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# Individual and Organizational Correlates of Automation

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Accelerating social change appears to be one of the few constants of our dynamic society. Scientific and technological developments are transforming our industrial and social life at an ever increasing pace. During the last fifty years machines have increased our productivity per man hour and revolutionized the working environment of man. Each new engineering invention has brought into being new methods of organizing men and machines. These new methods have had a large number of unsolved human problems implicit within them. The mass production assembly line, with its requirements for close adherence to a highly prescribed repetitive pattern requiring little ingenuity or range of skills, is an illustration. We have scarcely begun to understand the effects this kind of work organization has had on the workers in our society when we find the onrushing sweep of science and technology requiring new individual and organizational adaptations. We find human control being replaced by machine control; separate independent production operations by totally integrated processes of production. As we are caught up in another period of rapid transition--of technological acceleration and innovation[1]--it becomes imperative to design studies to investigate the demands which highly automated processes will make on man tomorrow.

The most careful descriptions of these automated processes have stressed these basic characteristics:[2] (1) greater mechanization and combination of work units; (2) more frequent use of automatic equipment; (3) greater integration and interconnectedness of all parts of the production process through greater control of operations by multiple, closed-loop feedback systems.

The new equipment incorporating these changes results in greater capital investment per employee--an increase in the proportion of fixed costs relative to labor costs. This heavy investment in equipment is likely to produce two other changes. First of all, in order to spread these fixed costs over more units of production, automated manufacturing will probably operate on two and even three shifts per day. This tendency toward around-the-clock operation will mean shift work for a greater proportion of the working population. Secondly, the almost complete interconnectedness of the production processes under this new technology will mean that the incapacitation of one machine will stop the entire system. Maintenance of this type of system must be on a preventive rather than a "crash" or repair basis to minimize the amount of "down time".

These changes in the engineering and production aspects of automation will affect the organization of jobs, the kind of people selected to fill these jobs, the kinds of training required, and the organization of supervision and patterns of supervisory behavior. These were some of the _intra-organizational_ effects we wanted to explore in our initial study of automation. We stress _intra-organizational_ because in this study we were concerned only with the changes on individuals and relationships within the organization, not with the broader social and economic problems, such as the long range effect of automation on the national level of employment.

In the fall of 1953 we became concerned about the effects which the new advances in feedback and computer technology would have on the meaning of work to the individual, and the organization of work in the factory and the office. To investigate _empirically_ the effects of such changes, two studies were initiated during 1954: (1) a longitudinal study of the effects of the introduction of electronic accounting in a white collar situation; and (2) an _ex post facto_ study contrasting an electric power plant of highly modern design with a plant of less modern design. This article deals only with the latter of these two studies.[3]

A Study of Automation in Power Plants

Anticipating a greater demand for electric power in its service area, an electrical light and power company expanded its production capacity recently by adding a new power plant to its system of older plants. In the design of this new plant, the company incorporated many of the latest engineering advancements. As a result of these equipment changes, the new power plant has many characteristics of the automated factory of the future. These characteristics led us to study the new plant as a prototype of automation.

Our study has focused on the perceptions and attitudes of the workers in this new plant. Not having recent measures of the characteristics of these men, we could not evaluate the actual changes in their attitudes resulting from their new working conditions. The decision was made to compare the attitudes of the men in the new plant with those of a similar group of men in an older plant in the system, where relatively few changes have taken place.

Approximately two years after the beginning of operations in the new plant, questionnaires were administered to the men in both plants. Questions were constructed to assess the men's perceptions and feelings about their working conditions, their jobs, their selection and training, shift work, supervision, and the company in general. The study had the support of the managements in both plants and of the union officials representing the men in the older plant. The men in the new plant were not organized.

A Brief Description of the Power Plants

Before describing the individual and organizational correlates of automation which differentiate the new plant from the older one, a short description of the major engineering differences is appropriate. In both plants, the general production process is the same--the continuous conversion of energy from coal, air, and water into electric power through a system of boilers and turbine generators. The design of the new plant, however, permits more efficient operations at very high steam pressures through the introduction of the unit system and additional feedback controls. Under the unit system, a boiler, a turbine-generator, and its electrical switching system are physically integrated and perform as a single independent unit. The new plant consists of four such units.

In the older plant, in contrast, the steam produced by many boilers is routed into a common source of supply (a header) from which it is directed into specific turbine-generators. Much of this plant is fairly typical of low pressure steam power plants. It was originally built in 1915, but it was modernized in 1936. In 1951 a high pressure side was added to this plant. This part of the plant is operated by a small fraction of the plant's total work force. The units in this part of the plant, however, do not operate at as high a pressure as do the ones in the new plant. The fifteen boilers and nine turbine-generators make this plant one of the largest steam power plants in the country. Its capacity is still, however, less than the total capacity of the four units of the new plant.

Paralleling the integration of the operations in the new plant is the integration and centralization of controls--especially control of the boiler-turbine-generator parts of the system. In the new plant, the major controls for the entire plant have been centralized on one floor in three control stations. In the middle of this floor is the electrical control room, where the switching both for the system as a whole and for the internal consumption of the plant is handled at massive, multiple-dialed control panels. In separate rooms, on either side of this central control room, are the two additional control stations. The operations of a pair of boiler-turbine generator units are controlled in each of these. This centralization of control contrasts sharply with the physical separation of the control rooms in the older plants, which are located near the equipment they govern. Thus, in the design of this new plant an integration of the operating and control functions--one of the previously noted characteristics of automation--has taken place.

Along with this integration in the new plant has come another major feature of automation, namely, feedback systems. Although feedback controls have been in operation to some extent in the electric power industry for many years, the design of this new plant permitted the introduction of many more. Four of these feedback control systems are of concern for our study. These are the ones which perform functions that are directly the responsibility of operating personnel in the older plant:

(1) One such control maintains the pressure of the steam from the boiler to the turbine at a specified level by continuously adjusting the rate at which coal is fed to the grinding mills. This control is required to meet changes in the demand for electric power by customers. In the older plant the rate of coal feed is manually regulated by the Fireman as he observes gages recording changes in steam pressure as turbines increase or decrease their demand for steam to meet customer electrical needs.

(2) Another feedback system observes the amount of coal being burned and automatically adjusts the quantity of air supplied to the boiler by the forced-draft fans and the removal of spent combustion gases by the induced-draft fans. The fans are coordinated, automatically, to supply the optimum amount of air for efficient combustion of the coal, to remove the spent combustion gases and to maintain a small negative pressure in the furnace as a safety measure for personnel and equipment. Again, this operation in the older plants is a job of observation and manual adjustment by the Firemen.

(3) A third set of automatic devices control steam temperature for operating efficiency and for the protection of the equipment in the new plant. These devices include the operation of dampers, spraying of water into the steam, and the recirculation of combustion gases through the boiler. Steam temperature in the old plant is manually controlled by the Fireman.

(4) Finally the regulation of the flow of water supplied to the boilers for producing steam has been simplified under the unit system, and the feedback system governing the level of water in the boiler has been improved. This simplification and improvement of boiler feed control has eliminated the jobs of the Auxiliary Operator and Water Tender, who are responsible for the more complicated system of pumps and valves in the older plant.

Although these have been the major feedback controls installed in the new plant, another function has been mechanized in this plant. This is the flue blowing job--the removal of slag and fly ash from the furnace walls. Whereas this job is done manually in the older plants--a man inserting a water nozzle and directing its operation--in the new plant the process is done remotely by an operator in a unit control station through a mechanical programming device.

## Impact of Engineering Changes on the Organization and its Personnel: Some Preliminary Findings

The first findings from our study of some of the dimensions of the human problems which may accompany automation suggest that this form of technological change will have both positive and negative effects on workers' lives, their job satisfactions and motivations. In the new plant the more highly automated, unit system of production has brought about significant changes in the occupational and organizational structure of this plant, as compared to the older plant.

Reduction in Work Force

The first impression a visitor to the new plant receives is one of a large amount of gigantic, expensive equipment going full blast, but with very few men apparently responsible for its operation. This impression is not an illusion. The personnel requirements of the new plant, relative to its productive capacity, are about half what they would be in the older plants. This reduction in the number of workers needed has taken place principally in the operating jobs. In this plant, there is greater reliance on machine than on human control systems.

Part of this reduction in the number of operating personnel has been effected in the boiler feed pump and valve operations by the simplification of the system and the improvement in the feedback controls described previously. The regulation of the speed of the pumps and of the opening of the valves is now performed automatically under the control of a pneumatic feedback system. Because of these changes, the specific jobs of Auxiliary Operator and Water Tender no longer exist. Any work on the pumps which might be required is performed by helpers, but these occasions are rare.

The job of Flue Blower-Ash Handler which exists in the older plants has been, in part, replaced also. In the description of the flue-blowing process, it was noted that an operator in the new plant directs this process remotely by an automatic, programmed device. The Flue Blower-Ash Handlers do this dirty job manually. The ash handling--removal of ashes from the furnaces--is still manually controlled by the helpers in the new plants.

A further reduction in the number of operating personnel has taken place in the control rooms. Whereas nine men are used on the electrical switchboards in the older plant, only two are specifically responsible for this operation in the new one. Similarly, many fewer personnel are used in the unit control stations than operate the turbine and boiler sections of the old plant. Many functions, such as maintaining the steam temperature, are now done automatically without operator control. This reduction has also been accomplished by the reorganization of the work which accompanied the centralization of control of the boiler-turbine-generator operations in the unit control stations.

The effects of these reduced personnel needs are reflected in a greater feeling of job insecurity for the workers in the older plant. These men recognize that technological developments will soon force them to acquire new skills or to supplement their present skills with others required in the operation of new high pressure equipment. The greater efficiency of the new plant is underscored as it is operated continuously at full capacity. Cutbacks in the load requirements and the work force on the week-ends in the older plant have made it clear to all the workers there that the efficiency of the new plant may affect their future markedly. Four out of five of the men in the older plant report they are likely to be laid off if business conditions in the service area of this utility were to become worse. Only one out of five of the men in the new plant have equivalent fears about their future job security regardless of economic conditions.

Job Enlargement, Rotation and Training

An extensive reorganization of the content of jobs accompanied the integration of the boiler-turbine-generator operations and the centralization of their control. The job of "operator" has been redefined and enlarged to include a knowledge of and responsibility for the three major parts of the production system rather than merely a specialized concern with boiler, or turbine, or electrical operations.

In the older plant there is a high degree of job specialization, related both to the type of work and to the degree of skill required. There are three major operating job groupings--boiler, turbine and condenser, and electrical. The job classification of the most highly skilled electrical job, Switchboard Operator 1st, is three grades higher than the grades of the most highly skilled turbine and boiler jobs, Turbine Operator 1st and Fireman, respectively. Jobs are also classified within each grouping by the degree of skill required. For example, in the boiler room in the older plant in this study there is the following hierarchy of jobs in order of ascending skill requirements: Flue Blower-Ash Handler, Fan Operator, Water Tender, Assistant Fireman, and Fireman. Similar skill hierarchies are present in the turbine and condenser rooms as well as in the electrical control room.

In the new plant the integration and centralization of operations and their controls dictated the combination of the jobs of the boiler and turbine operators into a single enlarged job. This enlargement required by the engineering changes set the stage for management to consider the advantages of further job enlargement. This consideration resulted in a decision to add the electrical operating jobs to the new boiler-turbine combination to ensure the development of personnel trained in all three functions. The only operating job classifications are A, B, and C Power Plant Operators. This organization of jobs is a hierarchy based on degree of skills alone. The older distinctions according to the particular equipment operated have been wiped out.

The A Operator is the most highly skilled classification. Each of these men is expected to have most of the skills and, especially, the knowledge and information previously held separately by the skilled boiler, turbine, and electrical operators. As his job title suggests, the Power Operator A must be capable of running all of the major parts of the production system. The B Operator is a less skilled worker in the process of acquiring proficiency on all the operations. Each B is paired with an A in his work, as he takes work orders and is trained by the more skilled man. The C Operator is really a helper. He performs the low-skilled, less desirable tasks which still remain after mechanization, under the informal direction of a B Operator.

The men who were A and B Operators at the time this study was conducted had transferred from operating jobs in the older plants, where they had performed specialized jobs in one of the three production rooms--boiler, turbine and condenser, or electrical. Each of these men had to learn new parts of the production process to a degree almost equal to the skill they already had in their own specialty. Former electrical switchboard operators now had to learn the steam side of the plant; former boiler firemen, the turbine and electrical; former turbine operators, the boiler and electrical.

As part of the on-the-job training for this job enlargement, job rotation was instituted. The men were rotated weekly between the unit control stations, the electrical control station, and other duties in the plant. Rotation has been continued even after the formal training was completed, so that, at the time of the study, the attitudes of the men towards their jobs were affected both by the fact that the job requirements had been vastly expanded over their previous jobs, but also by the fact that they changed the particular job they were doing for another one every week.

The effects of this job enlargement and rotation are marked. A significantly greater proportion of the men in the new plant report that their jobs are much more interesting and that they are more satisfied with the jobs they are doing than do those in the older plant. This feeling seems to arise generally because their jobs are more challenging. Moreover, more men feel that their jobs fully utilize their abilities. Another part of this greater satisfaction lies in the reduction of the monotony of the jobs permitted by job rotation. Each week the operators are faced with a different responsibility in a geographically and physically different job setting.

On-the-job rotation was only one part of a formal training program the company established to ease the transfer of men from their old specialized jobs to the new enlarged ones. The program ran the gamut from classroom sessions in the theory of operations, given by the technical engineers of the plant, to on-the-job training in all aspects of operation. Visits to other plants to observe particular parts of the production process in operation were also included. Despite this elaborate program, the men were generally agreed that they learned most about their new jobs from doing the jobs themselves while actually running the plant.

## Tension and Interdependence

More men in the new plant than in the old plant report they feel jumpy or nervous about their work. This tension reflects both the enlargement and the feeling of inadequate training. More than a third of the operators report that their training for these new enlarged jobs was too fast, and that it took more than a year for them to feel at ease on their jobs.

Another factor related to the men's feelings of tension on the job is the degree to which they depend on each other for information about the system. Because they found they learned most about the jobs while actually doing the operations--rather than from the formal classroom parts of the training program--the former steam men relied on the former electrical men, and vice versa. The greater the tension level, the more the men report relying on the other men for suggestions and advice about the particular work problems they face on the job. There seems to be some optimal level of interdependence for the men in these plants. Too much or too little leads to some dissatisfaction with the job itself.

## Reduction in Physical Isolation

Change in physical plant design has also affected the patterns of association among the men. The centralization of the control systems onto one floor in the new plant has brought the greater part of the operating personnel together at three stations. The design of the new plant has virtually eliminated the physical isolation of some of the jobs in the older system, where for example, the Fan Operator spends his entire working day on the top floor of the plant, seven floors apart from most of the other men. This change in location of jobs gives the men more contact with each other, more chance to talk with others on the job. Although no direct measures are available on this, there is strong indication that the men feel a greater unity, more like a single group than they did previously.

Change in Supervisory Structure

The change to the unit system of operation, the accompanying enlargement of the jobs of the A Operators, and the placing of the major control stations on one floor, have resulted in a reorganization of the supervisory structure. In the old plant, each shift has at least one boiler room foreman, a turbine and condenser room foreman, and an electrical operating foreman. Each foreman also has an assistant. These men report to the Operating Engineer, who is in charge of coordinating the activities of fifty men through these foremen, and is responsible for running the entire system on a particular shift. The Operating Engineer is in charge of the total plant during the evening and night shifts. He reports to the Plant Operations Engineer, who is a member of the top staff of the plant.

In the new plant, a single foreman (the Operating Foreman) is responsible for operations in the plant, and is in charge of the total plant during the evening and night shifts. He reports directly to the Plant Operations Engineer. There is no longer any need for an Operating Engineer to coordinate the boiler, turbine, and electrical functions. This level of supervision has been eliminated. Thus, the introduction of automation into this power plant has resulted in a streamlining of the organizational structure through the elimination of a level of supervision.

The Operating Foreman in the new plant does not directly supervise all of the men on his shift. He relies on the A Operators who have considerable knowledge of the operating process to direct the work of the B and C Operators. This organization of the direction of the work allows the A Operators to learn the human relations skills required to supervise people while they acquire technical knowledge about the equipment.

Patterns of Supervisory Behavior

Although a reduction in the number of workers and supervisors needed was easily anticipated by the forecasters of automation, there has been considerable speculation concerning the kinds of supervisory abilities which will be important. Some writers have suggested that technical proficiency will be the major stock in trade for the new supervisors. Concern for human relations will be minimal in the face of the new complicated equipment to be run, and the many fewer people to be supervised. Another group has said just the opposite. They claim that the workers will be the people who need the technical skills, and the job of the supervisor will be even more to supervise--to plan ahead and to maintain high morale and motivation among the workers.

Although our data offer no clearcut answer to this problem in prediction, several relevant findings should be mentioned. Those supervisors who are seen as most satisfactory by their subordinates are also perceived as being the most capable on both the technical and on the human relations side of their jobs. Those supervisors considered unsatisfactory are rated low in proficiency on technical and human relations skills. Among those supervisors who were rated as intermediately satisfactory, those who were perceived as competent in human relations, but not in technical ability, more often were considered satisfactory by their subordinates than the supervisors who were seen as good on the technical side but poor in human relations. Using the satisfaction of subordinates with their supervisors as the criterion, then, the good supervisor seems to combine both technical and human relations skills, with human relations ability being the more important. This seems to be equally true in the two plants.

Centralized Maintenance

While the maintenance of the equipment in power plants has long been on a preventive rather than a "crash" basis, the introduction of the unit system forced management to reconsider and, ultimately, to redesign the organization of plant maintenance. Before the unit system was installed, maintenance had been an in-plant function. Each man in the maintenance crew was a skilled craftsman--mechanic, electrician, pipe fitter, welder, boiler and stoker repair man, etc.--in a particular trade. In his maintenance activity he performed specific repairs. Under the unit system, when any part of a "unit" is incapacitated, its entire production is lost to the system. In order to minimize the "down time" for the new units, the major maintenance work has been removed from the individual plants, and made the responsibility of an enlarged department of construction and maintenance. The men in this department are usually engaged in the systematic overhaul of equipment and preventive maintenance. They move from plant to plant throughout the year. When an emergency arises, however, the entire group can swarm into the plant to make the necessary repairs as quickly as possible. The men in these construction and maintenance crews have retained their job specialties and particular trades.

Small repair jobs within each plant are still done by in-plant maintenance groups. Within these groups, however, old lines of specialization have been eliminated by combining five maintenance skills for the job of General Mechanic "A". The objective here has been to build multiple-skilled units in which each man is capable of doing several job specialties.

Some of these changes were strongly resisted by the union, but were eventually supported in arbitration. The difficulties met by the company in implementing this reorganization of jobs suggest the possibility that job changes of this order, if done too quickly, may be seen as job degradation rather than job enlargement, and decrease rather than increase work satisfactions.

Continuous Operation

Earlier we indicated that the increased capital investment may force automated factories to operate around-the-clock. The smaller work forces which are needed to man these factories will be asked to man them 24 hours a day. Since the production of electric power is a continuous process, our study allowed us to examine some of the problems of shift work. Moreover, the two plants which we contrasted have two different patterns of rotating shifts. One plant uses four shifts on a weekly pattern, while the other uses three with monthly rotation. These differences permitted comparisons of their effects on the lives of the workers involved.

The results of our study indicate that very few shift workers (six percent) actually like shift work. The more favorable attitude expressed by any sizable group in this regard could only be interpreted as a tolerance for ("I don't mind") shift work. Most of the men dislike working shifts. Shift work creates problems in the worker's physical well-being, his relations with his family, and his relations to his larger social world of friends and entertainment. Our findings suggest that the physical and social costs of working shifts are great.

We find a difference, however, in the workers' tolerance for one shift pattern over the other. The weekly rotational pattern used in the new plant was more tolerable to the shift workers there than the monthly rotational pattern was to the workers in the old plant. Although statistically significant, this difference was small. Even under the weekly rotational system, the majority expressed a distaste for shift work.

The change to centralized maintenance also resulted in the institution of shift work for workers who had previously worked only days. To avoid shift work, many maintenance men chose to remain in the in-plant staffs rather than join the centralized group.

It seems clear that unless some ingenious alternative solutions are developed for easing the difficulties imposed by shift work, this aspect of automation will have generally negative effects on workers' lives.

## Summary and Conclusion

The objective of this study has been to explore some of the individual and organizational correlates of automation. It has been our purpose to determine some of the social and psychological dimensions of this type of technological change. Toward this end our first study has been in a new, highly automated power plant. We chose power plants because their continuous production has long had many of the engineering characteristics of the new technology; we chose to study a new power plant because its changes in design and control appeared to be even more typical of new automated plants.

The introduction of automation into this power plant has produced major effects on its organizational structure and on the attitudes of the workers toward their jobs. Maintenance has been centralized for the entire system. Fewer levels of supervision are required for the smaller work force in the new plant. Job enlargement and rotation have resulted in greater job interest and satisfaction, but also in a higher tension level on the job. The effects of continuous operation on the workers' lives were generally found to be negative.

The findings in our study provide some indication of the dimensions of change which have accompanied automation in this one particular situation.

Some of these changes were dictated by the new engineering design and controls; others were instituted by management as they attempted to create the most effective organizational machinery to meet the demands of the new technology. It should be emphasized that the effects we have described may be specific to the particular situation. For example, the extent to which the operating jobs were enlarged in this plant was a management decision and was not forced by the engineering changes. Automation introduced in a different situation and in a different way will presumably have different effects. This study suggests some of the dimensions of the psychological and social problems to be investigated more intensively; other exploratory studies will be needed to uncover other areas.

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3. A fuller account will be given in a monograph by the authors titled: Man and Power Plants: A Study of Technological Change.