the counterpart. When the lower right is masked off, leaving the top left, errors are less than one percent. This tells us that certain parts of the numbers - in this case the top left - are more important than others, say, the lower right. The results are summarized in Figure 9.

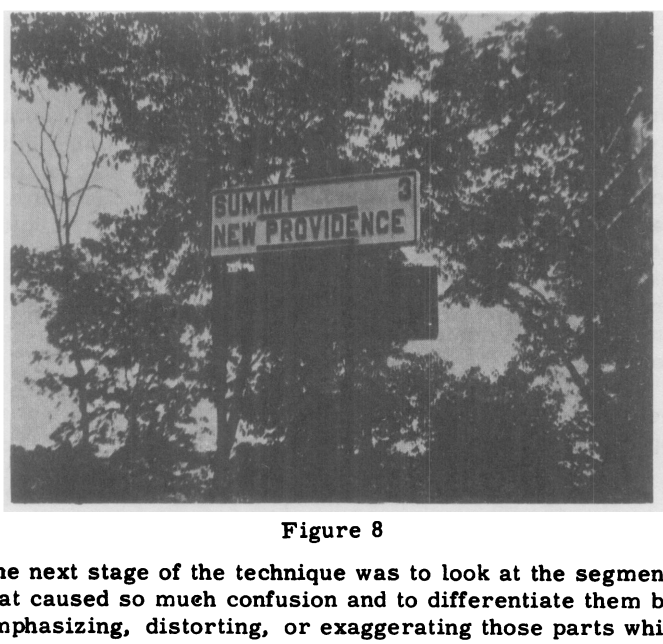


Figure 8

The next stage of the technique was to look at the segments that caused so much confusion and to differentiate them by emphasizing, distorting, or exaggerating those parts which are necessary for their discrimination. What Sleight got, as I say, are some rather unusual results, but I think that you might perhaps be interested in them, as shown in Figure 10. Well, I don't think that anyone is going to change our numbers. On the other hand, we do believe that these are in fact considerably more legible than the conventional kinds of numbers that you see about you.

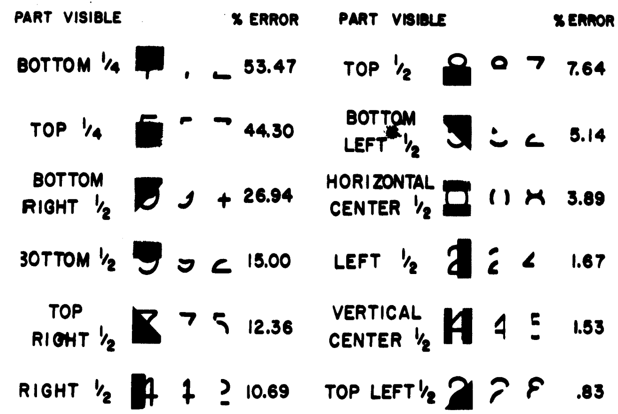


Figure 9

I would like to say a few words now about some researches we have done on problems of movements and controls. Perhaps one of the most important things we could say about this is that controls should move in natural or expected directions. Doing research on this is relatively simple. You set some controls out and ask people to turn his on, make that go off, or make the other go down, and see what they do. Figure 11 presents some recommendations we have made about natural directions

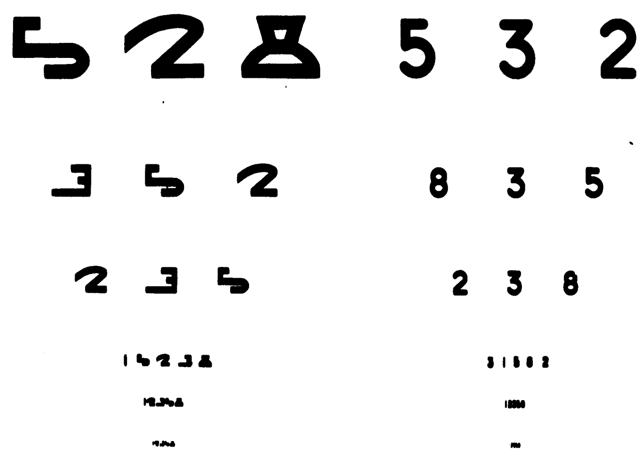


Figure 10

of movement which we think ought to be incorporated in equipment. To illustrate again that this is not a laboratory problem, but that you can find it in everyday equipment, I had our photographer follow me around in just one room of our laboratory. In that single room we found the four different switches shown in Figure 12. Note that each turns on by pushing in a different direction. Whenever you have such conflicting directions of movement you make it difficult for the people who have to use the equipment because they sometimes forget which device it is they are working with.

As a matter of fact, you don't have to go into a factory

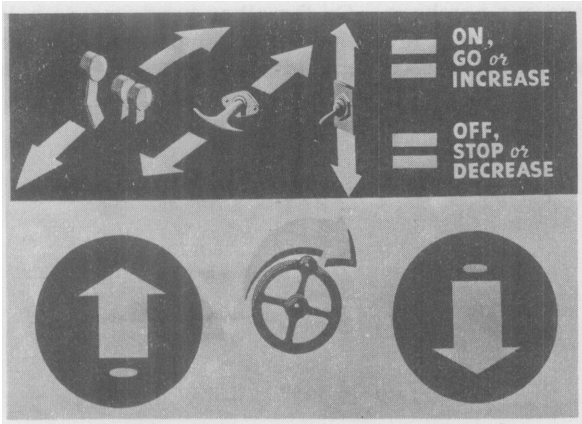


Figure 11

or laboratory to find examples of this sort of thing. I came home one day to find my wife in tears. Under the soothing application of a few Manhattans I managed to get the story from her. She had something in the oven, some thing on the burner, the washing machine was going, and then the head of our household, my son, came in crying because he had fallen down the front steps. At that point something boiled over on the stove. She reached to turn it off and -- well, now let's look at the stove in Figure 13.

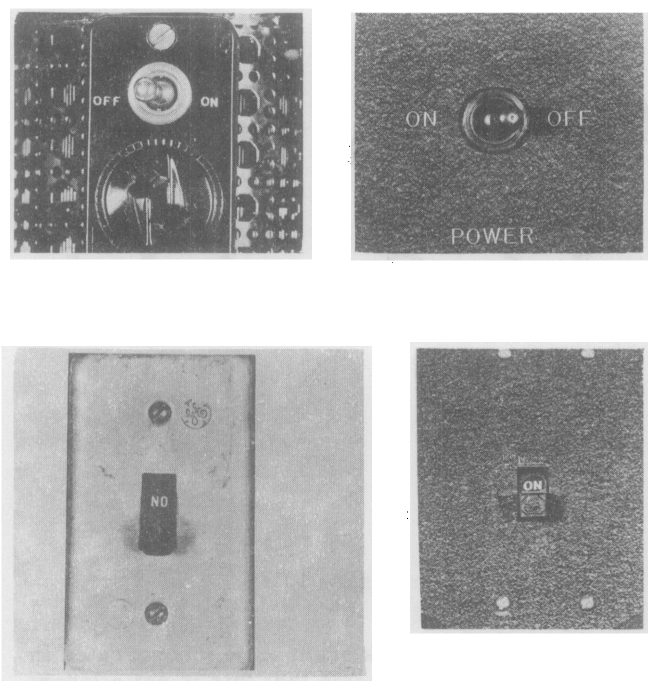


Figure 12

Here are three of the five controls on the front of this stove. The switch for the oven is on the left; the other two switches are for two of the four burners. To turn the oven OFF you rotate counter-clockwise, but if you turn the burner switches counter-clockwise you will turn the flame up higher. Well, I think perhaps you see the point.

In a talk as short as this, I have had, of course, to skip over many important and interesting kinds of researches. This has been only the briefest kind of overview or survey, if you like, of the kinds of research we have done. I only mention in passing the problem of making machines the right sizes. There are a great deal of data now on the sizes that people come in. We know how tall they are, how far they can reach, how high they are when they sit, how long their legs are, and a lot of things like this, which can be put to good use in the design of equipment for people. Now for an illustration, let's look at Figure 14, which is a commercial FM transmitter. This engineer is just a little below average height. I think you will agree that this equipment was not designed for a man of his height.

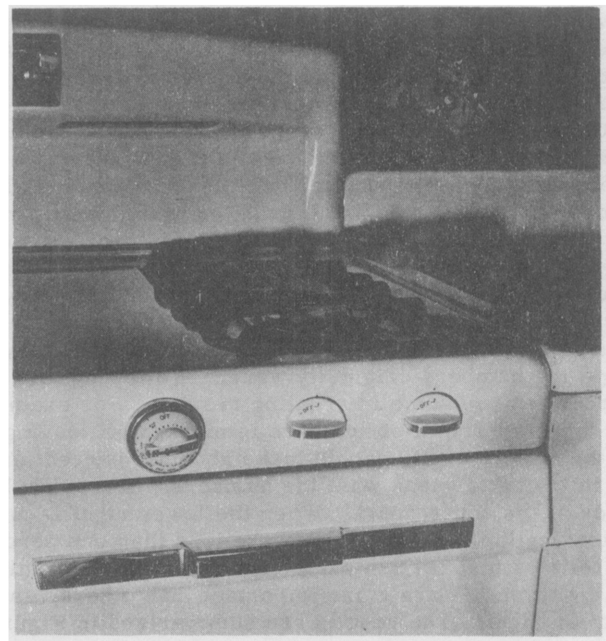


Figure 13

In conclusion, if I were to attempt to summarize some general principles from all of this research I would say that probably the three most important ones are these: First of all, the equipment should be designed to provide the operator with information about its operations and that this information be easy to read, accurate, and up to date. Secondly, the controls on the equipment must be designed so that they can be operated to produce the desired results. Third, equipment should be designed to simplify or eliminate mental computations on the part of the operator.

Perhaps you think that I have been critical of engineers for some of the poor designs I have showed you. I hope you don't get this impression, because I don't mean to give you this idea at all. Rather I feel that the design of machines today requires the services of many specialists. In the design of something like an electric iron, for example, the designer may have to go to someone who knows about cords and heating elements. He may have to go to an expert on metals. He may then have to go to an expert on plastics, and then he may take his preliminary sketches to an industrial designer so that the whole thing can be molded into a very pleasing appearance. I think that the essential point I want to make here today is that we must admit a new specialist into this family of specialists -- a specialist who is concerned with people -- how people see, how they hear, how they make movements, and how they make decisions.

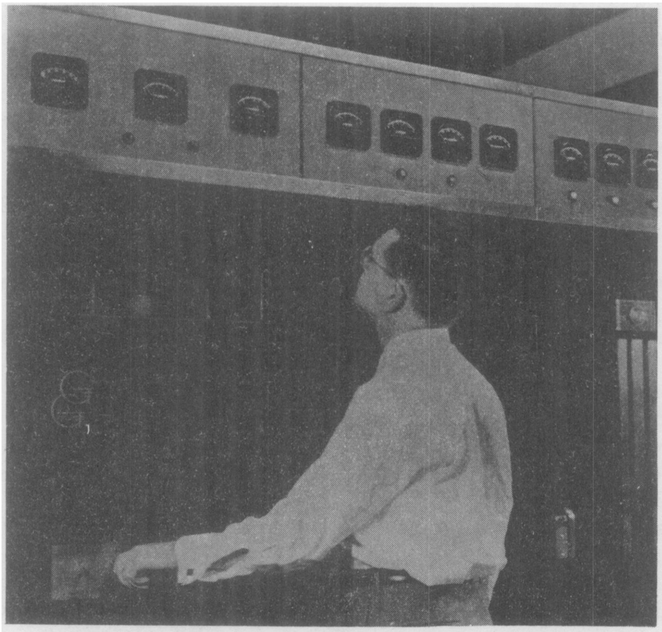


Figure 14

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HELPING PEOPLE TO ACCEPT NEW IDEAS

Gilbert Brighouse
Chairman and Professor of Psychology
Occidental College
Los Angeles, California

I appreciate the broadmindness of engineers in allowing psychologists to come to share some thoughts with you. The time was when your profession and mine viewed each other with considerable suspicion and that's a tragedy because we have many problems in common. We can learn much from you and I hope we have something that can be of assistance to you. Very often people are reluctant to accept new ideas. Often, in fact, the very best ideas we have seem to meet with disapproval or downright antipathy. Again and again from my engineering friends I hear the story that some very good thoughts which they have had have gone unappreciated. You may have heard of the gentleman who was fond of hunting and had a very fine hunting dog. It would bring back the birds and deposit them accurately at his feet. It had only one bad habit. As soon as it had dropped the bird right at his feet it would always shake itself and because it had a long coat it had a great capacity for carrying water and he got very wet. He tried to break it of this habit without success and then found a solution. He trained it carefully to walk on top of the water and he therefore didn't get wet anymore. After he had mastered this he invited a friend -- without telling the friend what he had done -- to come along to see the results. To his dismay, when the dog had walked out and brought back and deposited the first bird, the friend apparently didn't see anything different -- didn't say a word about it -- and he was hurt but kept quiet. Throughout the day this thing was repeated a number of times. Finally, while driving back that evening, he couldn't help but say: "How do you like my dog?" The friend said, "Oh, he is a good retriever, isn't he." The man said, "Yes, but did you notice anything special about him?" "Why, yes," said the friend, "I did. I didn't like to mention it but I noticed that he doesn't know how to swim." Many industrial engineers seem to be in a somewhat similar position. They come out with their good ideas and nobody is interested in the constructive aspects.

I would like to look first at the question of why is it that people are often so reluctant to take a new idea, and then turn to ask what can we do about it. There are a number of reasons, of course, why people are slow to change, but we can break them down into several categories. One of them certainly is that people don't take some new ideas because they don't understand the ideas. Perhaps the communication system has been at fault -- perhaps the words have not been good. I have a friend who was invited a while back to visit one of the most beautiful homes on Beacon Hill in Boston. It was a home that had been established by a captain of a clipper ship several generations ago and it had priceless Chinese vases and other antiques. Among the other guests was a lady with a four-year-old boy. This boy was going about pawing these various objects. The hostess was trying not to watch, and his mother was puttering after him and saying, "Junior, don't, Junior, don't touch that, please!" He came to one particularly magnificent vase and jiggled it and inevitably knocked it over and it shattered. His mother burst into tears and said, "Junior, why didn't you listen to me?" He looked up in wide-eyed astonishment and said: "But, Mother, you didn't say, 'Damn it, Junior, stop!'" We have to couch our messages in language that will be understandable to the people we want to change.

One engineer friend of mine awhile back was designing a new and quite delicate instrument used for measurement purposes. A central component was a magnet and it was essential that this magnet be treated with proper dignity. He issued a memorandum to production, urging that at all steps along the way it be handled very carefully. To his dismay, as he walked through the shop shortly after starting production, he saw a workman driving the magnet into place by putting it down on the floor and stomping on it. He charged into the office of the head of production and asked: "Didn't you tell your people that this has to be handled carefully?" And the production head said, "I didn't know anything about it, why didn't you tell us?" The engineer said, "Look at the memorandum." The production head said, "Well, I read this thing; it frankly didn't say anything to me." Later I saw it. It read like the instructions on a Federal income tax form.

I have a hunch that your profession is second only to mine in the obscurity of many of the things that we say to each other and to laymen. This particular engineer's communication was couched in very long words and sentences that you could get if you took a lot of time. Much misunderstanding reluctance to accept new ideas takes place because we don't make ourselves clear.

However, even when we do make ourselves clear, even when the recipient of the message understands it perfectly, there is still a tremendous amount of resistance because knowledge is not enough. Here was an investigation that illustrated this point. During World War II it was important, because of the meat shortage, to get people to use more of the speciality cuts -- brains, heart, liver, etc. A very well-trained psychologist with a good persuasive manner tried two ways of getting housewives to use these speciality cuts. In the one he gave the best lecture he knew how on the values of these specialities -- what good food properties they have, how tasty they can be, what savings they can effect, and so on. In the other he brought housewives together in small groups and had a discussion. The result was that in both cases the women learned many facts about these cuts. But when they listened to lectures only a minute percentage made any change in their buying habits. When they themselves participated in the discussion there was a considerably larger acceptance. So we can have knowledge and still refuse to change. How could that be?

Partly it is because habits can be so very comfortable. They are like old shoes -- we enjoy wearing them and we hate to get rid of them. Habits are so tremendously strong that they regulate a lot of the things that we do. Dr. Frederick Loomis has told how when he was first establishing his medical practice, just fresh out of medical school, he was called to the home of one of the first families in town. After he had examined the patient he wanted to give some instructions to the very stiff and carefully starched nurse and so he left the patient and the patient's family in the bedroom while they adjourned to the bathroom just off it. The nurse sat down on the bathroom stool and he sat down on the toilet and for a few minutes he gave her instructions about the care of the patient. Then he got up to go and automatically flushed the toilet. They were both very much embarrassed but there wasn't a thing to do except go out and pretend nothing had happened. But he was never asked back.

When a foreman year after year has been laying concrete pipe in the same way and you tell him of a better way he can do it -- faster and more economically -- one of the things you are going to have to overcome is the comfortable old shoe atmosphere that he has adopted that will make him reluctant to take up your improved method. We find that people vary along a continuum, at one end of which we could put the label free-flowing, or flexible, and at the other end we could set a tag of highly inflexible or rigid. Everyone belongs somewhere on this continuum. We would, of course, have more trouble with those who are at the rigid end. Because rigidity refuses to change habits it has its personality value. It gives some people a stability and meaning to life. If there is not much else that has meaning for them in life then their habits have to be clung to. For some persons to get up every morning at five minutes to six and to get the second cup of coffee at ten minutes to eight and catch the 8:02 -- these are the things that carry them. Such personalities are going to find it hard to accept changes.

But there is still another reason why people, even though they may understand the change and the reason for it, are reluctant to take it up and do it, and that is because they may perceive a change as a threat. It may be a threat to the individual's feelings of security. Here he has been accustomed to working in this atmosphere in this way and any change may make him feel less secure. He sees a threat in the bright, fair-haired boy with a stop watch who is going to find a way to reduce my crew from eleven men to ten.

We also resist anything we see as threatening to the area of freedom, to the various places in which we are free to make decisions. Clearly recent years have seen a tremendous reduction in the area of freedom of men in the line, especially at the lower levels of the line organization. A foreman of thirty years ago was free to pick his own men, to promote them, to give them a raise, to fire them, to make his own purchases, to do his own inspections, to keep his own accounts, to do all kinds of things that are now sharply restricted by all of the staff specialists who surround him. Government regulations and union contracts restrict his freedom still further. In consequence, people from the staff are likely to be viewed as suspicious characters because they seem to threaten the area of freedom and the security of line people.

I know several line men whose favorite story goes something like this. There was a young lady visiting on a dude ranch. She head the term "steers" and didn't know what they were so she asked a cowboy. He didn't like to tell her in so many words, but he looked around and said, "Do you see that field over there that has cows in it?" She said, "Yes." "Next to it is a field that has bulls and steers in it. What would happen if we opened the gate between the two fields?" She said, "I believe that the bulls would go into the field where the cows are." He said, "Yes, that is true. The steers would go along as well, but purely in a staff capacity." Some line men get a lot of comfort in that kind of story because it puts engineers, personnel men, and other staff persons in their places.

There is still another kind of threat that makes people reluctant to accept new ideas and this is any threat to their status -- to their feelings of prestige and importance. If a proposed change in some way or other might seem to lower status it will of course be met with resistance. So strong are some of these resistances that even when the man's best interests would seem to us to be furthered by the change, he may still uphold it because of other things inside himself. A utility company that I know not long ago had to change, in order to conform with other personnel, the titles given to the security force -- the policemen of the company. Up to this time they had had two kinds of policemen, security officers and senior security officers. To get along with other titles they were going to change the titles to security officers and deputy security officers. Because they recognized that this change might not be approved, they decided to give a raise in pay of $15 a month to both categories at the same time that the title change was made. But even though $15 a month is a very attractive amount, especially to people in the salary range of these cops, there was profound opposition because there was felt to be less status in the title of deputy and security officer than in the former titles.

Now let us ask what kind of things can we do to make changes easier for people. One of these clearly must be to communicate so that the other side can understand. This is an involved topic much too long to be considered in detail today, but there are a few principles that I would like to note about it. One is that we must use language which would be understandable. Second, we must present it in a form which will be as non-threatening as possible. One psychologist put it this way: "You can't expect people to learn if they feel threatened." We must present it in a way then that will be relatively innocuous.

We should also observe carefully the precaution that communication to work must be a two-way process. You can't simply have a transmitter and a set of receivers and hope to have the receivers continue tuned to the transmitter unless there is some form of feed-back. We must, in order to get people to accept new ideas, build up the feed-back system. They will take new ideas much better when there are possibilities of determining attitudes, ideas, and feelings. There was a cute little experiment done on this a while back in which the senders, who all happened to be college faculty, were to transmit designs in words to the receivers, who were college students. The designs were all made up of rectangles, and the transmitter would say something like this: "This design has a rectangle approximately 2 inches by 4 inches lying on the long side and going up from the upper right-hand corner is another rectangle." There were in each design six rectangles and there were two conditions. Under one, the receivers could give no feed-back. The sender was back of a screen -- he could not see their looks of puzzlement if he was not clear; they couldn't say anything. Under the other condition, there was free feed-back, he faced them directly, and they could ask questions. Well, as you can imagine, there was a very considerably higher degree of accuracy of transmission when there was free feed-back; but there were some other even more important results. One was that while under both conditions learning took place by both senders and receivers with succeeding designs, yet the learning was much greater with free feed-back. Still more important was the fact that both sides felt greater comfort in what they were doing with free feed-back. This was especially true of the senders. But most important of all was the result in terms of the feelings of people. When there was no feed-back resentments built up -- feelings of hostility and distrust and dislike -- which could not be expressed, but when the situation would change for a given group from zero to free feed-back the first result was to inflict a barrage of hostility against the new sender who is now allowing free feed-back. As soon as they could say things they began to express their resentment toward him. However, this hostility never lasted beyond the second design and usually was completely dissipated during the first design. After they had blown off this hostility they then began to feel camaraderie and pleasant comments would replace the negative ones. If one thing is allowed in a communication system -- for the receivers to take turns being senders -- they feel much better about it. That has important implications for getting people to accept new ideas. If we only send out a barrage of stuff, they will build up hostility and will turn down the idea if they can. If they have to accept it because ordered to do so, the new idea may enter only into the official system of values and not into the real feelings and enthusiasms of people. If, on the other hand, they have a chance to feed-back how they feel about things, we have a chance to check on their understanding and we have a chance to enlist their cooperation. The art of sweet reasonableness then is one of the most important things that we can do to become better persuaders.

I know a personnel man who listens quite often to exit interviews. These interviews are with people who are disgruntled about something and are coming in to quit. He has adopted this plan. A guy comes in sore as hell about something that is wrong -- maybe his supervisor is unfair. The personnel director doesn't answer him back and doesn't argue with him -- he just is a good listener and he finds that in a considerable percentage of the cases that these people are good employees. In fifteen minutes or half an hour they have blown off their hostility and say: "Well, I guess I might as well go back to work." He has saved a lot of good employees simply by letting them persuade themselves to stay. We can often persuade people to accept a new idea by letting them talk themselves into it.

Next, in addition to having a good communication system, there is a very important proviso that we cannot inflict successfully a new idea on a group if we remain outside the group. It is a good principle in cultural psychology that it is members of the "in" group who determine what changes will take place. If you as an outsider try to get people to accept an idea you may run up against a very considerable degree of opposition. If on the other hand you have taken time first to be accepted as a member of the working group then the ideas come from within and they are met with far less hostility. Here for example is a branch office of a utility. It has some seventeen or eighteen employees. As part of the folkways of this company they have a get-together about once a month when they meet at different homes and each wife brings along salad or dessert or an entree for a potluck supper. They have enjoyed doing this for a good many years. Not long ago they got a new manager in this office who came from outside the district -- a good, hardworking, sensible man. His wife was also hardworking and well intentioned. But it happened that it was her turn soon after she got there to be the hostess for the potluck supper and she suggested to them: "Instead of your bringing dessert and salad, and so on, this time let me provide the dinner -- I would like to." And so they said of course at first "no," but she insisted. She put on a beautiful spread that could have appeared in one of the ladies' magazines in color, candlelight and silver, white linens and all the trimmings, and the food was delicious. They all said the polite things but on the job the next day and for weeks after there was a barrier between the members of the office force and the new manager. They didn't trust him as much any more, because he and his wife had made themselves into strangers. If only she had waited a while longer and had been accepted as a full member of the group she might then have suggested a change. But when she as an outsider attempted to put a new pattern into effect they resisted it because they perceived her as an outsider trying to put on airs.

Here is the new head of an engineering drafting department. In this company the draftsmen happened to have a nice little practice of getting together for twenty minutes to half an hour in the middle of the morning to drink coffee, and talk. Now I know what they talked about; they talked about the job on the whole -- occasionally a story -- but pretty much they spent that time in coordinating their efforts and swapping ideas, and it paid. But the new manager didn't like to see these fellows sitting around drinking coffee. He said, "We have a ten-minute coffee break in this company and from now on you will take only ten minutes." He didn't even have the grace or guts to say it face to face; he put it on the bulletin board. They immediately stopped having a half-hour coffee break. They conformed officially but they now found better ways to waste time and the benefits which they had of coordination were dissipated. If we are to get an idea across we must be sure first that we are acceptable. We must be a member of the group.

Another principle is this: that to get people to accept a new idea the most important point of all is to get them involved in it. If they have no part in the new idea they will not like it and they are unlikely to accept it thoroughly. If, on the other hand, they have some pride of ownership, some feeling that they have contributed to this new idea, they will get deeply involved. In an aircraft company a while back there was to be quite a profound organizational and procedural change. One of the key people who would be affected was a very negative individual who would almost certainly oppose the change. He was handled very well by his boss on this particular occasion. Before the general announcement the boss took him aside and asked for his suggestions on how to get the changes accepted by others, since, as the boss pointed out, some of the others would be resistive to any change. After he had made several suggestions the boss asked him to be a missionary to convince other persons of the necessity of this change and the correctness of this procedure. Because he himself now got involved in it and had to persuade others, he became one of the most ardent proponents of this new view. This ties in with what many of us have observed -- that you don't really learn anything until you have taught it. They say you have to teach a course and then you begin to get new facts and you have a much better perception of it. The more involved we get the better the results will be.

How do you get a man involved, whether it is the president or the personnel director or Joe, the foreman? We do it, in part, by asking him rather than by telling him. If you tell him things he may put his back up. But if we can ask the right kinds of questions we can get the involvement. We do it in part by avoiding status differences as far as possible. The more difference a fellow perceives between his level and ours, especially if it is the wrong way, the more will he feel it necessary to oppose a change. If we can ask the fellow for his suggestions rather than tell him about it, we are going to lower his resistance and increase his enthusiasm. Especially is this true if he has to do something about it himself.

Harwood Manufacturing Company which makes pajamas has reported on this experience. Company policy required that all new women hired had to be under thirty. When with World War II new employees became harder to find, the personnel director sensed that they could perhaps find some useful people who were older. He tried hard to persuade top management to change the policy. Since he tried to persuade them, he at once ran into opposition, because immediately they said: "Well, older women are not so efficient, they cost more, they are absent more, they spoil more materials, etc." The personnel director said: "Look at Mary over there. We have had her a long time. She has been with us eighteen years and is a very good employee." They said: "Sure, Mary is good, but she is an exception." "Well," he said, "Look at Betty." "Yes, but Betty is an exception." No matter how many logical arguments he could bring up he ran into this wall of resistance. Then he changed his tactics entirely. He said to management, "Since we have these women whom we employed before they were thirty, but who are now in their thirties, let's find out how much they cost." That's a good question to ask management any time. Then he asked: "If we should investigate the productivity of our present older women, what would be the criteria?" He didn't tell them what the criteria should be -- he asked them. And they said: "Well, let us measure how many pairs of pajamas they make, how much material they spoil, how often they are absent." They suggested six or seven criteria of success. That was a good first step. Then he said, "Shall we take the women over thirty and women under thirty?" And the management said, "No, let us take women under 20, 20-24, 25-30, 30-35, and then over 35." So they got more involved, you see. Then he had them help collect data and they got more and more intrigued as they were doing this. When they had the data in they found sure enough that older women were in many ways superior to the younger ones. They were more stable on the job and often better producers.

Management was now convinced that they could employ older women. And they said, "Let us change the practice at once." But the personnel director asked, "What about supervision?" So he tried this on one supervisor, saying they were going to change their practice and he showed her the figures and she said, "Well, that doesn't mean anything. Older women aren't any good." He said, "Look at Mary." "Yeah, but Mary is an exception." He found that the more logical he got, the more clearly he presented the facts, the stronger the resistance became. So he had to get supervision involved too. By a succession of meetings they came to the place that they were willing to accept older girls.

The same principle holds true exactly in any thought or feelings that we have to reason with. If we can get people to ask the questions themselves and to suggest the answers themselves they become increasingly willing to do something about it. But if we do the thinking for them, if we tell them, resistances mount.

In summary, then, people resist ideas sometimes because they don't understand the message, don't know what is going to happen; sometimes because they understand but their habits are very comfortable; and sometimes because they feel threatened either in security or in area of freedom, or in prestige. Our best means of combatting these attitudes are first to be sure we are communicating as clearly as possible, to give them a chance to listen, to try to understand their points of view, and to join with them to build up the good feeling, the sense of belongingness, so that they can accept these ideas as members of a strong group rather than as isolated persons, and by getting them as involved as possible in the processes that are going on.

There is one final suggestion I have. If, having practiced very clear communications, having practiced the principles of belongingness, and having practiced the principles of involvement, you still find people slow to accept new ideas, the most important advice of all is to adopt a philosophical attitude. That goes a long, long way in your profession and mine. We do find that people are often slow in spite of the best of climates and if we can philosophically wait, put out ideas and wait around a year, five years, ten years from now, we often find those ideas do eventually sink in.

FUTURE HORIZONS SESSION

Session Chairmen: At Berkeley - EVERETT D. HOWE, Associate Dean, College of Engineering, and Professor of Engineering, University of California, Berkeley.
- ROY W. JASTRAM, Professor of Business Administration, University of California, Berkeley.

At Los Angeles - L. M. K. BOELTER, Dean of the College of Engineering, University of California, Los Angeles.

ELECTRONICS ENTERS INDUSTRIAL ENGINEERING

Simon Ramo
President and Executive Director
Ramo-Wooldridge Corp., Los Angeles
Research Associate, California Institute of Technology
Pasadena, California

Business and Industry Need New Techniques

Business and industrial organization have become complex and are rapidly increasing in complexity. Instead of hundreds, thousands and tens of thousands of individuals are now in need of close coordination to make for a successful industrial operation. It is not only desirable, but in some instances almost necessary, to keep track of what everyone is doing, to see that what everyone does is part of the job in accordance with the plan, to meter and judge to plan, and to be prepared to shift plans easily. This necessitates a tremendous amount of red tape and paperwork.

These factors are complicated by government and labor relations requirements and procedures. The number of slips, forms, and cards that must be filled out concerning every person and everything that happens in the operation increases so rapidly that these paper systems become the bottleneck in the operation. Further simplification, systemization, and automation, with the object of obtaining relief from this burden of red tape and paper, is urgently needed.

There is a great consciousness now in business and industry of the fact that it is desirable to know better what has happened, that is, to increase management "visibility." It is also desirable to control what is happening. Moreover, it is also valuable to be able to predict what will happen in the operation of a business as a function of the various parameters open to the planner, and as a function of the decisions that are being considered. This is particularly true at the present time when the complexity factor is understood to be large and industry is again becoming highly competitive. Appreciation is growing of the possibility of "optimizing" the operations of a business. Small differences in systems procedures, visibility control, and prediction ability can make or break some businesses.

The Present State of the Electronics Art

Quite independent of the growing needs of business and industry that make it ripe for the introduction of basically new techniques, the times are technologically right for the development of new synthetic intelligence devices through electronics and other new techniques of science and engineering. There are scores of aids to business and industry and transportation that the present technological art is capable of providing without a single new discovery in basic science. It is possible for engineers today, on the basis of known pure science, to design and produce devices which could displace a very large fraction of the white collar workers in business and industry who are doing jobs in which the proportion of their intellectual capabilities used is rather small. These people are engaged in routine paper work or routine intelligence transfer assignments, which can be reduced to simple, equivalent thought processes that electronic machines can handle, and can handle better. Moreover, modern technology has advanced to the point where it is possible for instruments to be designed to measure automatically various conditions and phenomena important in industrial processes and operations. These measurements can then be compared automatically with previous agreed-upon and recorded data, and automatic controls can be set off which will bring the process or procedure or operation closer to that which is desired than the measurement discloses to be the case. A very much wider range of data handling and of automatic control, replacing the present human handling of data and human control, could be provided in almost every business and industry without any further extension of the laws of physics and chemistry.

A perfect example of this status of scientific and engineering art applies to the military. For various reasons, the military today has a tremendous need for these synthetic intelligence devices. To see that this is so without revealing military secrets, we need only to consider the importance of control of the air, both to safeguard our own country from enemy bombardment and to make possible retaliation. With greatly increased speeds and the need for operation under all weather conditions, it has become necessary for the military to consider guided missiles, in which the human pilot is omitted and the problem of destroying the enemy in the air is left to synthetic brains which will find the enemy, close on him, predict where he will be despite his maneuverings, and destroy him. During such an operation, the synthetic brain must have memory, stored intelligence, the ability to reason, compute and deliberate, and the ability to make decisions. We are developing these things for the military today because our basic science permits it. The engineering art is developing, in other words, without having to wait for Einstein to come through with a second and more complex theory of relativity.

The military situation in the world is sparking the program and is financing the development of new techniques, many of which will have application to non-military requirements as well. Military applications demand that the available science be reduced to engineering applications in a period of several years. Business and industry have some similar needs, and the same science can make possible business and industry applications on some suitable time schedule.

The Need For Systems Analysis

Electronics offers the possibility of unusual speed, flexibility, and the handling of complex interconnections of data-handling and storage systems needed in a typical, complex modern business and industry. But the very factor that makes the potentialities of electronics interesting in business -- namely, the growing complexity of industry -- also should suggest strongly that mass application of new electronic techniques should not and cannot take place in business and industry without parallel high-quality detailed analysis of the business operation.

One of the characteristics of electronics development in the last quarter-century has been the rapidity of progress in its application. No home or business is without evidence of the advantages electricity provides when that electric flow is contolled in a free stream of electrons in evacuated electron tubes. This advance could not have taken place without the combined effort of scores of technically trained people who saw the possibilities, analyzed them, invented new devices, and reduced them to practice. In this whole practice we find certain kinds of applications where "the gadgetry" part of electronics dominates. Here comparatively simple individual devices do rather narrow individual tasks. An example of this is the simple home radio receiver. It is now cheap and reliable, and has been caused to be both by the flood of contributions over the years that resulted from "drops in the bucket" by many individuals, not generally coordinated. There is another side of electronics developments, however; it is exemplified by modern telephone systems. Here the greatest of attention has had to be given to the problem of complete system analysis and synthesis. As soon as large complex systems with many interconnections must enter the picture, the problem changes to one of substantially different character.

Now it may be that some individual electronic gadgets, applied here and there to individual businesses, may pay off very heavily. But I believe that it is true that the real possibilities of electronics in busines and industry have to do with the speed, flexibility, and interconnection possibilities of electronics, and that these pay off in large systems.

This is not generally appreciated. Today we see too many gadgets offered to business and industry, and therefore offered as tools to the industrial engineer, without the accompanying business and apparatus systems analysis. The performing of these analyses and the succeeding synthesis of improved data-handling systems constitutes much more of a bottleneck in the application of these new techniques than the state of the art of electronics.

Of course, it is not really possible to advance radically the business data-handling methods of a large company by electronics or any other new techniques, without great advances in the understanding and analysis of the parameters that constitute the controlling ones in the operation of that business and industry. Suppose we wish to equip the supervisory staff of a modern production organization with the means to predict the impact on their operations of various possible decisions which they are considering making. It is obvious that electronic machines that basically store data and compute new combinations of these data cannot arrive at any predictions unless there existed on the part of designers of these machines a quantitative understanding of the way the individual parameters of the business are related to give various results.

This problem has become especially noticeable in recent years in the case of complex military weapons systems. Many scientists were called into the solving of these problems, and the result has been an increasing appreciation of the possibilities of good scientific analysis of a military system before attempting to specify and design in detail the component parts of such a system.

What is being emphasized here is that research into the operations, analysis of the procedures, and definition of the problem are imperative parallels, if not prior tasks, in any major entrée of electronics into business and industry. The tools of the physical scientist are appropriate, though only part of the total tools. A complex business, like a complex machine or complex natural phenomena, can be approached scientifically, an attempt made to understand its laws of behavior, and an attempt to create approximate quantitative mathematical models of the operation, so as to constitute the first step in the possibility of predicting various results as a function of various possible actions and controls.

The Distinction Between Tools and Their Use

With the great needs of business and industry for new techniques, the acceleration of the development of such techniques by the military, and the theoretical foundation for such new techniques in modern science, the industrial engineer has the possibilities now of two interesting tools for potential application to business and industry. One of these is perhaps covered by the word "electronics," and is intended to signify new means of handling the data of a system and the thought processes necessary to compute and predict new data from stored or input data. The other techniques open to the industrial engineer are the analytical tools of the physical scientist, applied to business and industry as though they were complex physical systems. With both of these factors, great possibilities exist and, with both, the possibility of drastically bad results are equally possible.

Nothing perhaps could be worse for a modern business than to be analyzed by the wrong analyst, so that its operations are experimented with and its procedures and technique of operating and planning are altered to chaos. Nothing could be worse as a tool for this "wrong analyst" than large complex electronic gadgetry. Comparing this with a human being in need of medical attention, we have the possibilities of the wrong diagnosis, on top of which we have the possibilities of prescribed medicine that can make the man sicker or dead.

Physical scientists are very important contributions to our national welfare, our progress, and our security, though only a small fraction of physical scientists are well suited to directing the analysis of a complex business and industry. Too many of the scientists who are capable of contributing to over-all analysis are unable to see the broad problem. We have plenty of examples in military operations analysis of individual scientists gifted in the tools of analysis -- that is, who understand the mathematics and can set up complex equations and solve them -- but who make the wrong assumptions right at the beginning. They often become too enamoured of the multi-significant-figure possibilities of their optimization equations. The result is that they may not only miss the problem and work with rather minor ones, but they may arrive at wrong answers entirely. It is a difficult field. As a matter of fact, the analysis of a complex business and industry requires the application of quite a number of kinds of talents and understandings, so that the typical competent physical scientist should be at most only one ingredient of a complete team.

This is made even more serious when we move to the synthesis of new and improved systems. Here we have the possibilities of gearing the operation to particular machines which, if not really appropriate to the operation, may require that the operation adjust itself to them in a way that is harmful rather than beneficial. It is often true of the highly theoretical physical scientist, needed for comprehension of the higher mathematics of the typical tools used in the analyses, that he also overlooks certain practical matters. Typical such factors are realiability and maintenance of new equipment, the ability of a business or industry to assimilate new techniques, and psychological and physiological factors. It is also unfortunately true of the typical electronics enthusiast that he will too often claim for electronics its ultimate possibilities and ignore many limitations inherent in the specific designs with which he must work.

Not too many business men are likely to allow their business to be turned upside down by a group of scientists, nor are they likely to spend millions of dollars for complex new electronics systems on the claim that they may revolutionize the return on the investment. But many business men and industrial leaders are likely to develop a highly negative reaction to over-claims by the industrial engineering body. (I think for these purposes we can lay all of these effects at the doorstep of the industrial engineer. During a period when new techniques enter any engineering body from the pure science side, the engineering body can for awhile be absolved from blame, but actually the moment a Ph. D. in Physics becomes an "operations research man" in business and industry, he is at that moment an industrial engineer, whether he is willing to admit it or not.)

Properly carried through with caution, and with broad control of the over-all analysis and synthesis -- always accompanied by conservative claims -- the analysis of a business and industry with regard to the possible introduction of new techniques can undoubtedly create great improvements. In fact, I would not be surprised if the greatest improvement during the next few years results not from the installation of new electronic machines, but rather from the improved understanding of the operation that will result from the analyses of the operation and the attempt to synthesize new systems that can exploit the possibilities of the speed and flexibility of electronics.

Summary - The Outlook for Electronics in Industrial Engineering

Proper appreciation of both systems analysis of a scientific kind and the introduction of new electronic techniques gives the industrial engineer new tools with which, during the next decade, he can hope to make major improvements in business and industry. The most important item to remember is that this is basically a difficult field. It takes unusually competent industrial engineers. The number of available, competent individuals, including the electronics specialists and the theoretical physicists, is so small compared with the need and compared with the pressure to install new techniques that, in my opinion, this will continue to be the bottleneck for many years. Accordingly, the mass replacing of white-collar workers by electronic machines must be a very gradual process. The industrial engineer should seek to become acquainted with the possibilities of electronic techniques. Electronics is so new and promising that the industrial engineer and the business executive must be equally alert, and they must stay close to organizations that are developing these devices and to organizations that are making the analyses for the potential use of these devices. For the next few years, I believe that it is not nearly so important to press new electronic equipment into a business and industry as to go over the operation to reduce its problems of operating and planning to a set of logical thought processes. With or without eventual electronic exploitation, this analysis will undoubtedly help management to organize the company better and to make superior short and long-range decisions.

THE FUTURE INDUSTRIAL GROWTH OF THE SAN FRANCISCO - OAKLAND BAY AREA

William H. Park
East Bay Division Manager
Pacific Gas and Electric Company
Oakland, California

To speak of the future industrial growth of an area today one must concede that we have arrived at a point where industry is a major factor in the lives of many people, or the subject would be of little interest to anyone gathered here today.

It is true however that, with the passing of each month, the industrial growth in the whole State of California, becomes more and more important to our whole economy.

New people are still coming to California at the rate of about 300 families per day. These people need jobs - new industry means new jobs - expanded industry means new jobs - therefore the industrial growth is very necessary if we are to keep a well balanced economy.

During the past few years California observed its Centennial Anniversary. Many cities around the San Francisco Bay have had fiestas, special pageants and plays which were presented to show the dress and habits of our earlier settlers. I mention this subject at this time because people fail to realize how young our industry is on the Pacific Coast when compared to many industrial areas of the Central United States and the Atlantic seaboard.

It is sometimes hard to believe that it was as late as 1846 when Captain John C. Fremont arrived at Monterey and formed the Republic of California. The discovery of gold in 1848, and the large increase in population that followed this discovery, set the stage for the earliest period of any demand for industrial expansion. Prior to this period one could say that California was nearly a 100 per cent agricultural state.

The rush of people into California and the Bay Area, following the discovery of gold was great, and it is quite natural that a percentage of these were smart enough to see the advantages of remaining here to establish businesses, that would service people passing through the area into gold fields, and later establish industries to supply their needs.

In later years with the industrialization of mining and the passing of the "pick and pan", a great deal of the simple machinery moved into the Bay Area by vessel, and then up the Sacramento River by river boat for use on the western slopes of Sierras.

To service much of this equipment our first industries were the simple blacksmith shop, and machine shops. Later came the steam driven saw mill machinery - and a few foundries were established to supply and service the needs of the early miners.

In mentioning the importing of the simplest machinery from the eastern coast it must be remembered that practically all of this came via water, and it was not until 1869 that the first transcontinental railroad terminated its first trip to Oakland (85 years ago). The first Ferry service to San Francisco was established in 1868.

There is another subject that might be touched upon in discussing the early development of the Bay Area and that is the establishment of the Oakland Academy, which started in 1853 under the direction of Rev. Henry Durant. This is of great interest because by 1860 this small school had developed into a full fledged college and was later transferred to Berkeley in 1868. We are on the site it finally occupied and the first class was graduated in 1873. During the State Legislature of 1879 legislation was passed and this small college became the University of California. It has now grown to be the largest University in the world.

I have mentioned some of these earlier events because we have made tremendous strides in our industrial growth during the past 75 years - a short period.

Today as we look back our agricultural industry is still the largest - our oil industry starting with the development of the "Tar Pits" near Mission San Fernando in 1855; our steel industry and chemical industries are less than 100 years old; our great gas utility industry is just 100 years old, and our electric utility industry is 75 years old.

No discussion of industrial growth in California is complete without some mention of agriculture's contribution, because our future industrial growth in the Bay Area is vitally affected by the success of our farmers. Agriculture is California's biggest industry, producing each year the largest sum of new wealth, and the largest tonnage of goods for manufacture, transportation and trade. Farm production of fruits, nuts, truck and field crops now exceeds 25 million tons annually.

Cotton is the State's largest money crop, with an estimated value of $300 million for 1953. It moves into channels of trade for the making of textiles, furniture stuffing, explosives, cotton seed oil, stock feed and numerous other items. Much of this processing is done in the Bay Area.

The State produces nearly three million tons of grapes, providing the foundation for a $500 million business, which supplies fresh grapes, wine and raisins to domestic and foreign markets.

I cite these examples to substantiate the claim of business leaders in such cities as Fresno, Bakersfield, Salinas, Stockton and Marysville that 85% of all business in these community areas stems from agricultural production and income. For the State as a whole probably 40% of all commercial and industrial business has its origin in agricultural production.

Not only does California agriculture supply vast quantities of raw materials for use in commercial and industrial plants, but also the California farmer is an outstanding customer for the products which industry produces, and they also provide the market for a great wholesale business located in the Bay Area. He plants and harvests crops every month of the year. His operations are highly mechanized, his standard of living is above the State or National average levels, and he has an average gross income of nearly $20,000 per year, most of which is promptly circulated among the business concerns of the community in which he lives.

Anyone who is at all familiar with California farming conditions understands the importance of water for irrigation. Water has been our farmers' biggest problem, but the practical way in which they have handled the water supply problem has, more than any other single factor, enabled California to obtain the enviable position of the No. 1 agricultural state of the nation.

In the great Central Valley, where three-fourths of all the state's farm products are produced, an acre of unirrigated farm land will produce an average gross income valued at only $30 per year, but an acre of irrigated land will produce an average gross income valued at $280 per year, an increase of approximately 900%. Incidentally, you may be surprised to learn that 70% of all irrigation water used by farmers in the Central Valley is pumped electrically, 55% from wells, 15% from streams and canals. The remaining 30% is obtained from gravity flow streams, and canal systems.

There are approximately 6-1/2 million acres of farm land under irrigation within the state. Nearly 5 million acres of which are located within the great Central Valley. These figures are not static. Since 1945 new land has been brought under irrigation at a rate of about 150,000 acres per year, and based on careful surveys made under the direction of the State Engineer there still remains in the Central Valley more than 4 million acres of additional farm land which can be developed, and for which an adequate amount of irrigation water can be economically supplied.

In addition to maintaining an adequate food supply for the state's rapidly growing population, this potential represents a tremendous business opportunity and assures a sound basic structure for continuing business growth.

Previously I mentioned cotton as the No. 1 money crop of the state. Because of the foresight and guidance of a group of farm leaders dating back to about 1925, California now produces the largest block of single species (long fibre) high grade cotton of any place in the world. This is a special grade of cotton which has a ready market over mixed species grown in most of the other cotton producing states. However, because of California's rapid expansion of cotton acreage during the past six years the government's control problem which becomes effective this year enforces a reduction in California cotton acreage of about 34%, or 480,000 acres. This large reduction, coming all at one time, creates a problem of considerable magnitude, one which, it is hoped will be temporary, but which will undoubtedly reduce gross income for at least this one year.

This reduction in cotton production will also be reflected in the many cotton processing, warehousing and transportation agencies. However, the California farmer has more than 250 different crops to choose from, and this decrease in cotton acreage may prove beneficial to other agricultural industries. The experts tell us that in spite of this enforced displacement of cotton acreage, California's agricultural economy is on a sound basis, and we can look forward to a good year in 1954. One thing we can depend upon - the trend of California agricultural production over the years will be upward, and this trend will enable agriculture to continue its vast contribution to the expanding economy of the state.

Because of our central location many San Francisco Bay Area industries are now producing material for servicing the needs of this large agricultural industry. Some of these are:

- Commercial fertilizers
- Pumping equipment - metal piping for water distribution
- Food processing machinery
- Fuel supplies
- Farm equipment for planting and harvesting
- Warehousing and shipping facilities
- Distribution and service supplies

and our great Banks provide monies for commercial credit and use.

The November 23 issue of Fortnight says:

> "California is currently undergoing the early stages of a profound change in its basic economy ... realtors, utilities people, and other primary sources of information on industrial activity indicate that there is, right now, a more intense and healthy interest than ever before on the part of industrialists--both eastern and western--to branch out and establish more manufacturing and distributing plants in California. This means increases in industry, and payrolls for California. While it has been going on for some time now, it is stepping up in intensity and growing by leaps and bounds."

Men of engineering background are too thoroughly trained in precise thinking to accept such reports without asking, "Is there such a trend, and if so, what are the forces in back of it ... how durable are these forces ... what will their net effect be?"

Records collected by the office of the "Bay Area Council", an organization with representation from the 9 counties surrounding the Bay Area, and data secured from Chamber of Commerce files show that:

> Over 700 million dollars were spent for 3000 plus new or expanded plants in the Bay Area during the past 7 years. Of this total approximately 140 million dollars were spent for 1250 new plants and the remaining 560 million dollars were spent for expansions in approximately 1750 existing plants.
>
> To this can be added the new Ford Plant near San Jose where from 40 to 50 million dollars will be spent by the time of completion late in 1954 or early 1955.
>
> The slope of the curve for total new expenditures has been on a constant rise, each year since 1949.

These figures are for manufacturing and industry and do not include money spent for utilities to service this great industrial expansion - I shall touch on that subject later in my talk.

These figures indicate the continued growth of industry in past years but what of the future trend - will it hold up - will it continue or is it temporary?

Two years ago the "Bay Area Council" hired Elmo Roper, a nationally known Industrial Analyst, to discuss with leading manufacturers, and others in the Eastern cities, their opinions and plans, if any, for future expansion. That study showed that most firms considering a west coast location, are thinking of it in terms of serving the entire far western market. In other words, practically none of those Mr. Roper interviewed were considering a Bay Area location just to serve the Bay Area alone. These industrialists repeatedly said in effect, "California and the Far West now constitute a definite market that did not exist prior to World War II."

The ever increasing importance of the Bay Area and the Far West may be shown by a review of a few statistics.

In 1900, 4.0% of the population of the United States lived in the Far Western states. By 1952 there were 17,835,000 in these states, 11.4% of the U. S. population. In the decade 1940-50 the U. S. registered a 14.5% gain in population, the Far West, 46.0%. California led the nation with a 53.3% gain during the decade, Washington was third, behind Florida and Oregon, sixth.

The per capita income payments in the Far West have risen considerably above the U. S. average. Between 1929 and 1952 per capita income payments increased

209% in the United States. All of the far western states exceeded this increase:

Arizona	425%	Oregon	358%
California	344%	Utah	293%
Idaho	280%	Washington	305%
Nevada	447%		

The average per capita income payment in the U. S. during 1952 was $1,639; four of the far western states were above this average:

California	$2,032	Oregon	$1,733
Nevada	$2,250	Washington	$1,810

By 1952 the effective buying income per family throughout the country was $5,086. Four of the far western states exceeded this:

Arizona	$5,168	Nevada	$5,815
California	$5,408	Washington	$5,285

From this data one can see that the Western States have people that can afford to buy products and services that will support a large industry.

California has led the nation in the value of new construction in every year since 1941, this too indicates healthy payrolls, high employment and a great demand for building materials.

The growth of the manufacturing labor force is indicative of the expansion of manufacturing in California, and the Bay region has shared in this expansion. By the end of 1950 there were 26,220 manufacturing establishments in the Far West, an increase of 35.4% during the preceding decade compared to a 30.7% increase in the U. S. A part of the increase may be attributed to defense industry but long range industries are taking advantage of the opportunities offered in the area. For example, in the chemical and allied products industry, over 300 plants were put in operation in the area in the last 15 years, bringing the 1953 total to over 1200, more than a 35% increase.

The 7 western states, with a 29 per cent gain, will receive the lion's share of the estimated national population increase between 1950-60, as indicated by official Bureau of Census projections for the next decade.

According to the Census Bureau estimates by 1960, 4,825,000 more residents will be living in the 7 western states than in 1950. This gain is more than twice the entire population of the State of Washington in 1950.

The estimated population gains for the 7 western states during the decade of the fifties ranges from being twice as great as the estimated gain reported for the South Atlantic section to eight times as great as that indicated for the West North Central section. For the same period, the population of the United States as a whole will rise an estimated 12 per cent.

The San Francisco Bay Area is the only major market on the Pacific Coast which is centrally located to the entire growing west.

ESTIMATED POPULATION INCREASES FOR FAR WEST
(In Thousands)

STATE	Estimate 1950	Estimate 1953	% Increase Over 1950	Estimate 1960	% Increase Over 1950
Washington	2,348	2,612	7.0	2,838	20.9
Oregon	1,536	1,739	13.2	1,918	24.9
California	10,527	12,325	17.1	14,017	33.2
Idaho	599	641	7.0	673	12.4
Utah	697	766	9.9	823	18.1
Nevada	158	181	14.6	202	27.8
Arizona	754	869	15.3	973	29.0
TOTAL FAR WEST	16,619	19,133	15.1	21,444	29.0
U. S. TOTAL	151,672	161,748	6.6	169,371	11.7

SOURCE: U. S. Census Bureau (July 21, 1952)

The California Taxpayers Association says the best estimate for January 1954 population is 12,244,290, up 417,380 or 3.5 per cent from the 11,826,910 for January 1953, and up 1,658,067 or 15.7 per cent from the 10,586,223 of the 1950 census.

A study of the 1947 U. S. Census of Manufacturers reveals that labor in the west is generally more efficient than in the east. Plants located in California generally created a larger net value added per production worker in the manufacturing process than did plants situated in the north or south.

Value added per production worker in California was 20.8% above the U. S. average, according to the Census Bureau. In the Los Angeles Area, this output per worker was 16.6% above the national average; while in the San Francisco Bay Area, it was 28.1% above the U. S. average.

The equable climate, pleasant living conditions, newer and more modern plants, and the greater relative youthfulness of the population probably all combined to bring about these results.

DOLLAR VALUE* ADDED PER PRODUCTION WORKER
AVERAGE ALL INDUSTRY * 1947

U. S. A.	Average	$6,245
California	"	$7,543
Los Angeles	"	$7,283
Bay Area	"	$8,002 (28% above U.S. Average)

Concurrent with the increase in population has been an increase in the labor force. During the decade 1940 - 50 the labor force in the U. S. increased 11.9%, in the Far West, 38.6%. By 1950 there were 6,540,986 persons in the labor pool in the Far West, California accounted for nearly two-thirds of them, 4,327,703. Forty per cent of California's 1950 population was in the labor pool, 39.1% in the U. S.

The composition of the California labor force has shifted since 1940. Proportionately, there were fewer workers in agricultural and mining occupations in 1950 than there were in 1940 while construction, wholesale and retail trade and manufacturing showed gains. The manufacturing labor force grew from 16.5% of the total in 1940 to 19.6% in 1950.

The percentages of these figures have changed very little in the last 3 years.

In addition to the primary cause, "Growth of the Western Market", which impels manufacturers to seek Bay Area locations for their new plants, there are some secondary and tertiary reasons.

Transportation rates have climbed to a point where it now becomes more economical for manufacturers to decentralize and establish branch plants in various parts of the country. This is one of the reasons Texas and other southern states have been having a rapid industrial growth since the end of the war. It is also one of the reasons solidly supporting Bay Area industrial growth.

It is not a reason on which we need dwell long, for it is fairly self-evident. Perhaps it requires no more time than to express the opinion that although transportation may become swifter, freight rates for industry show no promise of substantial reduction in the foreseeable future. In fact, most of the leading railroads have given active recognition to the problem and have well staffed departments to help industrialists find suitable locations for decentralized branch plants. The new Ford plant near

San Jose, was located on land supplied by the Western Pacific Railroad Company.

It seems as if it is impossible to long discuss any basic problems without mentioning the Federal Government, and this problem is no exception. Our defense officials know that 71% of the nation's industrial capacity is located in 50 big metropolitan centers. We all know of Malenkov's announcements about Russian production of the A-bomb, and the H-bomb. These facts have led to the establishment of a national policy of encouraging the dispersion of all new defense connected industrial facilities. This policy does not embrace the relocation of any existing facilities, but it does apply to all large new strategic manufacturing facilities.

Perhaps many of you know that the criteria to be applied in finding suitably dispersed locations for industry were developed and tested first in the San Francisco-Oakland Bay Area by Stanford Research Institute, and the Bay Area Council working for the National Security Resources Board. The pilot study made here is now official policy for the entire nation. In application, it probably will mean that expansions which might have been made in a crowded Detroit, Pittsburgh, or elsewhere may be made instead in less congested West Coast locations such as parts of the Bay Area.

Another factor which supports optimism for the industrial future of the Bay Area is found in dissatisfaction with many existing "Home" plant locations. Frequently the original plant site of a manufacturer is now heavily congested with little or no room for parking of employee cars, or for future growth. All too often, these older plants are located on what is now extremely high value land -- of which practically none is vacant and available even at fantastic prices. As plants so located grow obsolete or inadequate to meet increased volume, it is only natural that prudent management consider afresh the problem of plant location. These very problems which frequently surround older eastern manufacturing sites are in and of themselves another force operating in favor of a new branch plant somewhere in the growing Far West.

I hope that this appraisal of the forces influencing the industrial outlook for the Bay Area has not led anyone to be over-optimistic. It is a bright future, but no good will be served by not recognizing the limiting factors as well as the favorable ones.

In the Roper survey which was mentioned earlier, industrialists made much comment regarding "Labor" in the Bay Area. It is true that we have received a great deal of unfavorable publicity about strikes and high wage rates.

Actually, the Department of Labor figures on work stoppages show a record which is neither particularly favorable or unfavorable as regards the Bay Area. This same source does show a definite tendency for wage rates in the Bay Area to be at or near the peak of those paid anywhere.

Two observations seem pertinent at this point. First, there is a persistent and undenyable trend for the spread in wage rates as between different areas to become smaller and smaller. It is a well known fact, for example, that the deep south is no longer an area of super-depressed wage scales. Or to take a case closer to our own door, there was a period when Los Angeles correctly had the reputation of being a non-union town with wage rates well below those of the San Francisco-Oakland area. Those days are gone too.

Perhaps equally pertinent is the observation that although wage rates in this area are somewhat above the national average, labor costs are not necessarily above the national average. In fact, census data rather strongly suggests that on a per unit of productivity basis, they are lower than the national average by a substantial, 28.1%, margin.

Labor problems certainly have not, on the basis of the record we examined at the start of this talk, kept the Area from having a very vigorous industrial growth. It is probably true that good healthy, free-enterprise competition from a lustily growing place called Southern California has done as much as any single thing to subvert industries which might otherwise have come to the Bay Area. This competition will continue. I am not one who is prone to point to such words as smog or water supply and say, "That will surely slow up their growth from here out".

Instead, it seems more reasonable and more realistic to me to recall the words of the late William Randolph Hearst, who is reported to have said, "If the Pilgrims had landed in California first, New England would still be a wilderness". I think Southern California will continue to offer strong competition to the Bay Area for new industries. It still constitutes the greatest mass market on the West Coast.

However, the Bay Area has a most potent competitive weapon -- its central location. The Bay Area, and only the Bay Area, is centrally located on the coast to serve most advantageously with lowest freight costs and fastest deliveries the entire growing West Coast market.

The degree to which the Bay Area can capitalize on its admittedly bright industrial future will depend in part on its ability to meet problems. Some of these, such as increased trade oppotunities with the Orient seem to be beyond the ability of the Bay Area to influence greatly. Other problems can be met by the citizens of the area, and no man alive can accurately foretell how great the industrial growth of the area will be unless he can also know how well these problems will be met.

The Bay Area must set aside and reserve for industrial growth industrial lands along the railroads, the highways, and the waterfront. These reserve areas should be protected against residential or other encroachment. Zoning and the action taken by City and County Planning Commissions will be of great interest.

The Bay Area, like Southern California, but to a much smaller degree, must forcibly deal with the twin problems of air pollution and water supply. Both areas must also deal with the, as yet unsolved, problems of mass rapid transit.

The real danger though seems to me to lie not in the existence of such problems, but rather in the too easy, and oh so wrong viewpoint that since the population is becoming larger and larger each month and since transportation costs for shipping merchandise to the west are very high, the area will grow industrially in spite of itself, and no real effective action need be taken in concert by the various parts of the Bay Area to achieve the bright industrial future which seems so genuinely probable.

As an official of the Pacific Gas & Electric Company may I tell you briefly how our Company looks upon California, and the confidence we have in its future growth and development.

Starting in 1946, after a delay in our expansion program caused by the War, we have in the last 8 years spent over 1-1/2 billion dollars to provide increased gas supplies and increased generating capacity to provide an adequate and dependable supply of these services for our territory. Our construction program has established a world record for any company and for any similar period of time. The population of our service area has increased 3.3 million in 1940 to about 5.7 million in 1954, an increase of 75%.

We are glad to report that we have expanded our ability to supply our services at a greater rate than the percentage increase for the demand of such services, and through the foresight of our management we are in a sound position to supply gas and electric service of any normal demand in new customers. Since the end of World War II we have added 1,917,600 KW of new electric generating capacity in 11 major plant expansions and through the construction of new plants. We now have 57 hydro plants with a capacity of 1,349,300 KW, and 17 steam plants with a capacity of 2,192,800 KW, or a total of 3,542,100 KW. There are at the present time under construction two major steam plants that will add another 900,000 KW, 600,000 during 1954 and 300,000 early in 1955. In addition to this we are planning early construction of 9 additional hydro plants with a capacity in excess of 800,000 KW.

It is interesting to note that in 1945 at the end of the War we had about 1/3 steam generation and 2/3 hydro, at the present time these figures are exactly reversed and we are now a major steam electric generating company.

To match our ability to supply electricity we have also made great strides in developing our gas supply. Since the introduction by PG & E of Kettleman natural gas to Northern California in 1929, we have developed a supply 400 million cubic feet per day by 1950.

In 1950 we began a delivery of out of state gas from Texas and New Mexico through a 32" "Super Inch" gas line that connected with a line constructed by the El Paso Natural Gas Company at Topock, California, on the Colorado River. The original line had a capacity of 400 million cubic feet per day, through paralleling a section of this line and by the installation of compressors we were able to deliver 550 million cubic feet of gas into Northern California in 1953. We are now constructing additional parallel lines to increase this capacity to 700 million cubic feet of gas per day.

The management of our company is blessed with foresighted planning, and plans have been studied and completed for future developments through 1960 that will take care of the increment growth of about 250,000 KW per year. This will provide for ample capacity during overhaul, dry years, and for unforeseen emergencies.

At the present time PG & E and Consolidated Edison of New York are running One and Two in various classes of comparison, but we are rapidly approaching the point where we can be considered the largest utility in the United States.

This in itself is an indication of the continuing growth of the San Francisco-Oakland Bay Area.

INDUSTRIAL ENGINEERING RESEARCH SESSION

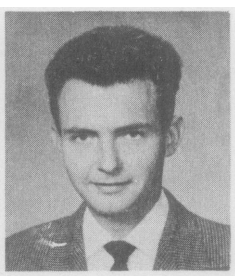
Session Chairmen: At Berkeley - E. PAUL DeGARMO, Assistant Dean, College of Engineering, and Professor of Industrial Engineering, University of California, Berkeley.
At Los Angeles - HARRY G. ROMIG, Chairman, Los Angeles Section, American Society for Quality Control.

THE ENGINEERING ECONOMY OF PLANT INVESTMENT: THE INTEREST RATE

Robert J. Brown
Manufacturing Trainee
General Electric Company
Cincinnati, Ohio

Feliciano M. Gonzales
Design Engineer
Philippine Manufacturing Company
Manila, P. I.

Edward C. Keachie (speaker)
Associate Professor of Mechanical Engineers
University of California
Berkeley, California



INTRODUCTION

To know when we are justified in spending money for capital improvements and when we are justified in refusing to do so is vital to the profits of the firm and eventually, in the sum of millions of such decisions, to the economic well-being of the whole nation's economy.

Robert J. Brown's "The Interest Rate in Engineering Economy Studies" is the second M.S. Thesis to come out of studies on the engineering economy of plant investment carried on here at the University of California in industrial engineering. The first thesis, "Evaluation of Investment in Production Facilities," was by Feliciano M. Gonzales, and was an outgrowth of a survey of engineering investment practices commenced by me in 1951. In this brief time only the general significance and some pertinent conclusions of these studies can be given.

Capital spending is an important determinant of business conditions, and we are of course definitely concerned with changes in business conditions. You who are participating in the Institute will probably be especially interested in the prediction on business conditions of Crawford Greenwalt, president of the DuPont Company, because he stresses the role of the engineer in the business situation. He points out that the key to future business spending is innovation initiated by engineers. This is of course in line with the basic idea of increasing sales by improving products and by improving methods to cut costs. Thus "prospects for profit" are brightened, to use the phrase of economist Sumner Slichter. The result is important as a determinant of business enterprises' spending for plant and equipment, which is the broad area of this research.

Engineering investment in plant improvement is not only relatively important as a catalyst in the economy, but is sizeable in itself, the current rate of spending for capital goods being some 27 billion dollars a year for the country as a whole. We do not imply, however, that our research is of the same order of magnitude.

BASIC IDEAS

The analysis and control of plant investment as a part of engineering economy leans heavily on the concept of the increase in value of money with the passage of time, or in reverse, the discounting of money which is to be paid in the future. The need for the concept of the time value of money is obvious in such industries as the utilities, but may be even more important profit-wise in competitive industry. Therefore the key to the time value of money, the interest rate, is of no mean importance.

Although the interest rate is an important determinant of costs, it is hard to isolate and to justify. There is even disagreement among so-called authorities regarding its use. Therefore I admire Brown for tackling the problem, and like other professors, let him go where I perhaps feared to tread.

In teaching engineering economy to our students I have been interested in the way our graduates and others were actually handling the problems of who, what, and how. The relation of theory to practice in plant investment seemed worthy of further study. There is of course never any real conflict between theory and practice - sometimes we may not use our theory, and sometimes we are hard put to explain practice in terms of theory, but the relationship is always there; we may need to dig to find it. Take for example the idea of sunk costs. When equipment is obsolete but not written off, the human tendency is to keep it operating and not recognize that the entire investment is really dissipated or "sunk." We should, in the words of one industrial engineer recognize that

> "It's cheaper to keep it idle than to use it and
> It's cheaper to throw it away than to keep it idle."

Procter and Gamble sent Feliciano M. Gonzales here from their factory in Manila to do his advanced work in industrial engineering. He did the thesis on the theory and field practice of different methods of analysis of the desirability of investments in plant. The first method was the payout period, in which one divides the investment by the annual profit (before depreciation) to get the number of years that will elapse before the investment "pays out" its original cost. [Pay-out period (years) =

Investment/Annual Profit before depreciation.[7] Other methods included the total cost method, the "M. A. P. I." (Machinery and Allied Products Institute) formula given in Terborgh's book "Dynamic Equipment Policy" and the Rate of Return method. This last takes the percentage return as the ratio of annual profit after depreciation to the investment, (% Return = Annual Net Profit / Investment) and is generally endorsed by authorities. Gonzales checked the theory in the books against the practice in the field, including companies' practices in screening proposals for expenditures to determine how decisions were arrived at. Incidentally, the word "decision-maker" has been popularized by Operations Research; its implications are nothing more than a new name for the old idea of getting to the boss' ear.

FINDINGS

As to highlights of the findings of these studies, it is apparent that:

In general, there are happy implications for the state of the art in the field in that eyes are focused on the "main chance" or purpose of money invested rather than on side issues, and pertinent facts seem decently available on which to base decisions.

On the negative side, ways of saving through better practices, without investing heavily, were not always taken advantage of, and the true values of alternative investment were sometimes not realized, as for example by failure to use the idea of the time value of money, and by not recognizing sunk costs. At least one firm even charged the new equipment for the unamortized value of the old!

Specifically, the most used criterion of desirability of an investment was found to be the pay-out period, with some more enlightened firms using the rate of return method. The pressure for a short pay-out period often leads to wrong decisions, for at least two principal reasons. Risk may be overoptimistically discounted to favor the short payout alternative, or the higher true return of better investments may be hidden, or both. The real result is lower overall profits, rather than higher ones.

In the decision making process, two levels were found to be most common and most important, the engineering department which makes the quantitative analysis, and top management which makes the final decision. Unfortunately there is evidence that integration of the two, for example in common policies and mutual understanding, was often lacking.

With regard to the interest rate, Brown's specific purposes were three-fold.

1. To compare the two broadest concepts of the interest rate.
   (a) That used for discounting future sums of money.
   (b) That at which capital earns money
2. To present the business man's choice of an Interest Rate. *
3. To find the common meeting ground between theory and practice in selecting an interest rate for an engineering investment study.

To pursue the interest rate theory would require a firsthand study of Brown's sizeable thesis but his conclusions are:

> As a result of this entire study the following conclusions seemed to be justified and to satisfy the original purposes. (1) that the abstract quality of the discount interest rate and the earnings interest rate required their identification with some method of calculating an investment criterion and since, for a firm which is in business to make profits, the only suitable investment criterion is the rate of return on the invested capital, the salient consideration is that interest rate which best suits a rate of return calculation; (2) that within the typical manufacturing company of Alameda County the time value of money was not considered to be of sufficient importance to merit the use of an interest rate in an engineering economy study. But that if an interest rate were considered to be necessary, the typical value used would be a low rate, very near the current rate on savings bonds; (3) that there are but two interest rates for use in engineering economy study calculations of a rate of return, which have a solid foundation in economic theory, are accompanied by complete and logical rationalizations for their use, and do not possess impractical features which would conflict with the customary division of authority found in the typical business firm's procedures for handling proposed investments. These two rates are the long-run future average earnings rate on future capital investments and the rate of return on the individual investment under consideration. However, between these two interest rates the rate of return on the individual investment may be considered the more elegant. This is so since it is not only self-determinant, but by its very nature it will act as an automatic predictor of the long-run future average earnings rate and thereby satisfy the theoretical conditions of both interest rates.

CONCLUSIONS

To conclude this brief outline of the work on plant investment theory and practice, three things stand out:

1. Many firms need more information on what facts are needed, how to make analyses, and how to get the facts. Important facts are highlighted by the check list at the end of this article.
2. More information is needed on how decision-makers currently <u>do</u> decide.
3. We need to know more about what Brown calls the problem of "defining the capital supply curve." In plain English - "Where do we get the money for a proposed investment and what is the cost of it?"

* A special preplanned interview form was used, in which the questions were handed to the interviewee, and an answer sheet of most likely answers was held and checked by the interviewer. Big advantages were comparability of replies between companies, and absence of the suggestion of a check-list. A sample of 27 firms was used in Brown's study, consisting of 10% of the manufacturing firms having over 50 employees in Alameda County: Gonzales sample was similar but included some firms in San Francisco.

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APPENDIX

PLANT INVESTMENT CHECK LIST

To highlight the things that affect costs and usefulness.

1. Volume
   (a) What is the best estimate of volume for the write-off period of the investment?
   (b) Can the volume be handled effectively by existing methods and equipment? By minor changes?
   (c) What are the possibilities for overtime, extra shifts, etc. ?
2. Quality
   (a) Can quality be maintained and scrap reduced?
   (b) Can more efficient controls be instituted, such as Statistical Quality Control, for either old or new methods?
3. Maintenance
   (a) What are the facts on maintenance, for both methods?
   (b) What is the source of the facts -- good records, poor records, vendors, hearsay?
   (c) Does the new equipment present new types of service problems?
   (d) How likely are breakdowns and how serious are they when they occur?
   (e) What is the vendor's record for parts and service?
4. Operation
   (a) Are operation costs known or estimated?
   (b) Will the proposal result in savings in preceding or following operations, such as the elimination of finishing, materials handling, or packaging?
   (c) Will inventories increase or decrease? Cost?
5. Labor
   (a) Can "released time" be effectively used elsewhere?
   (b) Have operators been "sold" on the new methods in advance?
   (c) Have employees' suggestions been invited?
   (d) What is the situation in regard to re-training?
   (e) What will pay rates be on the new jobs?
6. Overhead
   (a) Will more or less supervision be needed?
   (b) What cost differences will result?
   (c) Will there be layout and space changes? Cost?
   (d) Can released time and space be used more profitably than before?
   (e) What about property taxes and insurance?
7. Safety
   (a) What does the record say for the types of operations in question? Insurance rates?
   (b) Do workers object to any aspect?
   (c) Can legal and insurance requirements be complied with easily?
8. Stability
   (a) How stable is the demand for the product involved?
   (b) Have methods for producing the product been changing rapidly?
   (c) Is the economic (profitable) life and depreciation life of this equipment long in view of these facts?
9. Money
   (a) Where is the money coming from? Past earnings withheld, future earnings, borrowing?
   (b) Is this the best use for the funds?
   (c) Any effect on day-to-day financial operations?
10. Source
   (a) How did this proposal originate?
   (b) From production, because of bottlenecks, down-time, or excessive maintenance?
   (c) As part of a planned program of improvement and replacement, based on factual equipment records and known experience with technological change in this industry? Any expert consultation?
   (d) From salesmen? If so, is there any part of the proposal that can be used without capital outlay, such as machine rearrangement, motion study, and use of "two-hand" techniques on the existing equipment?
   (e) As a follow-up of an earlier investment? If so, what was learned and how it is being applied now? What groundwork is being laid to use the facts that will develop in this present proposal?

STUDY OF PRODUCTION MANAGEMENT IN SMALL MANUFACTURING COMPANIES

Earl E. R. Jones
Assistant Head
Engineering Extension
University of California
Berkeley, California

I should like to preface my remarks this evening with a word of caution. I hope that during the next few minutes, you will bear in mind two ideas: first, it is my purpose here to report on the findings of our survey. In so doing, I may say things which will surprise some of you. I hasten to add that it is not my intention to rattle skeletons in the closets of certain business firms, but rather to shed a bit of light upon the strengths and weaknesses of management arts and skills as practiced by a group of small manufacturers located in the area east of the San Francisco Bay. Second, because of the limited time available, I shall touch lightly upon many topics. Many interesting details must be left for private discussions after the talk or perhaps for publication at a later date.

* * * * * * * * * *

SMALL BUSINESS DEFINED

Before discussing the results of our study, it might be well to establish just what we mean by the expression, small business. It has been defined as a business smaller than a large business, but seriously, there are recognized limits defining this class of operation. We are all aware that the federal government distinguishes the small business as one employing fewer than 500 workers. In California, however, an organization of this size is relatively large. In his address at last year's Industrial Engineering Institute, Mr. Lloyd Thorpe stated that the average manufacturing firm in this state employs 30 people. The firms concerned in this study ranged in number of employees from 8 to 95. The average number of employees was 33. I shall say more about the selection of these firms in a moment. Let us retrace our steps for a moment to discuss the reasons that we at the University decided to make this study.

Part of a Long Range Program

During the past few years, and particularly following last year's Institute, the University of California through its offices of Industrial Engineering and Engineering Extension, has received many requests from the operators of small business for assistance in solving certain of their problems. These had to do with company organization and the planning, operation, and control of production. Recognizing the existence of vast amounts of such information concerning big business and the comparative dearth of similar material relating to the small firm, it was decided to conduct this survey.

Our objectives were twofold. First, we sought to learn about the present state of the art of management as it is practiced in small business. We hoped, moreover, to identify the differences, if any, in management practices to be found in the large and the small manufacturing organizations. Second, based on this and similar works, it is intended to develop at the University a course or group of courses which will be of direct benefit to small business. With these ideas in mind, the Industrial Engineering and Engineering Extension staffs, with the cooperation of the Oakland Chamber of Commerce, launched this study. We decided to approach the problem by interviewing a selected sample of small-plant managers. They were to be questioned regarding their methods of handling recognized planning, operating, and controlling techniques.

METHODOLOGY OF THE STUDY

A stratified sample was chosen so as to be representative of the size, function, and type of industries to be found among the small manufacturing firms in the San Francisco-East Bay Area. Mr. Kenneth Moeller, of the Oakland Chamber of Commerce secured the cooperation of 30 companies which had been selected as the sample. Of these, 27 participated in the study. The companies ranged in size as follows:

No. of Employees	Group	No. of Firms in Sample
8-24	A	12
25-49	B	10
50-99	C	5
33	Average of all companies	27

Companies interviewed included those designated as job shop, functional shop (that is, a specialty shop providing a service limited in scope, but expensive to duplicate for low volume production), manufacturers of custom products as well as those engaged in the volume production of solid or liquid items. Product-wise, the firms represented a cross section of local industry. Included were manufacturers of food and candy, metallic and non-metallic building materials, machine and electronic components, boxes and cosmetics, job shops and functional firms specializing in such services as galvanizing and heat treating.

THE INTERVIEW

Each firm in the sample was visited by an interviewer who spent from 3 - 4 hours with a number of top management. Whenever possible, the production facilities were inspected. In accordance with a previously prepared outline of topics, the interviewer asked questions calculated to reveal the firm's techniques and its effectiveness in applying the tools of modern management. The survey findings to be discussed in a moment are a compilation of replies given by managers in response to interviewer's questions. No reference will be made to matters of finance because it was felt best not to collect such information. The planning function was investigated by reviewing sales forecasting, production planning and scheduling, and the planning of materials, labor, processes, and product. Operational methods discussed included budget, standard costs, selection and design of equipment, facilities and production methods, wage payment plans and accounting. The methods of control that were examined included the control of production rate, labor, quality, costs, materials and tools. At the conclusion of the interview the management of each firm was asked to indicate what is considered to be the major problems confronting it in the conduct of the business.

OWNERSHIP

The ownership of the companies in group A was about equally divided among three classifications: single ownership, partnership, and corporation. Group B had a similar distribution but with a slightly larger number of corporations. Group C on the other hand included no single ownerships and was about equally divided between the others. In most cases the owners were participating actively in the management of their companies. The average age of the firms studied was just over 20 years; the youngest company had been in business for 5 years and the oldest for 66. About half of the firms had been in business during the depression of the 1930's.

ORGANIZATION

All the companies studied had a simple line type of organization. None of the organization structures contained staff departments or had staff personnel in the role of the assistant to the president or to the general manager. The executive officer, or general manager, was either the sole owner or a major investor. About a third of the firms reported the use of an executive committee which actually made management decisions in some cases while in others it acted as a sounding board for the ideas from one or more sources. In every case the chief executive of the firm was a member of this committee. In most cases it was difficult, if not impossible, to distinguish between individuals responsible for policy making, on the one hand, and for operation on the other. No effort was made to separate the two levels.

All of the companies reported the existence of two departments -- office and production. As a rule, however, most of the firms had only one formally organized department: production. Typically it was the largest in the company and the only one organized so as to provide definite levels of authority and responsibility, and having definite channels of communication.

Half of the general managers in groups A and B assumed direct responsibility for managing the production function. In group C this dropped to 40%. It might be mentioned however that in many cases the general manager took an active interest in overseeing the production function even though it was the responsibility of a member of the second level of company organization.

On the average, the number of foremen employed in the various production facilities is as follows: group A - 1; group B - 2; and group C - 3-5. In the latter case some of the individuals referred to as foremen might more properly be designated as supervisors who direct the activities of one or more sub-foremen or lead-men. (Under the heading of office were grouped a collection of residual functions which were actually performed or at least headquartered in the company's business office.) As indicated before, the office department was not carefully planned as to functions to be performed nor well organized. Of the firms participating, 30% reported having sales organization of departmental rank. For all sizes of companies, this function is the responsibility of the general manager in 80% of the cases. As mentioned previously, the concept of the staff man was not generally found; most of the staff functions being performed by line personnel.

PLANNING

Most of the companies reported little or no use of sales forecasting or production planning techniques. Though some schedule for as long as a week, most plants schedule daily. Often the real schedule can be found only in the scheduler's head, which leaves the workers at somewhat of a disadvantage. Materials planning frequently amounts to no more than responding to a hurry-up call from the foreman that - "We're almost out of 1/2 inch machine screws" - or simply waiting for orders to arrive and then investigating the stock on hand. Either of these methods can, and at times does, find the storeroom unable to supply needed materials rapidly. Purchasing, while it is frequently delegated to second-level of management, is often actually controlled by the chief executive. About 1/3 of the firms were equipped with reasonably formal materials controls.

OPERATING

Methods, layout and process planning are often considered carefully although informally, by the executive at the outset, but later on left to the foreman and workers with no provision for review, even when new equipment is added or new products are manufactured. Heavy reliance is placed on the skill and alertness of the foremen and workers rather than on such techniques as: budgets, cost accounts, quality controls, formal schedules. Only 14% of the firms employ the budget system, although several others indicated that they would like to try it. At least 65% of the companies ran a monthly trial balance but several had no accounting except for the annual balance sheet and profit and loss statement required for tax purposes. Standard costs were completely lacking. A somewhat satisfactory substitute was found in 2/3 of the plants where detailed job history cards are used as a basis for bids and informal production scheduling. By their own admission, many firms find it necessary to introduce variable "fudge factors" in order to arrive at satisfactory estimates of time and costs. Work standards and methods together with job evaluation applications were notable by their absence in most cases. The selection and training of personnel was found to be seriously limited. Often it amounts to little more than a single informal personal interview, followed by a month's exposure to the shop routine, with brief, interrupted talks by the foreman.

Six companies reported success in the use of profit-sharing or bonus payment methods. Many indicated that they pay premium wages for skill and seniority. A significant percentage of the companies, however, pay on a straight hourly basis in accordance with union contracts. - The minimum permissable pay rate. A majority of the companies indicated that seasonal variation presents no problem. Some of those who are not so fortunate handle the matter in one of the following ways:

a. Storage of seasonal raw materials so as to provide constant production load throughout the year;
b. Judiciously scheduling many or all vacations;
c. Manufacturing to stock during the slack season.

Unfortunately, the lack of operating capital, which plagues many small manufacturers, sharply curtails their off-season activities, not to mention those problems with which they must grapple during normal periods of operation.

CONTROL

Production control of the sort which rapidly informs management of its production situation and insists that properly-drawn schedules be met, was nowhere to be found. A possible exception may exist in firms deliberately underselling their markets, thereby maintaining a constant production rate of identical or similar products. Whereas a number of the firms is concerned with product quality, the overwhelming majority does not practice anything which even approaches statistical quality control. A few plants employ up to 100% inspection of their output, but indicate no method of controlling quality while the product is still in process.

SUMMARY AND COMMENTS

Again, the press of time precludes my discussing many interesting topics which were brought to light in the study. We hope to make all of the information available in published form some time this year. Many of the companies lean heavily upon the executive officer for innumerable decisions of widely varying nature and importance because they believe that the limited size of the operation precludes the hiring of a minimal number of trained managerial assistants. A considerable part of the difficulty is due, I suspect, to the refusal of the executive to delegate formally those duties of which his assistants and foremen are actually capable. Much of the important decision making is informally delegated to the foremen and even the workers without the accompaniment of the necessary controls and communication schemes. As a result, difficulty is experienced in maintaining clearly defined limits of responsibility and authority. Despite this, labor-management relations in the small plant are usually of such caliber as to be the envy of the larger firms. The executive committee system (including foremen and even selected skilled workers) is an effective aid to the top executive in the small plant.

It is well recognized that line personnel frequently have neither the time nor the inclination to make the careful, formal analysis required to make the staff decision. In the firms studied, however, the very concept of the staff man was missing. A firm employing 10 to 15 people may be able to do without one individual who is responsible solely for planning and controlling, but the firm of 35 to 100 is apt to discover itself woefully short of watchdogs when the general manager finds himself struggling to keep up with the details of sales, production and finance. "Of course", says the small manufacturer, "I can't afford a consultant at $100 - $150 per day." I ask, however, if he has considered employing a trained young man to work his way up into management or the retaining, at least on a part-time basis, of an experienced man in a staff capacity to set up methods of handling planning and control.

Whereas most of the businesses maintain that they enjoy a reasonably stable production rate and suffer from only minor seasonal variations, few attempt to forecast sales, failing thereby to provide a hook on which to hang production and materials planning estimates. Sales forecasting, as well as its first cousin production planning, may be materially aided through the review of pertinent, accurate and up-to-date market-report publications and the institution of cooperative marketing. One of the best ways of helping himself that the small business man has yet found is the close association of firms to share their mutual problems. This certainly should be encouraged and strengthened.

Many of the firms seem to be suffering from a lack of working capital with which to purchase materials and equipment in order to benefit from optimum market conditions. There appears to be no lending agency ready and willing to meet this need. For purposes of satisfactory managerial control, accounting procedures appear to be inadequate in most cases. More often than not, management not only is uncertain of its plans for the future, but isn't quite sure of where it has been in the recent past. Of primary significance, it seems to me, was the reply which the interviewers received to the question, -- "What are the major problems facing the management of your firm?" Aside from serious concern over tax questions, the great majority assured us that they had no problems. This then appears to be the crux of the problem: The recognition of difficulties so close at hand as to escape the notice of those who are most affected.

Again I emphasize that it has not been my purpose to rattle skeletons in the closets of those who cooperated with us in making this survey, even though it may have sounded that way at times. We hope that this work will pave the way for more studies in the future, all of them with the objective of improving the art and the skills of managing the small manufacturing firm.

USE OF SAMPLE MEAN RANGE IN ESTABLISHING INDUSTRIAL CONTROLS

Edward P. Coleman
Professor of Engineering
University of California
Los Angeles, California

INTRODUCTION

The industrial engineer constantly seeks methods for simplifying the application of scientific principles, facilitating decisions, and expediting action. Statistical methods applied to industrial problems have steadfastly occupied the attention of many people during the last quarter of a century. Recently Simon[1] aptly indicated that statistical methods have progressively an important adjunct to four industrial fields: manufacturing process, acceptance inspection, study of systems or processes (largely industrial management), and research and development. While this is a profound recognition that statistical methods are finding application in most industrial activities, Walter A. Shewhart[2] anticipated nearly every advantage of these methods as early as the 1920's.

Shewhart's expressions of "state of statistical control" and "stable system of chance causes" have intrigued industrial engineers from the time they were uttered. The unifying feature throughout Shewhart's development is that it is a system of experimental inference, and as such it has emerged as an established and practical aspect of the scientific method.

The industrial engineer's viewpoint of statistical methods is that, to be useful, they must provide a basis for action. In many on-going industrial organizations this action must take place "on the spot". For example, a manufacturer inspects his product to provide an objective basis for the immediate disposition of product already on hand or to provide a basis for deciding whether or not to immediately alter the production process for future product. The purpose of this paper is an additional step in this direction by providing the basis for a further industrial use of the sample mean range.

THE DEVELOPMENT OF CONCEPT OF SAMPLE MEAN RANGE

Karl Pearson[3] in 1902 is considered to have made the first mathematical formulation of a probability statement involving an order statistic. He stated Galton's difference problem essentially as follows: For a random sample of N individuals drawn from a very large population characterized by the probability density function p(x), it is required to find an expression for the average difference between the k^{th} and the $(k + 1)$ th individuals when the sample is arranged in order of magnitude of character. He concluded that his solution of this problem opened many new methods of inquiry. Twenty-one years later, Dodd[4] published some asympotic values for the greatest or least of N observations drawn from populations characterized by several different algebraic form, and he indicated several early actuarial applications for the number of survivors at age x from an original group of individuals. Early in 1925 Irwin[5] extended some of Karl Pearson's results, and later in the same year Tippett[6] published some results relating to the sample range, which is the difference between the largest and smallest sample value. It was this work of Tippett, under the direction of Egon S. Pearson, the son of Karl Pearson, that clearly singled out the sample range as a useful statistic. From this time onward Egon S. Pearson has supervised, authored or edited the publication of nearly all of the important results relative to the sample range. Some results useful to the industrial engineer can be found in the following references[7, 8, 9, 10, 11, 12, 13, 14].

THE SAMPLE MEAN RANGE

Let a quality characteristic x be normally distributed with unknown population mean μ and unknown population standard deviation σ. If a random sample x_i, = i = 1,...., N of N = mn measurements on x can be separated randomly into m groups, with n measurements in each, the sample mean range $\bar{w}_{m,n}$ is defined as the arithmetic mean of the m group ranges w_n. The group range w_n is defined as the largest value minus the smallest value of the random group of size n.

The sample mean range is an attractive statistic because of its computational simplicity which involves nothing more complicated than placing observations in ascending order of magnitude and performing simple algebraic operations. The sample mean range usually serves to measure dispersion in a sample or to form the basis for estimating dispersion in a population. The sample standard deviation has traditionally been used to measure or estimate dispersion, and it involves the root-mean-square operations which are often too laborious to facilitate immediate decisions requiring action. However, the use of the mean sample range introduces some new difficulties. Its sampling distribution is highly sensitive to slight changes in the parent population. Even when the parent population is normally distributed, its probability density function cannot be exhibited in simple algebraic form. Therefore, probability or fractile values may be found only by methods of numerical integration or other methods of approximation. In samples separated into small groups, the mean sample range is almost as efficient* a measure of dispersion in normal populations as the sample standard deviation, but as the group size n increases, the efficiency of the mean sample range decreases. It was Tippett and Pearson who first noticed this property, and they were first to suggest dividing the sample into random subgroups of equal size and computing the mean of the subgroup ranges.

It is interesting to note that Grubbs and Weaver[15] published in 1947 the results of some World War II calculations that shed some light on choosing a grouping combination for a given total sample size N. They took a slightly more general perspective of the problem by not requiring that each subgroup size be equal to n. Nevertheless, they found that the optimum subgroup size is

* One statistic is said to be more efficient than another for estimating a population parameter if the statistic varies less from sample to sample.

approximately 8 for estimating the population standard deviation with the average of group ranges. They indicated however that practically no precision is lost if the grouping combination is always chosen so that each subgroup size is $n = 6, 7, 8, 9,$ or 10.

In his thesis for the Ph. D. degree under E. S. Pearson at the University of London and in a later paper, Patnaik[16, 17] devised some very ingenious methods of approximation. The essential feature of his method was the introduction of the concept of fractional degrees of freedom f and a scale factor c in approximating the sampling distribution of a statistic with that of another. We will make use of Patnaik's methods in using the mean sample range $\bar{w}_{m,n}$ in the non-central g-statistic which we introduce below.

We here make use of the expected value operations E to find the mean value and the variance of certain statistics from random samples drawn from the normal population whose mean μ and standard deviation σ are unknown. A statistic is an unbiased estimate of a population parameter if the expected value of the statistic is equal to the parameter. The mean value and variance of the single group range w_n under random sampling are given by

(1) $$\mu_{w_n} = E(w_n) = \sigma d_n$$

(2) $$\sigma^2_{w_n} = E(w_n - E\, w_n)^2 = \sigma^2 b_n^2$$

where values of d_n and b_n corresponding to group sizes of $n \leq 100$ can be found in the summary paper of Pearson[8] in 1932. Table 1 shows all values of d_n and b_n needed for purposes of this paper.

Table 1
The Expected Values d_n and Standard Deviation b_n of the Sample Group Range w_n from Normal Population With Standard Deviational

Group Size n	d_n	b_n
6	2.5344	0.848
7	2.7044	0.833
8	2.8472	0.820
9	2.9700	0.808
10	3.0775	0.797

If we let w_{in}, $i = 1, \ldots, m$ represent the range of the i^{th} random group of the sample of N items, we have by definition of the mean sample range

(3) $$\bar{w}_{m,n} = \frac{1}{m}(w_{1n} + \ldots + w_{mn}) .$$

Then the mean value and variance of the sample mean range $\bar{w}_{m,n}$ under random sampling are given by

(4) $$\mu_{\bar{w}_{m,n}} = E(\bar{w}_{m,n}) = \sigma d_n$$

(5) $$\sigma^2_{\bar{w}_{m,n}} = E(\bar{w}_{m,n} - E\,\bar{w}_{m,n})^2 = \frac{\sigma^2 b_n^2}{m} .$$

We notice from (4) that the sample mean range $\bar{w}_{m,n}$ is not an unbiased estimate of the unknown population standard deviation σ. Let us then consider the statistic $\bar{w}_{m,n}/d_n$ for each group size n. The mean value and variance of this statistic are given by

(6) $$\mu_{\frac{\bar{w}_{m,n}}{d_n}} = E\left(\frac{\bar{w}_{m,n}}{d_n}\right) = \sigma$$

(7) $$\sigma^2_{\frac{\bar{w}_{m,n}}{d_n}} = E\left(\frac{\bar{w}_{m,n}}{d_n} - E\,\frac{\bar{w}_{m,n}}{d_n}\right)^2 = \frac{b_n^2\sigma^2}{m\, d_n^2}$$

It is clear from (6) that the statistic $\bar{w}_{m,n}/d_n$ is an unbiased estimate of the population standard deviation σ.

THE NON-CENTRAL g-STATISTIC

Let us suppose that manufactured product is submitted for acceptance in normally distributed lots (populations) with unknown mean μ and standard deviation σ. The decision to accept or reject a submitted lot will depend on the quality characteristic measurements x_i, $i = 1, \ldots, N$ from a random sample of N items of the product. The following definitions are useful.

Definition 1. An item of product is defective if its quality characteristic value of x_i is greater than a specified real number U, that is $x_i > U$.

Definition 2. An inspection lot is of acceptable quality if its fraction of defective items p is less than or equal to a specified fraction p_o, that is $p \leq p_o$, where $0 \leq p_o < 1$.

Definition 3. The constant K is defined as that value of the standardized normal variable z exceded with probability p, that is

(8) $$\int_K^{\infty} \frac{1}{\sqrt{2\pi}} e^{-\frac{z^2}{2}} dz = p.$$

If a consumer specifies the values of U and p_o to be given constants, then any normally distributed lot will be acceptable if it mean μ and standard deviation σ satisfy the inequality

(9) $$\frac{U - \mu}{\sigma} \geq K_o ,$$

where the constant $K = K_o$ corresponds to $p = p_o$ in (8). Using (9) as a lot acceptability criterion we propose to accept or reject a submitted lot on the basis of the value of the statistic.

(10) $$g_{m,n} = \frac{(U - \bar{x})\, d_n}{\bar{w}_{m,n}}$$

where the sample mean $\bar{x}$ and $\bar{w}_{m,n} / d_n$ are statistically independent and unbiased estimates of the lot mean μ and lot standard deviation σ, respectively. We shall call $g_{m,n}$ the non-central g-statistic with group choice $N = mn$ and displacement

(11) $$g = \frac{\sqrt{N}\,(U - \mu)}{\sigma} .$$

This nomenclature has been adopted because of its analogous role to that of the non-central t-statistics of Johnson and Welch in (18). We shall need the calculated results below to say that the statistic

(12) $$\frac{-c\,\sqrt{N}\; g_{m,n}}{d_n}$$

is distributed approximately as the non-central t-statistic with f fractional degrees of freedom and displacement

(13) $$\delta_t = -\frac{\sqrt{N}\,(U - \mu)}{\sigma}$$

where d_n is found in Table 1.

COMPUTATIONS

From (10) we observe that the non-central g-statistic is a function of the independent statistics $\bar{x}$ and $\bar{w}_{m,n}$. The sample mean $\bar{x}$ is distributed normally with mean μ and variance σ^2 / N. We use Patnaik's concepts to compute values of the scale factor c and fractional degrees of freedom f such that the mean and variance of $c / \sqrt{f}$ are equal respectively to the mean and variance of $\bar{w}_{m,n} / \sigma$. By use of appropriate methods of approximation, we are lead to

(14) $$d_n = c\left(1 - \frac{1}{4f} + \frac{1}{32f^2} + \frac{1}{128f^3}\right)$$

(15) $$b_n^2 = m\, c^2 \left[1 - \left(1 - \frac{1}{4f} + \frac{1}{32f^2} + \frac{5}{128f^3} \right)^2 \right] .$$

Substituting from (14) and (15) in

(16) $$r = \frac{b_n^2}{m\, d_n^2}$$

we find that

(17) $$r = \frac{1}{2f} + \frac{1}{2f^2} - \frac{1}{16f^3} .$$

If only the first two terms of (17) are retained a first approximation f_1 to f is given by

(18) $$\frac{1}{f_1} = -2 + 2\sqrt{1-2r} .$$

A better approximation f_2 is given by

(19) $$\frac{1}{f_2} = -2 + \sqrt{1 + \frac{2\,(r+1)}{16 f_1^3}}$$

In (14) we substitute f_2 and find c to be

(20) $$c = d_n \left(1 + \frac{1}{4f_2} + \frac{1}{32f_2^2} - \frac{5}{128f_2^3}\right) .$$

Values for f_2 and c have been computed for most sample sizes N between 4 and 1500. Table 2 shows values that have been extracted from these computations. This table is sufficiently extensive to facilitate the use of the non-central g-statistics in sampling inspection by variables.

TABLE 2

Scale Factors and Fractional Degrees of Freedom for Given Sample Sizes and Group Choices

Sample Size N	Number of Groups m	Group Size n	Scale Factor c	Fractional Degrees of Freedom f_2
6	1	6	2.67	4.680
7	1	7	2.83	5.489
8	1	8	2.96	6.250
9	1	9	3.08	6.981
10	1	10	3.18	7.682
12	2	6	2.60	9.163
14	2	7	2.77	10.773
16	2	8	2.91	12.291
18	2	9	3.02	13.748
20	2	10	3.13	15.148
21	3	7	2.75	16.049
24	3	8	2.89	18.324
27	3	9	3.01	20.508
32	4	8	2.88	24.355
36	4	9	3.00	27.266
40	5	8	2.87	30.384
42	6	7	2.73	31.864
45	5	9	2.99	34.023
48	6	8	2.87	36.413
56	7	8	2.86	42.442
64	8	8	2.86	48.471
72	9	8	2.86	54.499
80	10	8	2.86	60.528
88	11	8	2.86	66.556
96	12	8	2.86	72.584
104	13	8	2.86	78.613
120	15	8	2.86	90.668
136	17	8	2.85	102.725
152	19	8	2.85	114.784
168	21	8	2.85	126.838
184	23	8	2.85	138.896
200	25	8	2.85	150.952
224	28	8	2.85	169.037
248	31	8	2.85	187.117
272	34	8	2.85	205.201
296	37	8	2.85	223.285
320	40	8	2.85	241.376
344	43	8	2.85	259.452
368	46	8	2.85	277.535
392	49	8	2.85	295.618

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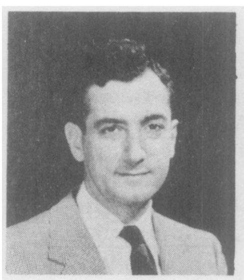
WORK SAMPLING (RATIO-DELAY) STATISTICAL TECHNIQUES APPLIED TO A MATERIALS HANDLING SYSTEM

Russell R. O'Neill (speaker)
Lecturer in Engineering
and
Joseph D. Carrabino
Lecturer in Production Management
University of California
Los Angeles, California

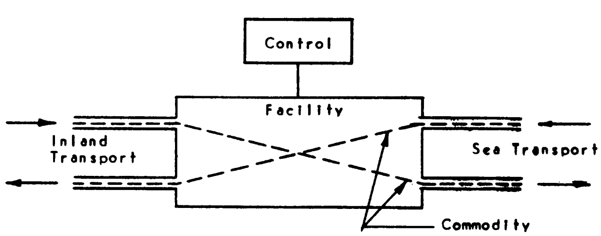


Despite the importance of cargo transportation to the economic health and military security of the United States there appears to be little formulated information on the subject of cargo handling. Several of the components of the system have been subjected to systematic analyses by naval architects, terminal designers, materials-handling specialists, economists, and others, but a systematic analysis has not been made of the system as a whole.

Realizing the need for a study of the subject, Dean L. M. K. Boelter of the College of Engineering, University of California, Los Angeles, proposed in 1951 a cargo handling research project that received the financial support of the Office of Naval Research and the Maritime Administration.

An engineering systems analysis of the system has been undertaken. An interdisciplinary team of part-time investigators has been formed comprising people on the University teaching and research staff with backgrounds in industrial, mechanical, electrical, and chemical engineering, psychology, sociology, and engineering statistics.

On the basis of interviews with military and civilian leaders in the shipping industry and observations made on military and civilian piers, it was decided to limit the scope of the study, for the time being at least, to the basic system shown in Figure 1.



Basic Cargo Handling System

Figure 1

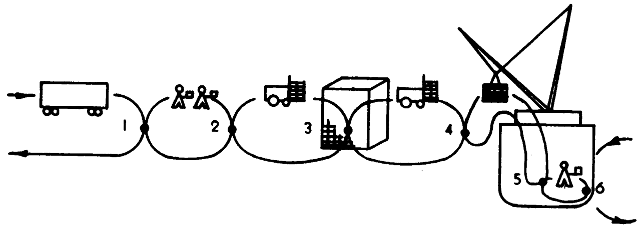
The cargo handling system is here defined as consisting of five major elements:

1. Facility (F) consists of the structures, materials-handling equipment, sources of energy at the terminal, and the physical features of the port. Structures include the man-made improvements; e. g., roads, rails, and outside storage. Materials-handling equipment includes the harbor lighters and barge cranes. The energy sources available for the transportation of cargo are electrical, mechanical, and thermal as well as manpower. Physical features are the contours, tides, and weather. In general, these are natural, but they may be artificial i. e., dredged channels, breakwaters.
2. Sea Transport (S) is the vessel that carries the cargo to another facility. The cargo-handling gear on the ship is included.
3. Inland Transport (L) is the carrier that connects the facility to the inland area. This may be truck, train, airplane, or river barge. All the material handling equipment attached to the carrier is included.
4. Commodity (C) is the item that is shipped, including the package or crate. Dunnage, however, is considered to be a separate commodity.
5. Control (M) is the communication of information that regulates the movement of the commodity through the facility. The record system is included in control and both labor and management are involved.

The commodity follows a unique path through the facility, determined by all of the elements defined above. If F, S, L, C, and M are considered causes, the path is the effect. The effect may be observed in the field and subsequently used to induce information about the causes. Thus, the dependent element is the Process (P) which is defined as the space-time coordinates of the path taken by the commodity or the transporting agent. One of the components of Process is time, a basic measure. It is postulated that these six elements completely define the cargo-handling system and are necessary and sufficient for the transfer of cargo between a land carrier and the hold of a ship. One of the main objectives of this study therefore, is to formulate equations that state the relations between these significant components of the cargo handling system in terms of time. This knowledge will make it possible to predict the effects of any change in one component of the system on the rest of the system and at the same time, it will be possible to decide which specific problems to attack first.

When a transporting agent is used to move the commodity, the operation is cyclic. The transporting agent, which may be a forklift truck a hook attached to a boom, longshoreman, etc., moves with the commodity from one point to another and then returns to the starting point to repeat the operation. By this definition, pipelines, chutes, and certain types of conveyors such as roller conveyors are not considered to be transporting agents. Belt conveyors, however, are cyclic and consequently are considered transporting agents. A schematic diagram of a specific cyclic process is shown in Figure 2.

A commodity, case of canned peaches, arrives at point 1 by rail. These cases are unloaded by four men, one case at a time, to a pallet at 2. The transporting agent here is a man. There are four transporting agents (men) completing the same cycle. The unit of commodity



Schematic Diagram of a Specific Cycle Process

Figure 2

is one case of canned peaches, described by the dimensions, weight, strength of carton, etc. A forklift truck picks up 36 cases stacked on the pallet in a definite pattern and moves the pallet to the transit shed. The unit of commodity is now a pallet of 36 cases. In addition to the dimensions, weight, etc., the maximum allowable acceleration is an important characteristic since the cases should not topple from the forklift truck en route. Point 3 is the location of the stack in the transit shed. The strength of the carton may become an important component of commodity during storage because it influences the height to which the commodity may be stacked.

After a period of time in storage, the commodity, still a pallet load of peaches, is moved by forklift to the apron 4. The pallet is hoisted over the side of the ship and into the hold, 5, by a hook attached to a boom. In the hold the pallet is unloaded by the hold men, one case at a time, and stowed in the wings of the ship, 6. Ideally, once the movement of cargo begins from the point of rest, 3, in the transit shed to the point of rest, 6, in the hold, the working portion of the time for each of the three cycles (3 to 4, 4 to 5, 5 to 6) through which the cargo moves, should be equal in order to have a continuous flow of goods. However, in practice, it is more usual to find "bottlenecks" or unbalances in the cycle times.

Referring again to Figure 2, each cycle or link in the chain represents the space-time trajectory of the transporting agent. The trajectory of the commodity is, of course, undirectional and is represented by either the upper or lower segment of the link. At points 1, 2, 3, 4, 5, and 6 which have been called nodes, the commodity is transferred from one transporting agent to another, and the unit of the commodity may be changed; e.g., a case of peaches to a pallet load. Between two consecutive nodes, however, the commodity is moved by a single transporting agent, the unit of the commodity does not change, and there are no storage states.

At any point in a cycle, there may occur a delay. The delay can originate outside or inside the cycle. If the delay is caused by the storage condition at either node or if it is "forced upon" the cycle, and has its cause outside of the cycle then this delay is called an induced delay. Examples are: waiting for load from previous cycle, or waiting for load to be taken by the following cycle. All other delays are called internal delays. These are delays whose causes are internal to the cycle. Examples are: personal time, conversation pertinent to cycle operations, personal conversations, and intra-cycle equipment failures.

The total time that it takes a transporting agent to complete one round trip or cycle can be broken down into six element times as shown in Figure 3:

T_p = pick-up load

T_1 = transport loaded

T_r = release load

T_e = transport empty

T_a = internal delay

T_d = induced delay

The cycle operation time T_o is the sum of the element times T_p, T_1, T_r, T_e, T_a of the particular cycle. Internal delays are included because there are always certain delays associated with the operation. Induced delays, on the other hand, are not charged to the cycle. The total cycle time T equals the cycle operating time plus the induced delays T_d.

The rate at which the commodity is moved from one node to the next is defined as the weight of the commodity carried by the transporting agents per trip divided by the average time required to make the trip. If during an interval of time, the net change in the amount of storage at a node is zero, the average rates of flow in the preceding and succeeding cycles are equal. However, the operating rate (defined as the weight transported divided by the average operating time T_o) of each cycle may be different. The operating rate is determined by the characteristics of the particular cycle only and is not influenced by the restrictions imposed by the adjacent cycles. The cycle with the slowest operating rate controls the rate at which commodity is moved from one point of storage to another. In each series of cycles, as for example, cycles 3 to 4, 4 to 5, and 5 to 6 in Figure 2, there is one cycle that controls the remainder. The other cycles must have induced delay.

The aforedescribed element times for cycles can be used as the dependent variable for one set of relations between the major elements. If the element times can be determined as a function of a reasonable number of parameters, the total time required can be calculated for a specific cycle. With additional information about the storage conditions at the nodes, the time required for an entire cargo handling operation can be predicted.

To summarize: it has been possible to devise equations for the flow of material through a particular ideal cargo-handling system. These equations can be used for the prediction of the time required to load or unload cargo or for the development of optimum methods and designs. They could be extended to the prediction of energy requirements and dollar costs by a transformation of the coordinates.

The work-sampling or ratio delay technique, originated by L.H.C. Tippet in 1935 has been used to determine the element times for cycles. The use of this technique is a good deal more complicated in this situation than in the usual industrial situation because it was used to obtain data on the simultaneous activities of a gang of longshoremen comprising eighteen men. This gang structure is typical of the Pacific Coast. Referring to Figure 2, the distribution of the eighteen men is as follows: at point 3, four dockmen load goods on pallets, then two forklift trucks or jitney drivers pick up the loaded pallets and move them to the side of the ship; two front men at point 4 place the hooking gear on the pallet; one winchman operates a winch located on the deck of the ship which controls the movement of the boom; one hatch tender who stands on the deck of the ship in such a position so that he can observe the activities at the side of the ship and in the hold of the ship signals the winchman and thereby guides his operations; eight men in the hold unload goods from the pallet and stow them (cycle 5 to 6).

The work sampling method is based on the random sampling theory employed in statistical quality control. The procedure is to select samples at random from the population, and, when a sufficient number of observations have been taken, an estimate is made for the population. The estimate is based upon the theory that the percentage of readings recording the activity in a certain state of operation is a reliable estimate of the percentage of time spent in that operation.

In using the work-sampling method of obtaining the element times the following definitions are required: N_p = number of observations of picking up load; N_1 = number of observations of transport loaded; N_r = number of observations of transport release; N_e = number of observations of transport empty; N_a = number of observations of internal delay; N_d = number of observations of induced delay. All of these observations are taken at time intervals which were selected from a random number table. The total number of random observations (N) is:

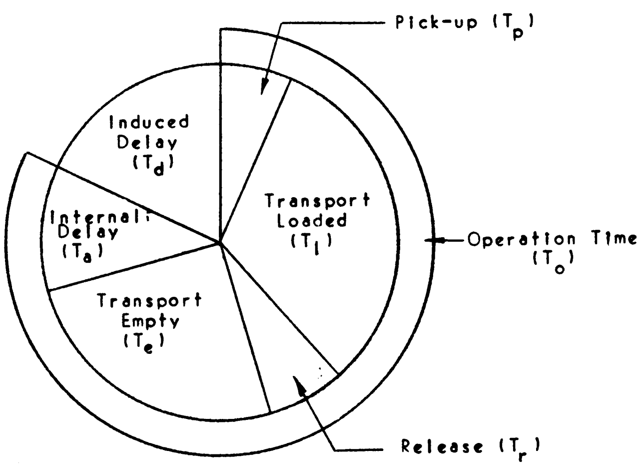
$$N = N_p + N_1 + N_r + N_e + N_a + N_d$$

Also, the number of random observations of cycle operating time is defined as:

$$N_o = N - N_d$$

From statistical theory underlying work sampling, the average time required for element T_p can be determined from the following relationship:

$$\frac{T_p}{T} = \frac{N_p}{N}$$



Element Times

Figure 3

The preceding discussion of element times based on those shown in Figure 3 has been simplified. The transporting agents can also spend time described by each of the following symbols:

T_u = transportation or preparing dunnage, shoring, and lashing materials

T_c = transporting agent can't be found by the observer

T_x = entire loading or unloading system stops operation temporarily

T_q = time required for the transportation of materials handling equipment such as pallets

T_o = this is cycle overlap which occurs when a transporting agent is productive in another cycle but non-productive in its own cycle

T_g = this occurs for the hook only when it drags a load from the wings of the ship to the hatch opening

T_s = set-up time; the time during which the transporting agent is occupied in preparing for operations, i. e., removing hatch covers

The total number of samples or observations N to be taken can be determined from the following formula: if a binomially distributed population is assumed the formula for the standard error of a percentage is:

$$\sigma_p = \sqrt{\frac{P(1 - P)}{N}}$$

where P = an element time's percentage of the total cycle time expressed as a decimal. The value of P is either estimated or is based on a trial run. The value of $_p$ is determined from the following relationship:

$$\pm \frac{B}{100} P = Z_g \sigma_p \quad \text{where}$$

$\pm$ B = the percent of accuracy desired in the determination of P.

$\pm$ Z = the number of standard deviations which will enclose the sample observations at the desired confidence level g; i. e., when g = 95% then Z = 1.96.

In sampling plan such as was used in this study which had several P's (p, 1, r, e, a, d) it is theoretically necessary to base N on the smallest estimated P. However, practically it is sometimes necessary to combine some of the smaller elements or compromise on the reliability of prediction of the less important elements.

In this cargo handling study the data was recorded on the following forms which were specially designed: (References will be made to Figure 2 in this discussion.)

1. Process Chart (Figure 4) - this chart was made for commodity studied. It showed the sequence of operations for cycles 3 to 4, 4 to 5, and 5 to 6.
2. Work Sampling Observation Sheet I (Figure 5) - this form was used to record the activities of the transporting agent in cycle 3 to 4 (tractor or fork-lift truck) and the transporting agent in cycle 4 to 5 (hook).
3. Work Sampling Observation Sheet II (Figure 6) - this form was used to record the activities of the transporting agents in the hold, cycle 5 to 6 (men).
4. Cycle Times (Figure 7) - this form was used to record the start and finish times, for each of the transporting agents in cycles 3 to 4, 4 to 5, and 5 to 6.

Facility________ Berth________ Loading/Unloading Obs.________ Code No.________

Commodity________ Package________ Sheet No.____ of____

Ship________ Type________ Hatch________ Hold Position________

Process Description (indicate cycle divisions)	Chart Symbols	Men Req'd (No.)	Dist. Moved	Time Req'd (min.)	Equipment	Load Characteristics: Shape	Length	Width	W't.	Units per Load	Wt. per Load
	○○△□										
	○○△□										
	○○△□										
	○○△□										
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	○○△□										
Summation					Unit Characteristics						

Notes:

Holdmen: Frontmen:
Winchmen: Dockmen
Hatchtender: Truck drivers:
Total:

Code No.

Figure 4

WORK SAMPLING OBSERVATION SHEET I

Sheet No.________ of________ Observer________ Code No.________

Hatch No. and Comm.								
Units/Load								
No. Trans. Agents								
Time \ Cycle								
:00	54	42						
00	55	46						
01	57	47						
04	57	47						
04	58	50						
05	59	51						
06	:01	51						
07	02	52						
07	02	53						
08	03	55						
08	04	57						
09	05	59						
10	06	:01						
12	07	03						
15	08	03						
17	09	07						
20	10	08						
21	11	08						
24	12	10						
25	12	12						
26	13	13						
26	13	14						
29	15	15						
31	17	15						
33	19	17						
34	20	19						
34	20	20						
34	24	24						
35	25	25						
36	25	25						
37	26	26						
37	28	27						
38	29	28						
42	29	30						
43	32	30						
43	32	30						
44	36	34						
44	37	34						
50	38	35						
50	39	35						
52	40	35						
Σ	P	Q						
	L	O						
	R	G						
	E	S						
	D							
	A							
	U							
	C							
	X							
	ΣΣ							
No. of Cycles								
Average Gross Cycle Time								

Code No.

Figure 5

WORK SAMPLING OBSERVATION SHEET II

Sheet No.________ of________ Observer________ Code No.________

Hatch & Comm.										
Units/Load		No. Trans. Agents								
Cycle										
Time	Comm	Comm	D	A	U	C	X	Q	O	S
:00										
00										
01										
04										
04										
05										
05										
07										
07										
08										
08										
09										
10										
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59										
ΣP										
ΣL										
ΣR										
ΣE										
Σ%										
Number of Cycles										
Avg. Gross Cycle Time										

Hatch & Comm.										
Units/Load		No. Trans. Agents								
Cycle										
Time	Comm	Comm	D	A	U	C	X	Q	O	S
:01										
02										
02										
03										
04										
05										
06										
07										
08										
09										
10										
11										
12										
12										
13										
13										
15										
17										
19										
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24										
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32										
32										
36										
37										
38										
39										
40										
42										
46										
47										
47										
50										
51										
51										
52										
53										
55										
57										
59										
ΣP										
ΣL										
ΣR										
ΣE										
Σ%										
Number of Cycles										
Avg. Gross Cycle Time										

Code No.

Figure 6

CYCLE TIMES

Sheet No.____ of____ Observer________ Code No.________

Cycle			Cycle			Cycle		
Comm.			Comm.			Comm.		
Hatch			Hatch:			Hatch		
Cycle Time			Cycle Time			Cycle Time		
Start	Finish	Total	Start	Finish	Total	Start	Finish	Total

Notes:

Code No.

Figure 7

TALLY SHEET

Sheet No. ______ of ______ Observer ____________________ Code No. ____________________

HATCH AND COMMODITY

Code No. ______

Start:	Start:	Start:	Start:
Finish:	Finish:	Finish:	Finish:
Units/Load:	Units/Load:	Units/Load:	Units/Load:
Code No:	Code No:	Code No:	Code No:
Total Time:	Total Time:	Total Time:	Total Time:
No. Units:	No. Units:	No. Units:	No. Units:
Time/Unit:	Time/Unit:	Time/Unit:	Time/Unit:
Start:	Start:	Start:	Start:
Finish:	Finish:	Finish:	Finish:
Units/Load:	Units/Load:	Units/Load:	Units/Load:
Code No:	Code No:	Code No:	Code No:
Total Time:	Total Time:	Total Time:	Total Time:
No. Units:	No. Units:	No. Units:	No. Units:
Time/Unit:	Time/Unit:	Time/Unit:	Time/Unit:
Start:	Start:	Start:	Start:
Finish:	Finish:	Finish:	Finish:
Units/Load:	Units/Load:	Units/Load:	Units/Load:
Code No:	Code No:	Code No:	Code No:
Total Time:	Total Time:	Total Time:	Total Time:
No. Units:	No. Units:	No. Units:	No. Units:
Time/Unit:	Time/Unit:	Time/Unit:	Time/Unit:

Figure 8

FREQUENCY DATA

	TRANSPORTING AGENT														CYCLE TIMES IN	
	P	I	R	E	D	A	U	C	X	Q	O	G	S	Σ	INTERVAL	FREQUENCY
FREQUENCY																
% OF OBS.																
ELEM. TIME																

	COMMODITY					
	P	L	R	E	ΣD−S	Σ
FREQUENCY						
% OF OBS.						
ELEM. TIME						

TALLY		NOTES:	AVG.
TOTAL TIME			
NO. OF UNITS			
LOADS/HR			
LONG TONS/HR			

Figure 9

CYCLE ____________________ CODE NO. ____________________

COMM. CHARACTERISTICS	PROCESS L/D
COMM ____________	HATCH ________ STOW POS ________
PACKAGE ____________	T A ____________
SHAPE ____________	DISTANCE MOVED I ______ F ______ NO ______
L ______ UNITS/LOAD ______	JOB DESCRIPTION ____________
W ______	
H ______	
WT ______	
SHIP CHARACTERISTICS	NOTES
NAME ____________	
TYPE ____________	
FACILITY	
OPERATOR ____________	
BERTH ____________	
STEVEDORE ____________	

Figure 10

5. Tally Sheet (Figure 8) - this form was used to obtain information on the rate of loading. The observer made a tally every time a load was taken over the side of the ship during some time interval.
6. Data Summary Card (Figures 9 and 10) - this card is a Hadley Unisort Analysis Card with punched holes on which data is summarized on both sides. A different card is used for each cycle (3 to 4, 4 to 5, and 5 to 6) and for each different commodity. All the data on the aforedescribed forms is finally reduced and summarized on these cards. The punched holes facilitate the selection of particular kinds of data and the analysis of these data.

Note: Much of the background material presented in this paper is presented in greater detail in An Analysis of Cargo Handling, Report 53-21, Department of Engineering, University of California, Los Angeles, October 1953. Another report is now in process which will contain a section describing in complete detail the methodology used in obtaining all the field data. This research is being sponsored by the Office of Naval Research, United States Department of the Navy, under Contract Nonr 233(07) with support and assistance from the Maritime Administration, United States Department of Commerce.

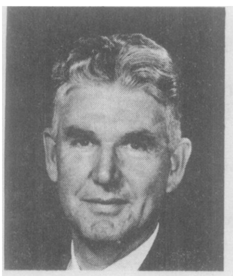
PERFORMANCE SAMPLING IN WORK MEASUREMENT

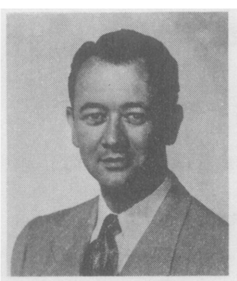
Ralph M. Barnes
Professor of Engineering and Production Management

Elwood S. Buffa (speaker)
Lecturer in Production Management

Donald C. Demangate
Production Management Laboratories Supervisor
and
Robert B. Andrews
Research Assistant

University of California
Los Angeles, California





Performance rating is one of the important tools available to the industrial engineer. This rating procedure has been widely employed in industry particularly in its application to stop-watch time studies. Its use is not limited solely to supporting roles however, as it can be a primary analytical device in itself. An example of the direct application of performance level indices is the determination of a representative rating factor for an entire industrial activity. The ingenuity of the industrial engineer has resulted in an ever increasing number of new and different applications for this tool. Typical of the newer uses is its combination with delay studies to audit existing time standards or to establish new time standards.

Because of its many and varied possible uses, there exists a need for an economical and accurate method of measuring productive effort. To meet a similar need for determining and measuring delays in production, L.H.C. Tippett[1] devised a statistical sampling method which has become commonly known as "Ratio-Delay." Statistical random sampling appears equally suited for work measurement. Toward this goal a study was initiated for the development of a performance sampling technique which would enable management to determine objectively, with a preassigned reliability, the productive level of manually controlled activities within an industrial organization.

This investigation of the applicability of statistical methods to work measurement has been divided into three main phases:

1. The investigation of the type of statistical distribution which is representative of rating factors of manually paced operations.
2. The development of the specific statistical technique to be used based upon the appropriate distribution.
3. The determination of the validity of the chosen statistical method by its actual application in cooperation with local industrial organizations.

The purpose of this discussion will be to summarize the procedures used and the results obtained to date and to outline briefly the methodology proposed to complete this investigation.

THEORY OF PERFORMANCE SAMPLING IN WORK MEASUREMENT

Part one of this study, the determination of the representative distribution, has been completed and the results published.[2] For this phase rating factors of manually paced operations were obtained from two local manufacturing organizations. Conferences with industrial engineers and statisticians had indicated that such indices would most likely be normally distributed. The Chi-squared Test was used to test this hypothesis. The result of these tests was the strong rejection of the hypothesis of normality for both sets of data. The probability that the data from either company was from a normally distributed population was less than 1 to 1000.

With the rejection of the hypothesis of normality, it was obvious that no generalizations could be made about the distribution of rating factors. Consequently, non-parametric statistical methods, i.e. the field of statistics encompassing the techniques which require no assumptions about the form of the distribution, had to be used to develop the specific statistical technique. One relationship applicable when little is known about the distribution of the population is Chebyshev's Inequality. This law states that the amount of area under the curve which is farther from the mean than k standard deviations is always less than $1/k^2$. For example less than $(1/2)^2 = .25$ of the area under the distribution lies more than two(2) standard deviations from the population mean regardless of the form of the distribution. Using this inequality as a basis enabled the development of relationships directly applicable to work measurement sampling.

The definition of symbols to be used in the subsequent discussion are as follows:

$\bar{x}$ = sample mean

μ = population mean

α = level of significance

$1 - \alpha$ = confidence level

n = sample size or the number of observations in the random sample

d = desired maximum variation between the population mean and the sample mean

σ = population standard deviation

s = sample standard deviation

$\sigma_{\bar{x}}$ = standard error of the mean

σ_s = standard deviation of the distribution of sample standard deviations

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

β_2 = relative kurtosis

c = constant of a distribution reflecting its kurtosis or the degree to which the distribution is "peaked". It is obtainable from tables[3] if β_2 is known.

V_1, V_2, V_3 and V_4 = first, second, third and fourth moments of the distribution about the assumed calculation mean.

π_2 & π_4 = second and fourth moments of the distribution about the actual sample mean.

A distribution of sample means drawn from a non-normally distributed population will be approximately normally distributed if the same size, n, is greater than 50. Thus the use of a minimum sample size of 50, enables the applying of normal distribution relationships to the distribution of sample means. Normally distributed sample means vary at random about the population mean with a standard deviation equal to the population standard deviation divided by the square root of the sample size, or

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}} \quad .$$

Chebyshev's Inequality makes possible the determination, with a pre-assigned confidence level, of the sample size necessary to obtain a sample mean that will lie within a predetermined distance of the true population mean. Less than $1/k^2$ of the area is farther from the population mean than $k\sigma_{\bar{x}}$.

Letting d, the desired maximum difference between the population mean and the sample mean, equal

$$k\sigma_{\bar{x}}, \quad k = d/\sigma_{\bar{x}} \quad \text{and} \quad 1/k^2 = 1/\frac{d^2}{\sigma_{\bar{x}}^2} = \frac{\sigma_{\bar{x}}^2}{d^2}$$

$$\text{but} \quad \sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}} \quad \text{so that} \quad 1/k^2 = \frac{\sigma^2}{d^2 n} \quad .$$

The quantity $1/k^2$, however, must be equal to our level of significance, α , so that the confidence level $1 - \alpha$ will equal the total area included in the interval between the population mean plus and minus d, or

$$\alpha = \frac{\sigma^2}{d^2 n} \quad .$$

Solving this expression for the required sample size results in

$$n = \frac{\sigma^2}{d^2 \alpha}$$

Thus with a predetermined desired accuracy, d, and level of significance, α , the sample size required so that the sample mean will fall within a pre-assigned distance of the population mean ($1 - \alpha$) 100 percent of the time is dependent only upon σ , the population standard deviation.

Various solutions to the equation

$$n = \frac{\sigma^2}{d^2 \alpha} \quad ,$$

for a level of significance of 0.05, are shown graphically in Figure 1.

CLASS MIDPOINT t	NUMBER OF INDICES a	t = t₀ + iU = 105 + 5U				
		U	aU	aU²	aU³	aU⁴
90	7	-3	-21	63	-189	567
95	6	-2	-12	24	-48	96
100	15	-1	-15	15	-15	15
105	28	0	0	0	0	0
110	15	1	15	15	15	15
115	6	2	12	24	48	96
120	3	3	9	27	81	243
TOTALS	80		-12	168	-108	1032

$$V_1 = \frac{\sum aU}{n} = \frac{-12}{80} = -0.15 \qquad V_3 = \frac{\sum aU^3}{n} = \frac{-108}{80} = -1.35$$

$$V_2 = \frac{\sum aU^2}{n} = \frac{168}{80} = 2.10 \qquad V_4 = \frac{\sum aU^4}{n} = \frac{1032}{80} = 12.90$$

$$\bar{X} = t_0 + iV_1 = 105 + 5(-.15) = 104.3 \qquad \pi_2 = V_2 - V_1^2 = 2.1 - (-.15)^2 = 2.08$$

$$\pi_4 = V_4 - 4V_1V_3 + 6V_1^2V_2 - 3V_1^4 = 12.90 - 4(-.15)(-1.35) + 6(-.15)^2 2.1 - 3(-.15)^4$$

$$\pi_4 = 12.4 \qquad \beta_2 = \frac{\pi_4}{\pi_2^2} = \frac{12.4}{(2.08)^2} = 2.87 \qquad \text{FOR } \beta_2 = 2.87, \; C = 0.96$$

$$s = i\sqrt{\pi_2} = 5\sqrt{2.08} = 7.2 \qquad K = \frac{1}{\sqrt{\alpha}} = \frac{1}{\sqrt{.05}} = 4.47$$

UPPER CONFIDENCE LIMIT FOR $\sigma = s + \frac{CKs}{\sqrt{2n}} = 7.2 + \frac{(.96)(4.47)(7.2)}{\sqrt{(2)(80)}}$

OR 9.6 WHICH IS LESS THAN THE ASSUMED VALUE OF 10

ACTUAL POPULATION VALUES: $\mu = 102.3$ AND $\sigma = 7.05$

Figure 1

Although the solution to this equation requires a knowledge of σ , the population standard deviation, in order to determine the exact sample size, an approximate sample size can be determined by making a reasonable estimate of σ . Examination of production output distributions would seem to indicate that a σ of 12 units would be typical. If the mean of the actual performance indices in an industrial organization was 100, this value of σ would mean that roughly 90% ($1-1/k^2 = 1-1/3^2$) of the indices would lie within 3σ of that mean or between 64 and 136.

If a sample of size n is taken based upon a reasonable estimate of σ such as 12 units, the sufficiency of the sample size may be tested. This is accomplished by the determination of the upper confidence limit of the population standard deviation σ . The upper confidence limit is based upon s, the sample standard deviation. Its value is compared with the assumed σ . If its value is less than the assumed value, the sample size was sufficient for the desired accuracy and statistical confidence. If, however, it is greater than assumed, additional sampling will be required. This process of sampling and comparison must be repeated until the calculated value of the upper confidence limit is less than the assumed population standard deviation.

The upper confidence limit of σ is based upon the distribution of the sample standard deviations and Chebyshev's Inequality. The standard deviation of the distribution of sample standard deviations is approximated by

$$\sigma_s = \frac{cs}{\sqrt{2n}} .$$

From Chebyshev's Inequality, the upper confidence limit is then given by the expression $s + k\sigma_s$, where the desired significance level $\alpha = 1/k^2$. Substituting

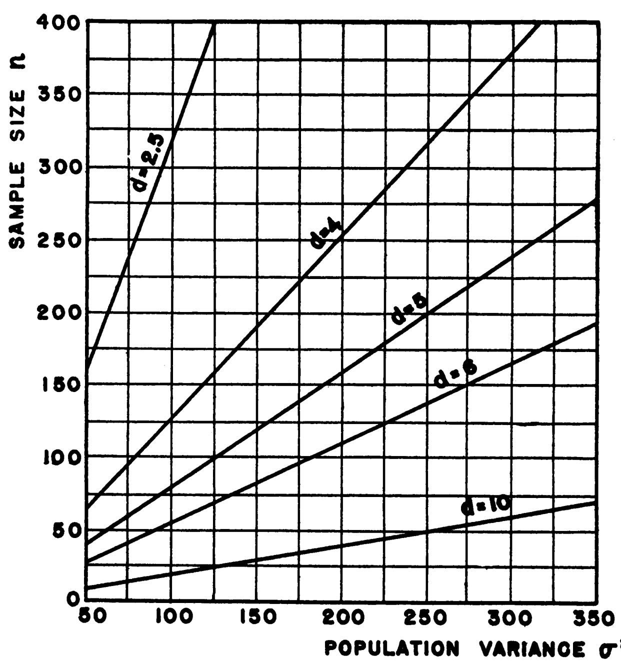
$$\sigma_s = \frac{cs}{\sqrt{2n}}$$

into the expression results in the upper confidence limit being equal to

$$s + \frac{kcs}{\sqrt{2n}} .$$

The illustrative example in Figure 2 may aid in demonstrating this method of analysis as applied to the results of a work measurement sampling. The random sample shown in the frequency distribution was drawn from a population of approximately 3000 rating factors with the aid of a random number table. These 3000 observations were the result of a study in which eight operators were rated once a minute throughout an entire eight hour working period. The population standard deviation was assumed to be 10. Letting $\alpha = .05$ and $d = 5$ units resulted in the sample size of

$$n = \frac{\sigma^2}{d^2\alpha} = \frac{10^2}{5^2(.05)} = 80.$$



SOLUTIONS OF THE EQUATION $n = \frac{\sigma^2}{d^2\alpha}$, $\alpha = .05$

Figure 2

PERFORMANCE SAMPLING PROCEDURE

Assuming that it is desired to make a work measurement study of a manually paced activity, how does one proceed if it is decided to gather the information through performance sampling? The necessary steps may be outlined as follows:

Step 1 - Fix the desired accuracy d and the statistical significance level α .
Step 2 - Make a reasonable estimate of the population standard deviation σ, based upon past experience if possible.
Step 3 - Determine an estimate of the required sample size n from the applicable equation

$$n = \frac{\sigma^2}{d^2\alpha}$$

or graphs such as the one shown in Figure 1.
Step 4 - Based upon the estimate of the required sample size and the number of operators in the activity to be measured, calculate the number of different sampling times that will be required. Randomness of these sampling times is absolutely necessary in order statistically to validate the study. A random number table is the most convenient method for determining the sampling times while at the same time insuring that they have been chosen at random.
Step 5 - Take a random sample of size n. Observations are made of each worker chosen at the established sampling times. At the instant that the observer views each worker, the state of operation is noted.

a. If the operation is in a productive state, the worker's performance level is rated and the rating is recorded.

b. If the operation is in a delay state, it is so noted by the use of a convenient key.

Step 6 - Convert the sample into a frequency distribution to facilitate calculations. Compute the required statistics including the sample mean which is the estimate of the average performance level of the operators within the selected group.
Step 7 - Determine the upper confidence limit of σ by evaluating the expression

$$s + \frac{cks}{\sqrt{2n}} .$$

Step 8 - Compare the computed upper confidence limit of the population standard deviation with its assumed value. If the confidence limit is less than assumed, a large enough sample has been taken. If, however, it is greater, additional sampling will have to be undertaken. When the sample size has been shown to be insufficient, the new estimate of the required sample size should be made by substituting the computed value of the upper confidence limit for σ in the equation

$$n = \frac{\sigma^2}{d^2 \alpha} .$$

VALIDATION UNDER ACTUAL OPERATING CONDITIONS

Only the determination of the practical validity of this statistical sampling method by its actual application to industrial situations remains to be completed. For this final phase, it will be necessary to compare the sampling estimates with the actual average performance levels to determine whether the desired accuracy can be obtained. Among the methods proposed for this purpose are the comparison of the results of performance sampling with all day time studies, and with daily performance indices which are calculated for payroll purposes.

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STATISTICAL EVALUATION OF WORKER PRODUCTIVITY

Donald C. Demangate
Graduate Student
University of California
Los Angeles, California

A title that would be more descriptive of this paper would be "The Effects of Wage Incentives Upon Productivity," since the research done in connection with it has been mainly a comparison of productivity under a wage incentive system with productivity under ordinary daywork conditions.

Productivity has been defined by S. A. M. as "Actual performance as compared with expected or standard performance, or with a base period." The measure of productivity used for all data in this paper is the "performance ratio," the ratio of actual production to standard production for a period of time, expressed as a percentage. This is the most common measure and is the one usually used in most textbooks when discussing productivity. With this measure a productivity or performance of 100% indicates that actual production equals standard; a performance above 100% indicates that actual exceeds standard, while less than 100% means that the standard is not being met.

Almost every textbook on Motion and Time Study illustrates the productivity of a group of workers working under incentive conditions with the familiar Normal, or some similar bell-shaped curve, showing the average performance at about 125%, with the tails at about 90% on one end of the distribution and about 160% on the other. But very few of these texts discuss or show any productivity distribution of people working under ordinary daywork conditions. Yet, to evaluate and measure the effects of a wage incentive program, we must know where we started from; that is, what conditions existed before the installation of the incentive system.

One of the reasons for this omission in textbooks is the relative scarcity of such data. Most companies that keep accurate and complete records of employee productivity are on incentive anyway. Finding a company that isn't using an incentive plan but that has these records is a hard thing to do. Nevertheless such a company was found in the Los Angeles area. All of the data presented in this paper was gathered from this company's records.

This company, a young manufacturing firm with about 1000 employees was planning to install a wage incentive system in their plant and, in preparation for it, set time standards in all their departments. These standards were all set by stop watch time study and checked with Elemental and Standard Data. After the standards were set in each department the incentive was not immediately installed, but instead the department continued on working under daywork conditions for a period of at least three months, during which time complete records were kept of individual and departmental productivity.

Figure 1, showing the historical trend of productivity in two departments of this company, is a graph of the average weekly productivity for each department for a period of time before and after incentive. From this graph

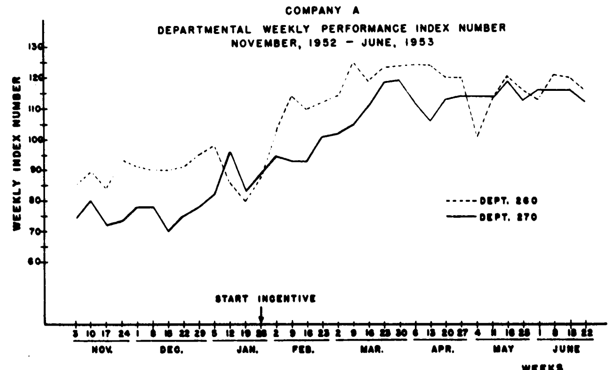

Figure 1

it can be seen that, for department #270, the average weekly productivity varied between about 70% to 80% under daywork and increased to between 110% and 120% after incentive, while department #260 had a productivity of about 90% before incentive and about 120% after. Department #260 is an assembly department where all operations are manually paced. Department #270 is also an assembly department with about 70% of the operations manually paced and the rest machine paced.

The daily average productivity (Figure 1 is the weekly average) of these two departments, plus two more not shown in the figure, were analyzed and found to be significantly different from one another both before and after incentive. (This is easily seen in Figure 1 for the period of time before incentive but is not so apparent after incentive.) The implication of this is that productivity under either daywork or incentive conditions is not <u>one</u> particular percentage for all departments, or all companies, but probably is dependent on several or many factors. Such factors as "effectiveness of supervision", "type of operations performed", and "size of department" may all have some effect on this productivity. Nevertheless this data still gives some indication of "typical" values that productivity may take under either condition.

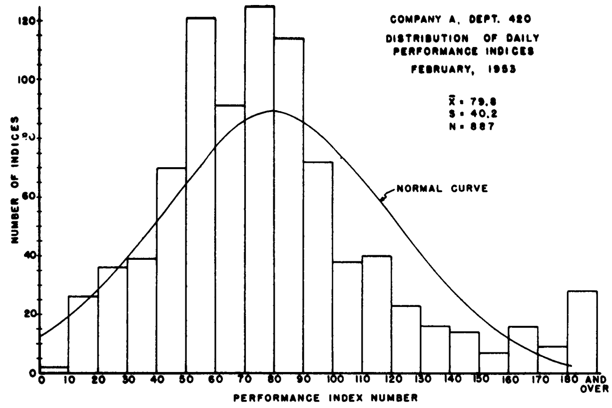

Figure 2

Figures 2 and 3 are distributions of productivity for a one month period in one department. Figure 2 is the distribution for daywork conditions; Figure 3 is for incentive conditions. It should be noted that the distributions include all <u>daily</u> performance ratios in the department for the period of time covered. Thus, most workers in the department have about 20 (the approximate number of working days in the month) daily performance ratios included in the distribution. This combining of all the daily distributions of productivity into <u>one</u> large distribution was desired so that a large sample size could be had

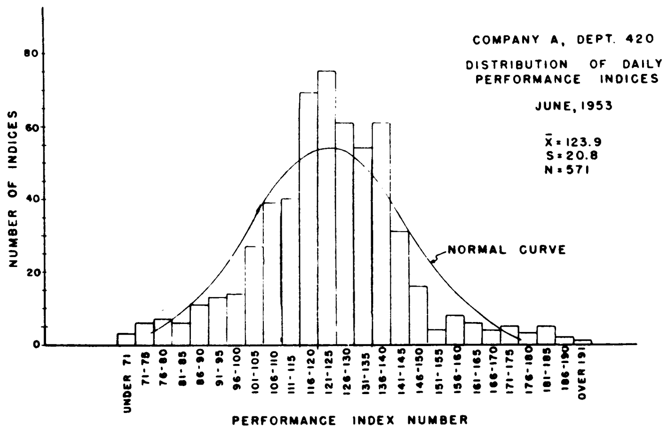

Figure 3

for testing for Normality. It was justified by a statistical analysis which showed that each daily distribution was essentially like each of the others, and therefore could be combined into one distribution. Validation was obtained when it was found that this lumping of values together increased the standard deviation only .9 percentage points over the average daily standard deviation. (from 39.3% to 40.2%). Thus, the combining of all distributions into one had little effect upon the spread of the data.

Examination of each of the distributions shows that, before incentive, the average productivity was about 80%, and that it increased to about 124% after the incentive was installed. Also, the spread of the distribution, as measured by the standard deviation was about 40% before incentive, but only about half that amount afterwards. Since both distributions have their upper tail at about the same value (180%), this decrease in spread was accomplished mainly by increasing the lower and middle values of performance, thus tending to make all values of performance more nearly equal and at a higher level.

Both Figures 2 and 3 also show Normal curves drawn with the same mean and standard deviation as the data of the distributions. It is easily seen that these curves are very poor fits to the distributions.

These two distributions were made up of all the workers in the department and therefore included performance ratios of individuals working on different jobs and operations having different standards. This no doubt had some effect on the distributions. Therefore, a similar analysis was made of a distribution of productivity of only people working on the same operation. This operation was a small hand assembly operation, 100% manually paced.

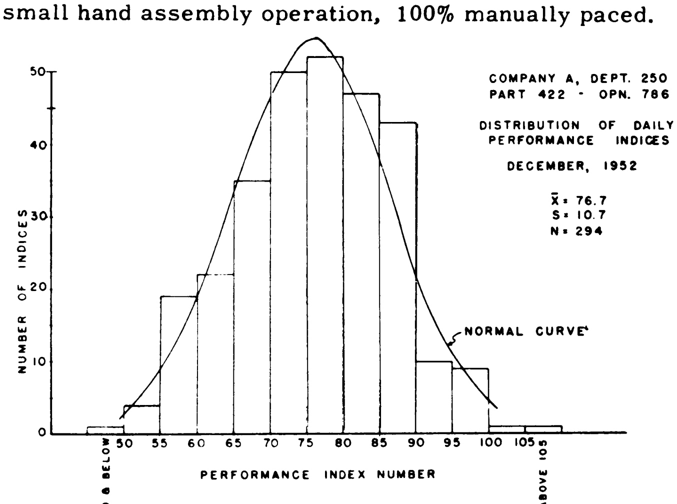

Figure 4

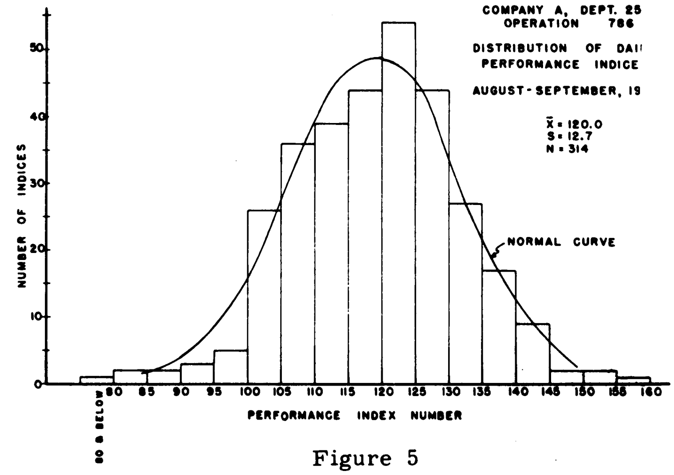

Figure 5

Figures 4 and 5 show the distributions of productivity of this operation for before and after incentive. A comparison between them shows that, outside of the difference in menas, (the average productivity increased from about 77% before incentive to 120% afterwards), the two distributions are very similar. The Normal curves that are drawn with the same values of mean and standard deviation are statistically good fits, and the spread is about the same for both distributions. (Actually, the standard deviation after incentive is statistically greater than the one before, but the absolute difference is small anyway.)

It is interesting to note that the distribution of productivity after incentive agrees very closely with the theoretical distribution found in most textbooks; it is Normal, has its mean in the range of 120% to 130%, and has about 5% of its values below standard.

Now these distributions give some indication of how incentive affects the productivity of groups of workers, but do not tell much about how it affects individuals; that is, they give no indication of whether each worker was motivated the same amount or not.

To answer this question a study was made of the productivity of 17 workers doing essentially the same kind of work. It was found that, for both before and after incentive, workers tended to keep a definite ranking in productivity from week to week, but that the ranking before incentive was entirely independent of the ranking afterwards. In other words high productivity workers tended to remain high from week to week, low productivity workers tended to remain low, and so forth, under either daywork or incentive conditions, but the high producers before incentive were not necessarily high producers afterwards, and vice versa. Therefore, the conclusion is that the incentive increased some workers' productivity more than others. Since everyone increased their productivity some amount, it must be concluded that some workers were more motivated than others.

To summarize the results obtained from the analysis of this and some similar data, it can be concluded that:

(1) "Typical" performance under daywork conditions is about 80%. Once again it is emphasized that this figure is typical, but not necessarily representative of all departments, companies, or industries. A great many factors, including probably the "type of operations performed" and the "effectiveness of the supervision" may greatly affect the level of performance. More

research is needed on this subject before definite conclusions can be stated.

(2) "Typical" performance under incentive conditions is about 120%. The same emphasis discussed above applies here also.

(3) Besides increasing productivity, incentive tends to decrease the differences in performance between different jobs or operations, tending to make equal in performance.

(4) Distributions of productivity tend to become more and more Normal as the operations performed become more and more identical. Thus a distribution of departmental productivity in most cases would not be Normal, but a distribution of productivity involving only one operation can probably be assumed to be Normal or nearly Normal.

(5) Workers tend to keep their relative (to one another) ranking in productivity from week to week, under either day work or incentive conditions, but the incentive motivates them differently. Thus, it may make a worker who is a consistently low producer under daywork into a consistently high producer under incentive, and so forth.

RECENT DEVELOPMENTS IN THE PACKAGING OF CITRUS FRUIT

Roy J. Smith
Associate Professor of Agricultural Economics
University of California
Los Angeles, California

The marketing of fresh fruit and vegetables has sometimes been cited as one field in which industrial engineering could contribute little. The technical requirements have been assumed to be so specific and rigid in character as to forestall handling changes of any great significance. Changes in transportation and storage had occurred; but other than in refrigeration, the technical methods at the most had been only modified. Fortunately in the last few years a renaissance of technique has begun to occur which bids fair to revolutionize fruit and vegetable marketing. Within five years, 75 per cent of lettuce shipments have been converted over to field packing in the corrugated box carton and to vacuum cooling. The apple industry is gradually converting to a new container and controlled atmospheric storage. Other changes are occurring.

The industry to which our attention is directed, however, is lemons, and here the change has been phenomenal. The first shipment to an eastern market in other than the old standard wrap pack was in June, 1951. Today I would estimate that only about 5 per cent of our shipments are in the old package, about 10 per cent are in a new wooden half box, and about 85 per cent in a completely new half box carton made of corrugated paper.

The net cost reductions to all segments in the marketing process approximate 90 cents per standard box. Tables I and II outline these cost reductions, the first table showing reductions which have been immediately available to typical growers and the second table showing reductions which either are potentially available to various growers or are available to other segments of the industry.

The key change was to a new corrugated paper container laminated inside with a fungistatic material called Biphenyl. The package is tight and non-abrasive to the fruit so no wrap is needed. In place of the old laborious hand wrap and pattern pack, the fruit now is simply spilled into the carton and shaken down to a solid fill. Since the carton is much lighter than the old, a significant saving in freight is achieved., The only problem is in storage. Under the old technique, the shipping box was first used for storage. It is, of course, no longer available and until a properly designed storage box has been developed, costs of storage will be increased. The net change in costs immediately available to growers approximated 39 cents per standard box.

Other cost reductions, however, are equally important. Some other gains are possible directly to the packing house. Most houses are cooperative owners of timber and mills for the manufacture of the shook used in the old box and with conversion of all citrus varieties to the new container, there is no need for the timber and mills and a capital gain of real significance can be looked for. Its value is unknown but some indication may possibly be gained from the greater immediate gain of houses which

Table I
Cost reductions immediately available
(Houses owning own timber and mills)

Item	Standard box	Half-box carton (2)	Cost difference decrease	Cost difference increase
	(cents per standard box equivalent)			
Materials (billing out prices)				
Standard (incl. construction)	65.10			
Carton (incl. collar and glue)		49.20	-15.90	
Packing Labor				
Standard				
Direct (25.20)				
Training (1.50)	26.70			
Carton (volume fill)		6.00	-20.70	
Freight (Standard)	165.80	154.40	-11.40	
Unloading and material spreading and loading cars	3.10	2.70	-00.40	
Total reduced costs			-48.40	
Storage box (cost 42.60—10 uses)		4.30		+ 4.30
Cleaning and repair		2.00		+ 2.00
Shape sorting		1.00		+ 1.00
Depreciation (new equipment)		2.20		+ 2.20
Total increased costs				+ 9.50
Net cost reduction			-38.90	

Table II
Other cost reductions

	Extent of application	Estimated reductions Specific (cents)	Estimated reductions Industry average (cents)
Packing houses			
Current discounts	85%	4.68	
Extra reductions to houses not owning timber and mills	13%	11.00	
Capital gain from timber and mills	87% of industry	?	
Transportation			
Refrigeration	Almost all houses		8.00
Recooperage	100%		5.00
Wholesalers			
Box cutting	1/4 to 3/4 of trade	25.00	
Retailers			
Box handling and unwrapping. 9-12 minutes	100%		20.00 to 40.00

did not participate in this ownership of timber and mills. Their shook for the old box had been costing them about 11 cents more, and of course their immediate advantage with the new container was increased over the other houses by that amount.

For various reasons, two 5 per cent discounts are now available to most houses on the cartons relative to the billing rate shown in Table I. Not only is this an additional cost reduction available, but another and better carton design is now available which will require 5 to 7 per cent less paper and consequently cost that much less.

The new carton is highly insulating and since lemons are packed at an ideal shipping temperature, the cartons will keep the lemons at a proper temperature without so much refrigeration as was needed with the old ventilated carton. Almost all houses on which reports have been available have made significant changes in their icing practices and the resulting cost reductions can be considered as equaling at least 8 cents per standard box. This reduction will most likely be larger as more experience is gained and shippers and buyers gain confidence in the new practices.

One of the most surprising results of the new carton was the virtual elimination of recooperage cost to the railroads. The old wooden crates, while strong in certain respects, were extremely rigid and easily loosened. Once loose, they each acted as a battering ram and breakage was common. The last estimate (verbal) from the Container Committee of the American Railway Association was that the average recooperage bill was $24 a car or over 5 cents a standard box. With the new carton, on the other hand, the railroads have sustained almost no loss. Even if a box is torn or crushed, no fruit is damaged. This advantage, of course, goes to the railroad.

The old crate was too large for an important portion of the trade. Sales in the typical store were so slow that some of the fruit would wilt and shrivel if not decay before sale. The investment was too great for grocers to ignore the loss so they usually tried to buy half boxes. Wholesalers, in consequence, had to saw the old box in two. One half might be nailed together into a rough but fairly presentable container. The other half, however, had to be held together with rope or wire and was a most unsightly and awkward container. The extent of the practice is unknown but one well informed estimate was that 50 per cent of lemon boxes were so treated. The proportion varied with the season. The cost also is unknown but no one has ever suggested a cost below 20 to 25 cents. The new half-box carton naturally eliminated all this.

In the retail store itself, more important economies were obtained. The most onerous task with the old package was taking off the wraps and disposing of them. If the store bought a full crate only a strong man could handle it and frequently two and even three trips were made to the sales counter with a single container to display some but not all of the fruit each time. The new carton eliminated all this onerous work. Cost reductions equal to 75 cents a standard box have been estimated but more conservative estimates range from 20 to 40 cents depending on whether a half or whole box was purchased and on various other circumstances.

The surprising and most fortunate development was an improvement in the quality of the fruit delivered. The Biphenyl in the tight box not only prevented decay but delivered the fruit in a fresher and more inviting appearance. This single factor could well be dominate in the rapid expansion of sales. Premiums over the old ventilated crate came to be expected. Thus an old tradition and seemingly permanent technique was destroyed.

The contributions which made these changes possible came from widely distributed sources. The Kraft paper companies under the leadership of the International Paper Company made the most important contribution. Many factors had a hand in the development of Biphenyl, but the Weathers Packaging Service of Orlando, Florida, was primarily responsible for the specific application. Industry organizations such as the Ventura County Citrus Growers Association and the Citrus Industry Research Association not only gave impetus to industry interest but made the specific University of California contribution possible. It was packing house management, of course, that had to venture the fruit in the experimental shipments.

The viewpoint required was the gamet of the market channel. Every step was involved from the moment of storage after picking to the final sale. The initial objective which was recognized as offering a clear gain was the elimination of fruit unwrapping in the retail store. The initial suggestion was the use of a transparent wrap which the consumer would buy on the fruit and a great deal of research effort was expended to that end.

The first really successful step, however, was the mechanics of filling a corrugated paper carton. This process, so far as mechanics was concerned, was proved long before a satisfactory carton was offered and before Biphenyl was tried. The confusing factor here was maintenance of satisfactory standards for inspectors, and the closest cooperation of state and industry administrative personnel and of the research people involved was required for its solution. The potentialities of labor saving was an attraction to the packinghouse managements from the first. Administrative participation in working out the compromises involved in standardization, however, required some actual experience before it could be achieved.

Figure 1
New and old lemon containers. New containers just one-half as many lemons as the old.

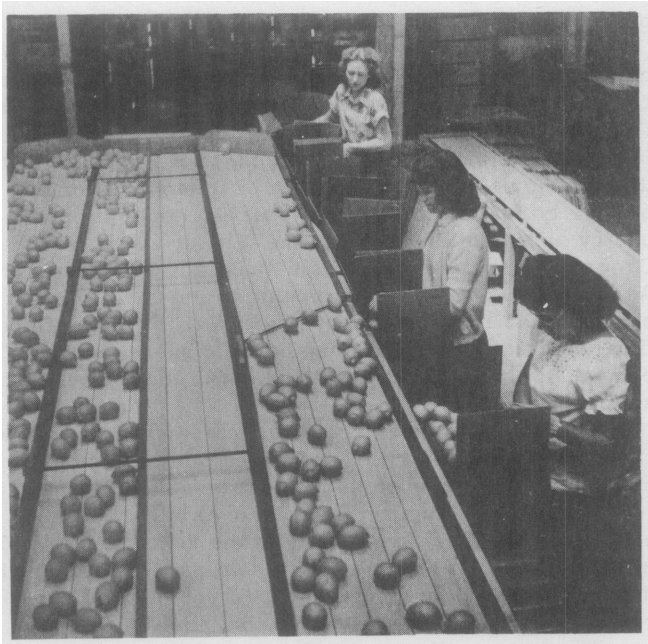

Figure 2
Volume fill process of packaging lemons. Girl at back folds boxes and places them in shoot. Center girl controls flow of fruit into box. Next girl top dresses lemons. In next step fruit is shaken down to solid fill.

The dimensioning of the box required attention not only to the structural strength limitations of the paper material involved but also to the ease of handling in packinghouses and in stores. It must be fitted to the machinery required such as for sealing. It must load properly in refrigerator car and truck. Finally, it must pack fruit properly. Before the volume fill technique was adopted this packaging required a dimension in which a pattern of fruit could be formed for each size group which would give a number equal to the size pack numbers used in the old pack.

These many considerations establish the need for a broad viewpoint on the part of both the industrial engineer and marketing economist. The success of the venture would seem to justify the feeling that in the fresh fruit and vegetable field there is much more to be done along these lines. It would also seem to indicate the desirability of workers in these two fields of research being bound together in close cooperation.

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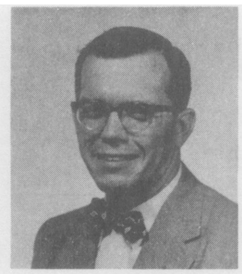
A STUDY OF INTRA- AND INTER-INDIVIDUAL DIFFERENCES IN THE PERFORMANCE TIMES OF THREE EVERYDAY LIVING TASKS

John R. Huffman
Associate Professor of Industrial Engineering
University of Southern California
Los Angeles, California



INTRODUCTION

The Artificial Limbs Project in the Department of Engineering Research on the Los Angeles Campus utilizes the "motion and time method" to evaluate the relative merits of prosthetic devices (Fig. 1). This method compares the performances of an amputee wearing each of several artificial limbs on three scales:

a. The time required to perform a task and the therbligs constituting it.
b. The number of the movements required to perform the task.
c. The extent of such movements.

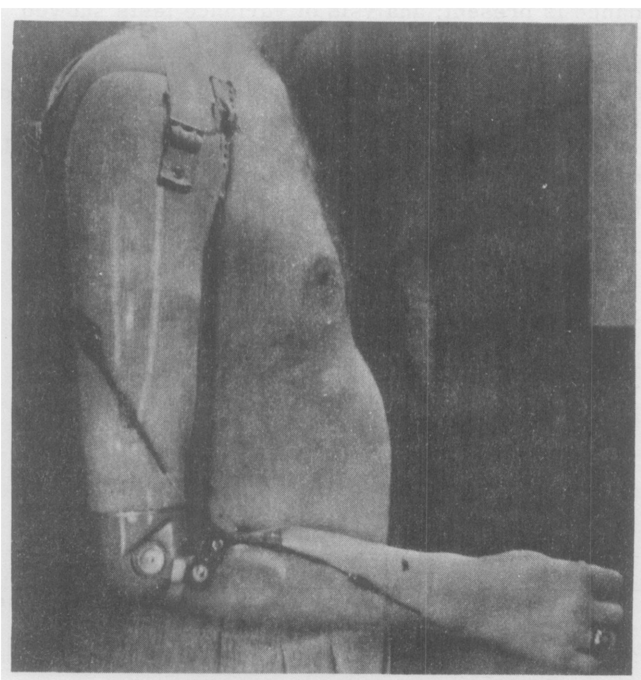


Figure 1
A Typical Upper Arm Prosthesis

It is assumed that the better prosthesis allows the amputee to perform a task in less time with fewer and less extensive movements.

The comparison of prostheses on these three relative scales has been necessitated by the lack of data that describes both the times and movements required by non-amputees performing tasks and is also suitable for prosthesis evaluation. It was the primary purpose of this preliminary investigation to supply some of this missing information -- i.e. to ascertain and to describe the times required by non-amputees to perform three evaluation tasks and the therbligs* constituting them.

Secondary purposes of the research that might interest this group were two:

a. To compare performance times obtained with and without prior practice.
b. To compare mean non-amputee times with those predicted by standard data from industry.

It is important to note that the immediate and unqualified use of standard data to establish non-amputee task times is precluded by two considerations:

a. Standard or elemental data is concerned with levelled, single-valued times for specified methods. This research is interested in estimating not only the performance time but also the variability due to differences in method and effort. A prosthesis that permits amputees to perform within ∔ or 1.5 sigma of the mean of all non-amputee performance times may be perfectly satisfactory.
b. Motions are probably performed at one speed in the factory and another in living activities outside the plant.

THE EXPERIMENTAL DESIGN AND PROCEDURE

Since upper extremity artificial limbs are designed for maximum general utility, evaluation tasks or sequences of motions have been designed to include most of the motions required of a natural limb. These sequences, which include opening a door, sharpening a pencil, answering a phone and ten similar tasks, are called "everyday living activities."

In this preliminary experiment three of the everyday living activities were investigated. These were:

a. Hanging a weighted coat hanger on a wire and removing it.
b. Answering a phone.
c. Ladling soup.

Twelve subjects -- ten male and two female -- participated in all phases of the research.

<u>Phase I</u>: The first portion of the experiment sought to determine for each task:

a. The mean time required by all subjects to perform each task and therbligs constituting it.
b. The variability in mean performance times from one individual to another.
c. The variability in times of successive performances by one person.

Data were obtained for one pace defined by the instruction "do the task naturally -- as you would every day" and for a maximal pace defined by the instruction "do it as fast as you can without disturbing or spilling the phone, soup, etc."

The tasks were so simple that it was possible to execute them after a verbal description that stressed the body position at beginning and end. One performance of each task at "natural" pace and one at maximal pace were recorded on 35 mm. motion picture film (for later micromotion analysis) during one test session. This procedure was repeated after several days -- but with a different

* Therblig times are not discussed in this paper but will be included in the formal report of this research.

task order. Different orders to task performances and the time delay were an attempt to make the cycles a random sample from the everyday performances of each task.

Phase II: This phase of the research sought to determine the effect of changed instructions and prior practice on:

a. The mean time required by all subjects to perform each task and its therbligs.
b. The variability in times of performance from one individual to another.

In this phase of the experiment each subject practiced each sequence at a pace defined by the instruction "perform the activity casually, not too fast or too slow." Each trial was timed and recorded. When a subject performed any task within a similar range of times at three successive practice periods, a representative cycle was again filmed for later micro-motion analysis.

RESULTS

Phase II: Representative means and standard deviations for the performances of each task at different stages of practice are shown in Table I below:

Table I
EFFECT OF PRACTICE ON CASUAL PACE
(All times in seconds, n = 12)

Activity		Practice Session #1	#4	Last
Hanger	Mean	8.04	8.77	8.81
	S. D.	1.28	1.03	1.16
Phone	Mean	5.06	5.73	5.60
	S. D.	.79	.90	.95
Soup	Mean	6.26	6.99	6.92
	S. D.	1.02	.92	1.07

It is apparent by inspection that there are no significant differences among these means or standard deviations. This constancy of the mean is in contrast with the usual reduction in average time that accompanies practice; it is, however, a measure of the success of this experiment. If the mean performance time had decreased, it could have indicated the tasks used were not "everyday tasks" to these subjects.

The mean and standard deviations of the net times for the filmed cycles from Phase I (no prior practice) and Phase II are shown in Table II below:

Table II
COMPARISON OF TIMES FOR FILMED CYCLES FROM PHASES I AND II (in seconds)

Activity	Phase	Session	Mean	S. D.
Hanger	I No Practice	A	8.64	1.36
		B	7.82	.97
	II With Practice		8.48	1.19
Phone	I No Practice	A	4.49	.65
		B	4.30	.50
	II With Practice		4.50	.70
Soup	I No Practice	A	5.95	1.13
		B	5.40	.99
	II With Practice		5.70	.71

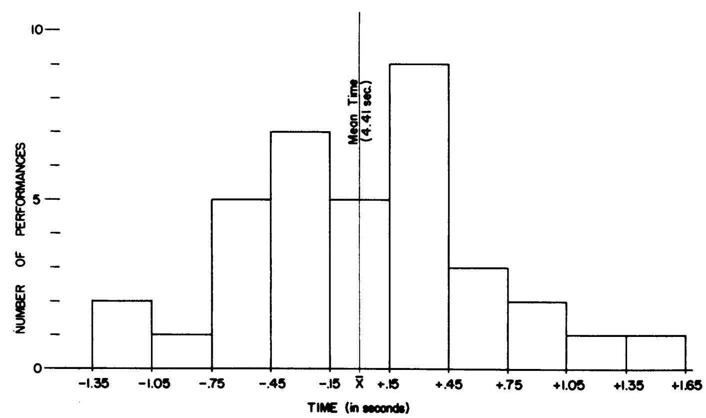
Since there are again no significant differences among the means and standard deviations for any one task, it seems that net cycle times obtained under the natural pace instructions and without practice describe the performance of non-amputees as well as the times obtained after extensive practice. The performance time data from the filmed cycles of Phase II were therefore combined with that from the filmed cycles of Phase I and used to describe the performance times of non-amputees.

Phase II: Some significant facts about the pooled data for the three tasks are shown in Table III below:

Table III
CHARACTERISTICS OF TIMES FOR ALL FILMED CYCLES
(in seconds)

Activity	Observed Times Range	S. D.	Mean	Elemental Std. Data	Std. Data Time/ Mean Observed Time
Hanger	5.9-11.6	1.33	8.3	7.4	89
Phone	3.2-5.8	.61	4.4	2.9	67
Soup	4.0-8.1	1.00	5.7	3.8	67

It is apparent that the customary 2 to 1 range of performance is present; analysis of variance tests showed that the performances of individuals were significantly different (as it should) for two of three activities. The standard deviations correspond roughly to those obtained by R. M. Barnes in his study of the learning curve (2). The distribution of performance times shown in Figure II is normal. ($Chi^2 = 2.75$, D.f = 6, Pr [$Chi^2 = 2.75$] is approx. .85)



DISTRIBUTION OF INDIVIDUAL PERFORMANCE TIMES FOR PHONE TASK

Figure 2

The ratios of task performance times, as estimated by elemental time data, to the mean times established in this experiment indicate that the natural or casual pace for the phone and soup activities is approximately the non-incentive pace found in many plants prior to the standardization of methods and introduction of time study standards. The hanger activity does not conform to this pattern--probably because the variability in methods of executing it distorted either the MTM analysis or the performance times.

These results at least look promising.

While net cycle times have been used in this discussion, similar data are being established for the therbligs constituting each task and will be reported at a later date.

USING THE RESULTS TO EVALUATE A PROSTHESIS DESIGN

Figure II shows the distribution of population mean times for the phone task (n assured = 5). On the same figure is shown the mean time required by one amputee to perform this same task with the Northrop Ideal Arm. It is obvious that this prosthesis does not permit the amputee to approach a non-amputee's performance. This conclusion is confirmed by a value of 17.4 which corresponds to a probability of 0 that the Northrop arm performance could come from the population described by the distribution of means. The improvement necessary in prosthesis design is obvious.

As better prostheses are designed, conclusions of this sort will not be so obvious and the net cycle and therblig times will be more useful.

In this case there is no need to compare this artificial limb performance with non-amputee performance for standard deviation. Then the mean performance time of amputees cannot be distinguished from that of non-amputees, variability comparisons will be required and can be made with data from this experiment.

A comparison of the MTM time for the phone task shows that it too is significantly different from the mean time of this experiment. The z value here is − 5.5 (n assumed = 5) which corresponds to a probability of .0001.

COMPARISON OF VARIOUS PERFORMANCE TIME DATA

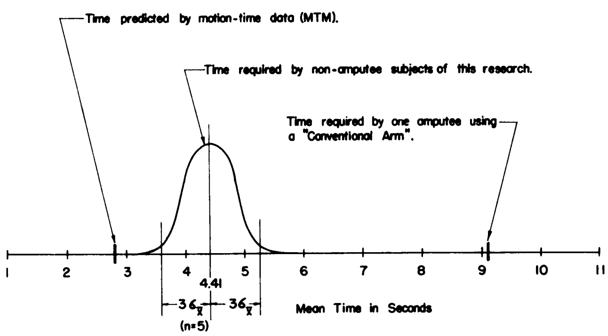


Figure 3

SUMMARY OF RESULTS

This experiment has provided statistics describing the means and variabilities of three everyday living tasks and the therbligs constituting them. These can be used by engineers as prosthesis design and prosthesis evaluation criteria.

It appears that suitable similar data on other tasks or activities can be obtained by the economical practice of frequent performance sampling without prior practice. There are also indications that industrial elemental standard data-- adjusted to non-incentive pace -- may provide another, and even less expensive, method of establishing task times. If this proves to be true, prosthesis development will have utilized not only the micro-motion technique of the industrial engineer but also his standard data.

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2. Ralph M. Barnes & James S. Perkins, "The Study of the Effect of Practice on the Elements of a Factory Operation," University of Iowa, Studies in Engineering Bulletin #22, November, 1940.

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