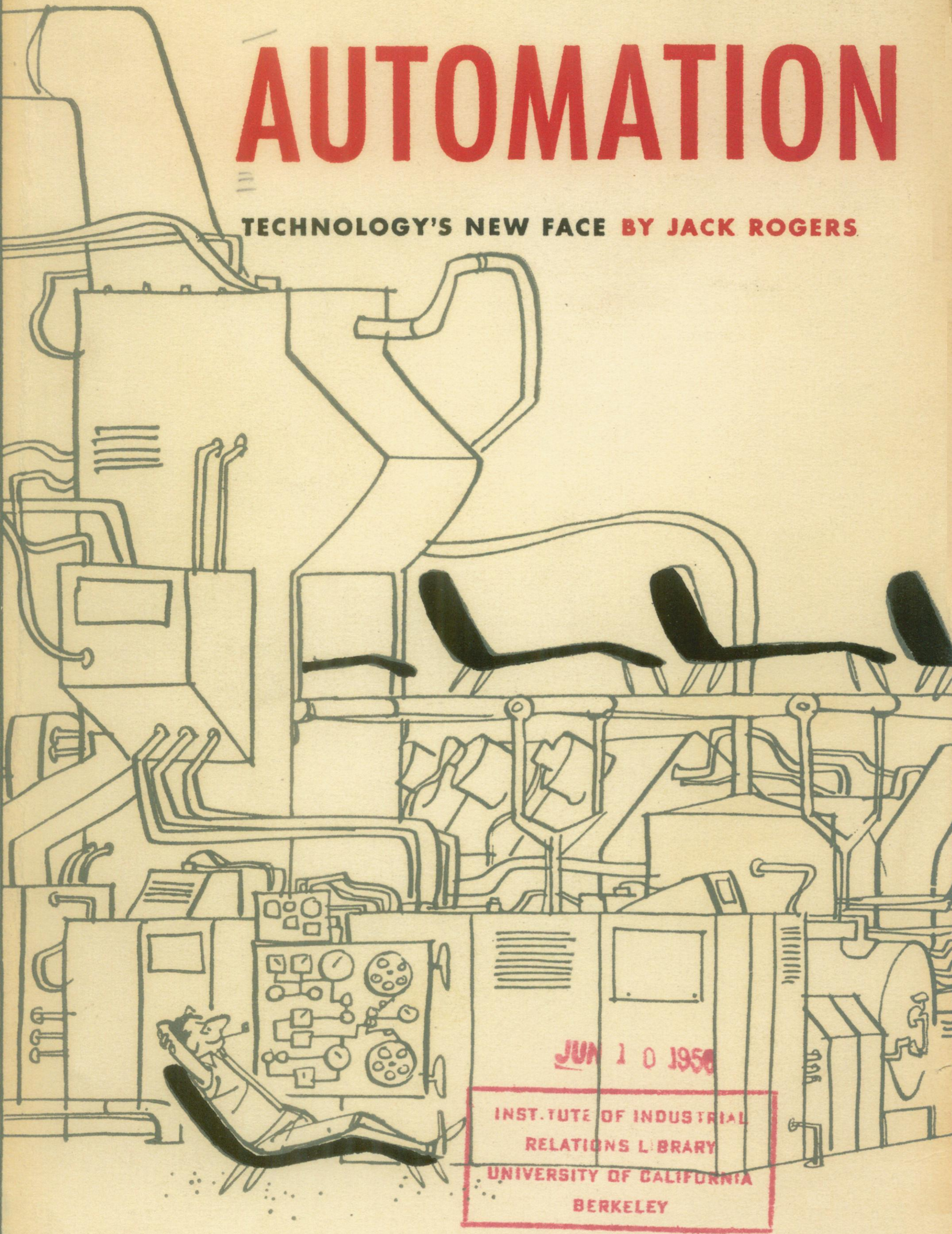
Univ Shelf
C.2

AUTOMATION

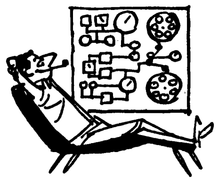
TECHNOLOGY'S NEW FACE BY JACK ROGERS



JUN 1 0 1956
INSTITUTE OF INDUSTRIAL
RELATIONS LIBRARY
UNIVERSITY OF CALIFORNIA
BERKELEY

INSTITUTE OF INDUSTRIAL RELATIONS • UNIVERSITY OF CALIFORNIA, BERKELEY 50¢

AUTOMATION



TECHNOLOGY'S NEW FACE *by Jack Rogers*

Edited by Irving Bernstein

Drawings by Bill Tara

INSTITUTE OF INDUSTRIAL RELATIONS
UNIVERSITY OF CALIFORNIA, BERKELEY

COPYRIGHT, 1958, BY
THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

POPULAR PAMPHLETS OF THE INSTITUTE OF INDUSTRIAL RELATIONS

Northern Division:
Pensions under Collective Bargaining, by William Goldner
Strikes, by William Goldner
Hours of Work, by William Goldner
Productivity, by Peter O. Steiner and William Goldner
Guaranteed Wages, by J. W. Garbarino
The Business Agent and His Union, by Wilma Rule Krauss and Van Dusen Kennedy
Local Employers' Associations, by William H. Smith
Unemployment Insurance, by Margaret S. Gordon and Ralph W. Amerson
Automation, by Jack Rogers

Southern Division:
Collective Bargaining, by Edgar L. Warren and Irving Bernstein
Making Grievance Procedures Work, by Abbott Kaplan
Employing the Seriously Imparied, by Robert D. Melcher
Wages: An Introduction, by H. M. Douty
Union Security, by Orme W. Phelps
Wage Structures and Administration, by H. M. Douty
Health Insurance: Group Coverage in Industry, by Richard N. Baisden and John Hutchinson

Copies of these pamphlets may be purchased at the following rates:
1 to 9 copies—50c per copy
10 to 99 copies—40c per copy
100 or more copies—30c per copy

Order from the
INSTITUTE OF INDUSTRIAL RELATIONS

Northern Division:
201 California Hall
University of California
Berkeley 4, California

Southern Division:
Business Administration–Economics Building
University of California
Los Angeles 24, California

Foreword

THE INSTITUTE OF INDUSTRIAL RELATIONS of the University of California was created for the purpose, among others, of conducting research in industrial relations. A basic problem is to reach as large an audience as possible. Hence the Institute seeks through this series of popular pamphlets to disseminate research beyond the professional academic group. Pamphlets like this one are designed for the use of labor organizations, management, government officials, schools and universities, and the general public. Those pamphlets already published (a list appears on the preceding page) have achieved a wide distribution among these groups. The Institute research program includes, as well, a substantial number of monographs and journal articles, a list of which is available to interested persons upon request.

Despite the fact that "automation" has become virtually a household word during the last two or three years, there is still a great deal of confusion about the meaning of the term and even more confusion about the probable effects of automation on production and employment. Although much has been written on the subject, the reader who is anxious to clear up his own confusion about automation does not always have the time to read several volumes of congressional hearings, a book or two, and a variety of magazine articles. It is hoped that the present pamphlet will help to fill the need for a convenient and relatively brief discussion of the technological concepts involved and the implications for management, labor, and the economy.

The author is unusually well qualified to deal with his subject in an authoritative and readable manner. He specialized in mechanical engineering as an undergraduate at the University of California and later received his doctor's degree in industrial economics at the Massachusetts Institute of Technology. His earlier publications include *Industrial Standardization: Company Programs and Policies,* (National Industrial Conference Board, 1957), as well as a number of articles.

The Institute wishes to express its appreciation to the following persons for their review and constructive criticism of the manuscript: Dr. Eugene Burgess and Dr. George A. Pettitt of the University of California and E. M. Grabbe of the Ramo-Wooldridge Corporation.

The viewpoint expressed is that of the author and may not necessarily be that of the Institute of Industrial Relations or the University of California.

ARTHUR M. ROSS, *Director*
Northern Division
GEORGE H. HILDEBRAND, *Director*
Southern Division

Contents

I. What Is Automation?

Few newly coined words have attained wide usage as rapidly as "automation" has. Five years ago it would have been hard to find anyone who had heard it; today it would be hard to find anyone who has not. Yet misunderstanding and controversy continue to surround it.

For some, mention of automation conjures up an image of a world of robots in which humans do no work. For others, automation suggests the intricate engineering problems of self-regulating systems. To many, automation is practically synonymous with mechanization in industry. For most, however, the term is a vague one having something to do with electronics and automatic production. Just what it all means for the man in the street is not too clear.

Predictions of the consequences of automation are sharply contrasting. It has been said that most of industry ultimately will be involved and that we are in the midst of a Second Industrial Revolution. It also has been said that only a fraction of industry ever will be affected and that no discontinuous development worthy of being called a revolution is in prospect. Alarmist articles warning of sweeping technological unemployment have been answered by debunking articles with the theme that automation will create new employment opportunities. What automation will do to or for jobs, workers, unions, companies, industries, and consumers has been foretold with an abundance of disagreement. One thing is plain: unless we understand what automation is and is not, we are in a poor position to evaluate its effects. In order to gain this understanding, we must spend some time in becoming acquainted with the concepts and terminology of automation.

Short stretches of what is to follow will be tough going for the reader who is not used to technical language. We will try to be as uncomplicated as we can, however, and explain what may be unfamiliar terms as they crop up. Those who are interested mostly in automation's effects and either know how it works or don't particularly care to find out in detail may skim until they reach Chapter III.

1. MECHANIZATION AND AUTOMATIC PRODUCTION

Before we can begin to discuss the subject in even a preliminary way, we must define it. As we go on, we can refine our tentative statement as necessary. The following definition will remain valid even when special meanings are given to parts of it later:

Automation refers to the design, manufacture, and use of automatic equipment for industrial or other processes. The word itself is a compression of the awkward word "automatization" and apparently was invented independently by John Diebold, the author of *Automation: The Advent of the Automatic Factory*, and by D. S. Harder, a Ford Motor Company executive. If "automation" is to behave like other words, "to automate" must mean "to make automatic" and "automation" must mean "the process of making automatic," the reference being to industrial processes primarily.

What automation actually means, as a word then, depends on the meaning given to "automatic." Here is where the trouble starts. The dictionary tells us that automatic means having the power of self motion, self-regulation, or self-action. Most of the machines used in industry today have some properties of self-action, so why should we need a new word to describe an old fact? Those who use the word must have more in mind.

Let us set out from familiar ground. One of the major trends of industrial development since the opening of the nineteenth century has been progressive mechanization, the substitution of mechanical and electrical devices for human functions in the performance of work. Today lifting and carrying operations are done by cranes, fork-trucks, and conveyors instead of by men's backs, arms, and legs; fabricating operations such as cutting, melting, sewing, nailing, grinding, and other processes which change the form or state of materials are performed with the aid of powered equipment; refining, sorting, counting, inspecting—in fact almost every conceivable kind of manufacturing step—is performed by or with the aid of machines. Most of the industrial equipment in use currently, however, requires operator surveillance and control. Men must feed material to machines, watch their operation, and regulate their actions.

Mechanization has transferred man's "muscle functions" to machines. The embodiment of man's "sensory functions" and "mental functions" in equipment has been of less importance. Properties of self-action have been built into machines mainly by providing for repetitive activation as in the firing sequence of the cylinders of a gasoline engine, the alternating polarities of rotor and stator in an electric motor, or the cam-directed successive indexing of tools in a screw machine. Production equipment commonly is classified as manually operated, semi-automatic, or automatic depending on whether an operator must control throughout every cycle, load and unload work during each cycle, or tend the equipment only intermittently. Manually operated equipment, however, may be self-acting to a degree (for example, a pneumatic hammer or portable electric drill) and semi-automatic equipment may complete unattended a cycle consisting of several individual operations.

Development of equipment which is to some degree automatic always has been part and parcel of mechanization in industry. For this reason it is sometimes asserted that automation is really nothing new or that the word serves mainly to describe production systems in which materials and parts are handled in and out of machines automatically in contrast to those in which this feature is absent. In recent years, the linking up of special purpose machines by conveyors and other work handling devices to form assemblages called "transfer machines" has permitted performance of long sequences of metalworking operations without operator intervention. In substance, this advance amounts to incorporation of the "line production layout" long familiar in mass-production industries into the equipment itself, with work stations consisting of machines alone instead of men and machines. A plant in which every operation on a product was performed without human intervention as it moved automatically from station to station would be a true "push-button" factory. This condition now is approached closely in some of the component manufacturing plants of the automobile industry. Automatic production of this type has been labeled "Detroit automation."

A closer look at the kind of automatic production just described reveals that it is automatic in a strictly limited sense. The machines which compose such a system are set to perform one sequence of operations and one only. The dimensions to be held in fabricating the parts determine the position of the individual machine elements and their tool settings. An elaborate system of limit switches and interconnected stops or gates assures that only one piece is in position at a station at a time and that the way is clear before a piece is advanced. Inspection operations also are built into the line's equipment so faulty pieces can be sidetracked mechanically. Controls which signal the need for replacement when tools begin to wear past permissible tolerances are included.

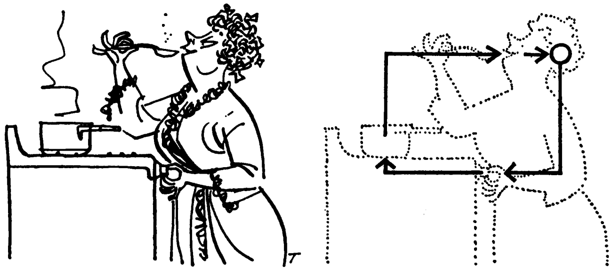
For a *fixed sequence of fixed operations* the whole complex functions automatically so long as none of the preselected conditions are violated. The process, however, is not self-regulating in the sense that what is happening in it can alter it. Operation is on an all-or-none basis: output either is completely satisfactory or there is no output.

Highly automatic machines of the fixed sequence-fixed operation type of manufacture of standardized articles exist in many branches of industry and account for a large share of all industrial production. Although they typically represent large equipment investments, they reduce unit cost of output as compared to methods of production using less specialized equipment and relying more heavily on manual operations. Their superiority lies principally in high output rates and uniform quality which are characteristic of mechanized production. A listing of specific examples of equipment for this type of production easily could run to hundreds of pages and include such varied items as knitting machines, rolling-mills, paper-making machines, glass bottle molders, can sealers, strip ovens for bakeries, bag fillers, carpet looms, rotary printing presses, barrel rolls, screw machines, mechanical stokers, plastic molding presses, and die casting machines.

If automation consisted only of extension of the principles of mechanization in designing, making, and using equipment for production to put greater power at the command of the worker, reduce manual effort, permit operation at higher speeds and more continuously, and integrate individual machine operations into larger units, it would be worthy of attention as a significant industrial development. Automation, however, is more than mechanization in the view of many authorities. In important respects it is a "jump" in technological progress and not just a gradual acceleration. The reason is that full automation is the application of the theory of automatic control in technical innovations to make possible full automatic production with self-regulation as well as self-action. It contemplates the wholesale reproduction of the sensory and mental functions of human operators in production systems which go far beyond the fixed sequence-fixed operation variety of automatic production.

2. FEEDBACK AND AUTOMATIC CONTROL

A simple concept, and an old one, is the keystone of all methods and devices for automatic control. Whether called control through feedback, closed-loop control, or something else, the unifying principle is the same: what happens in a process may be used to affect the process to achieve a desired result. When there are physical cause and effect relationships in a system, the effects can be made to serve as modifying causes by proper translation. As is true of many fundamental concepts, it is not the statement of the idea that is impressive but the implications of it. Potentially, practically any physical process controllable by man can be made to control itself. A process which cannot be controlled satisfactorily by man may be made self-controlling. Since a factory basically is just a location where a number of processes take place to change materials from one form to another, the idea of a workerless factory is no different in kind than the idea of a self-regulating machine, though more grandiose.



We have used the words "process," "system," and "control" so far in an abstract way. The notion of control through feedback becomes much clearer in example. Imagine a "sytem" consisting of a wood stove, a pot of soup, and a housewife. The "process" is the heating of the soup. "Control" of the process consists of getting the soup to the proper temperature without its boiling over. Taking the system as a whole, the temperature of the soup is the condition to be controlled, the housewife is both the means of judging the condition and doing something to control it, and the stove is the energy source for the process.

There are several ways in which the control may function. The housewife may look at the soup, smell it, or taste it. In any case the state of the soup is compared to the desired state and some action taken. If it is getting too hot, the pot may be pushed to the back of the stove or the damper closed. If it not hot enough, more wood may be fed to the fire or the damper opened. The process continues until the soup is to be served with the housewife acting as its regulator in a loop which runs from soup to housewife to stove and back to soup again.

Obviously this is not an automatic control system even though information concerning the state of the soup is "fed back" and results in alteration of the process. Technically it is an open-loop control system into which an operator's functions must be inserted when it is to function.

If we substitute an electric heating unit for the wood stove, we can "close the loop" by replacing the housewife's observations and actions with a temperature monitoring and regulating device. The control device will permit current to flow to the heating unit so long as the soup temperature is below that set and shut off the current when the set temperature is exceeded. The soup will be brought to the desired temperature and held within a few degrees of it. Our new arrangement, in which the process guides itself by altering its own state as necessary, is closed-loop automatic control.

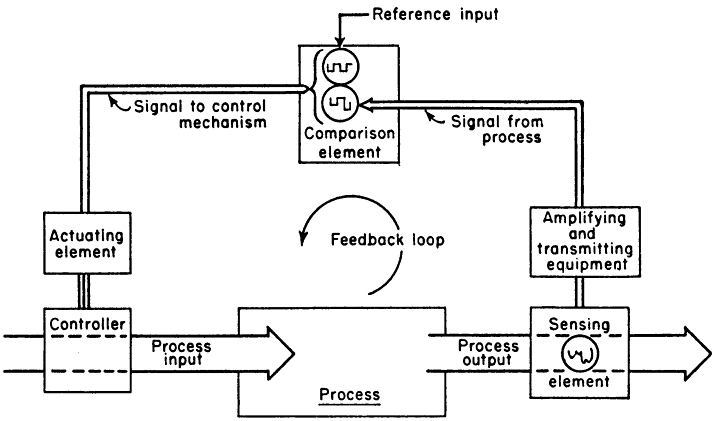
For satisfactory automatic control it is necessary that (1) the process be one which can be controlled by changes in a regulating device (e.g., a valve, a brake, or a variable resistance), (2) the variable to be controlled be measurable, and (3) the measurement and resulting regulation take place fast enough to keep the controlled variable near the desired value. If there are appreciable time lags in the system, as between measurement and change in the regulating device or between change in the regulating device and change in the variable, the system may oscillate in undesirable fashion. Depending on the relation between the process and the means of control, the value of the variable may fluctuate above and below the desired value during correction of a change and these fluctuations may die out, be sustained, or increase.

Oscillation in a control system may be illustrated, in the case of the housewife and her soup pot, by assuming that she wants the soup at serving temperature at a given hour, but has difficulty adjusting the fire and the position of the pot to bring about this result. Opening the damper and pulling the pot over the fire bring a too rapid increase in heat. Closing the damper and pushing the pot to the back of the stove to prevent boiling causes the soup to cool too much. Theoretically, by standing at the stove and making corrections fast enough, she can bring the soup to just the right temperature. If she has other things to do, however, each time she gets around to the soup she may find it has cooled too much or has begun to boil.

Most automatic control systems have a somewhat similar problem, caused by time lag between determination of the need for a correction and the start of the correction process, on the one hand, and over or under correction on the other. The problem is met in various ways. For example, monitoring devices are made more or less sensitive to increase or decrease the strength or frequency of feedback, high speed communicating means are employed to shorten time lags, or secondary feedback loops are used to introduce corrections to the

Figure 1

DIAGRAM OF AN AUTOMATIC CONTROL SYSTEM



corrections. Leaving out the refinements which are necessary to secure exactly the control behavior desired, the typical elements of a control system are those shown in the diagram of Figure 1.

Beginning at the lower right-hand corner of the diagram we have the sensing element, any device that measures some characteristic of the process and emits signals representing the measurements. Apparatus for amplifying the signals may follow the sensing element in the feedback loop. Next comes the comparison element which is designed to compare the signal it receives to a signal fed into it as a so-called "reference input." This comparison is made for the purpose of detecting deviation of the feedback value from the desired value represented by the reference input. A deviation causes the comparison element to originate a signal which when conveyed along the loop will operate an actuating element. The actuating element, in turn, governs the operation of whatever mechanism is used to vary the process characteristic—in this case a controller which varies the process input and thereby the process output which is being controlled.

If we compare a system for automatic control to control based on the actions of an operator, we see that the judgment of a human being is replaced in automatic control by what amounts to decision-making equipment. It is true that the decisions must be reduced to very simple terms, such as plus or minus, that the built-in criteria are inflexible, that a separate control loop is needed for each characteristic to be controlled, and that characteristics which cannot be measured cannot be handled. Nevertheless, in a crude sense the system "reasons"—at least well enough for it to substitute for some routine mental process. As a necessary adjunct the system has some sensory function which is the equivalent of a human sense. In short, an automatic control system observes, communicates internally, decides, and acts.

If automation has to do in large part with the application of automatic control in which functions corresponding to physical, sensory, and mental functions of an operator are embodied in equipment, our original definition should be revised:

> *Automation refers to the design, manufacture, and use of automatic equipment and self-regulating systems for industrial or other mechanized processes.*

For purposes of this definition, any process performed with powered equipment is said to be mechanized; automatic equipment is that which normally does not require control by an operator but which need not be self-regulating; self-regulating systems are those which employ feedback for control. Whenever the necessity for operator control of a mechanized process is eliminated, we have automation according to our definition. Although this is a somewhat broader statement than the technically-minded may like, it takes account of the fact that the word automation has been and probably will continue to be used loosely to refer mainly to elimination of operator control functions.

3. THE IMPORTANCE OF INFORMATION HANDLING

Automatic control, and hence automation, depends more on the handling of information than any other single factor. We have seen already that any closed-loop control system functions by feeding back information about a process to govern it. A self-guided missile, for example, must have some way of ascertaining where it is at all times if it is to make course corrections automatically and hit its target; position information is essential to its operation. An automatic process controller for a chemical reaction functions by interpreting information about the state of the reaction and initiating actions which hold within prescribed limits such variables as concentration, temperature, pressure, or other quantities which determine the yield of the reaction. An automated tin-plate mill relies on the continuous generation and interpretation of information concerning the gauge of the steel strip to regulate roll pressure and tension for production of strip of uniform thickness.

Automation may be regarded as the process of arranging for one kind of machine to run another kind. Machines of the first kind have as their function the handling of information. The function of the second kind is transformation of materials or performance of useful functions. Machines which handle information commonly are called "computers," because computation thus far has been the principal task assigned to these electronic instruments. Electronic computers operate with closed-loop control and constitute "systems" in themselves. If clerical or computational routines are viewed as "processes," automatic production of numerical results from data is parallel to automatic production of goods from materials. Business and industry may employ automation in office work, in manufacturing, or in both, for numerical results can be translated into actuating signals for process control.

It is possible to conceive of a single, large, fully automatic computing and production unit which would eliminate the manifold tasks of recording and analysis of information which now accompany the planning and direction of business activities and tie together all routine management processes and production activities. Input information would consist of criteria to be satisfied by the plant's operation and data including prices, sales quantities, and material qualities. Operation of the plant would be adjusted automatically toward an optimum with every change in external and internal conditions. Needless to say, the instrumentation of such a manufacturing unit would be intricate and expensive. No manufacturing unit of this description exists now, but technology probably is now far enough along to allow its development if it were justified economically. Exactly how far away the day may be when automation equipment becomes sufficiently simple, reliable, and cheap to bring integrated, fully automated production on the scene no one can say.

4. THE MEANING OF AUTOMATION

The problem of definition should not be allowed to obscure the implications of automation. Any major change in the rate or the nature of mechanization—the replacement of men by machines—is bound to have far reaching effects. Whether or not automation comprises only automatic production accomplished through feedback control, the fact remains that an upsurge in technological change is in process. As a direct consequence, the rate and scope of replacement of human functions in industry is climbing. Human information handling functions which in the past have been more resistant to the incursion of the machine than energy providing functions are beginning to be supplanted on a significant scale. In the popular view, this is automation.

The real meaning of automation lies less in the machines involved than in what the machines will do. The possibility of substantial change in the relation between men and machines brings with it the possibility of change in conditions of work, occupations, and the structure of enterprise. Automation means technical change and technical change always has meant economic and social change. After we have looked in the next chapter at some of the ways automatic control is being put to work, we will consider what the results may be as automation matures.

II. Automation in Action

FOR SEVERAL REASONS the extent of automation in industry cannot be gauged accurately at present. There is no clearly defined "automation equipment industry," facilities for automatic production are intermixed with older equipment, many installations are experimental, and there is even disagreement about what comes under the heading of automation. Although we cannot say how many dollars are being spent on it or what proportion of national output comes from it, by looking at specific examples we can see what directions automation is taking and what forms it assumes in practice.

Developments which increase automaticity of operations and reduce need for operator control are discussed without attempting to decide which constitute "true" automation and which do not. The main purpose is to acquaint the reader with what is taking place and show that automation is something more than an idea.

1. CONTINUOUS PROCESS INDUSTRIES

The logical way to begin a survey of automation in action is to discuss its application in continuous process industries operating on continuous flow principles as exemplified in modern petroleum refineries and chemical plants. It is logical to begin here because the earliest and closest approaches to current conceptions of automation and the most widespread usage of it are identified with flow control. In all probability when the first workerless plant appears, it will be a continuous flow plant.

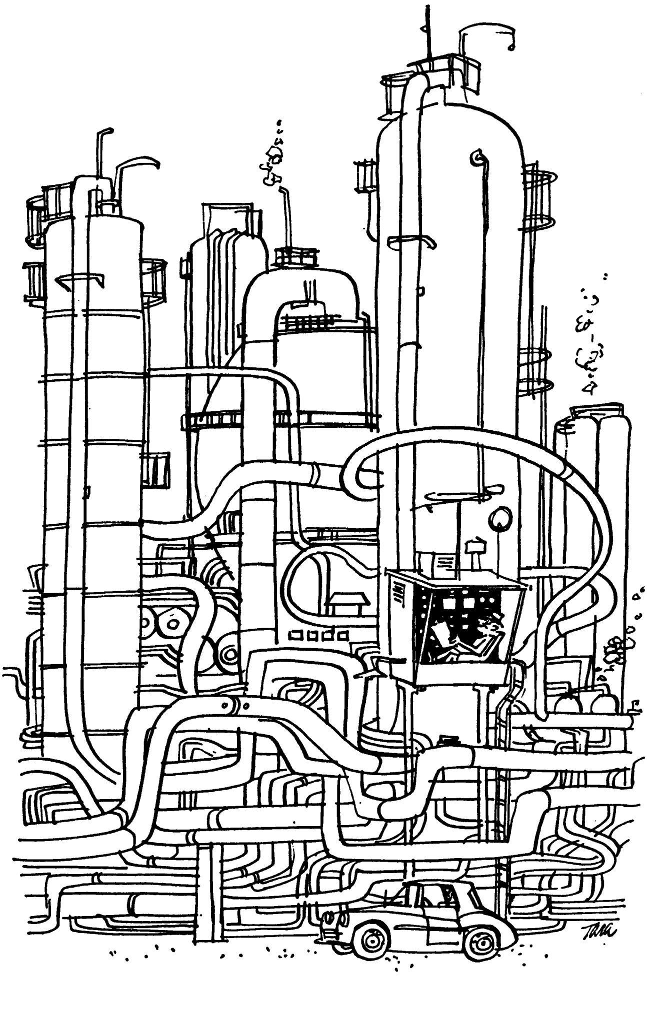
A continuous flow plant is just what the name implies: a plant in which ingredients flow through processes in an uninterrupted stream as they are converted from raw materials to products. Typically the materials are in a liquid or gaseous state or they are solids such as powders, suspensions, or slurries which can be handled the same way as liquids or gases. For practical purposes there is no such thing as an individual product unit in flow processing and production is measured in tons, gallons, or cubic feet. Materials must be confined in closed vessels or tanks throughout the production cycle and the features of flow plants that impress the observer are the mazes of pipes, valves, and instruments and the lack of outward evidence of activity.

What is happening in the process cannot be determined by direct visual observation. Only by measurement and interpretation of variables such as temperatures, pressures, liquid levels in vessels, rates within and between processes, and analysis of the products coming out can it be determined whether the processes are functioning satisfactorily. Extensive instrumentation for automatic control in flow plants is not a luxury but a vital necessity. Critical phases of processes may have time durations of only seconds. Total volume in process in the plant at any time may run to hundreds of thousands of gallons. Small changes in process characteristics may mean large changes in product yield or quality or operational efficiency of equipment. Catastrophic results can be caused by loss of control of processes operating at high temperatures and pressures and producing corrosive, poisonous, inflammable, or explosive products.

Process control in most modern flow plants is accomplished through a combination of operator control and automatic control. Automatic, feedback mechanisms turn valves, start and stop pumps, and hold process characteristics such as temperature, pressure, reaction rate, and product composition at set levels under normal or stable operation in which only small variations appear. Recording instruments which continuously register the state of important process variables are mounted on control panels which are the operators' only contact with the process. These instruments are supplemented by warning devices which set up an alarm if critical levels are exceeded in the process or equipment fails and by automatic emergency controls which can shut down processes and dump contents of vessels to forestall potentially hazardous conditions. Here, too, are the remote control devices which allow operators to intervene to operate equipment by manual control and to give instructions to automatic process controllers via their comparison units. The operator's job usually involves taking over control completely only during start-up, shut-down, or emergency. Most of the time he scans the recording instruments and makes minor corrections in automatic control equipment settings intended to bring the process toward optimum yield or to change product properties in some way which laboratory analysis of output samples indicates as necessary.

Operation of a catalytic cracking unit in a petroleum refinery well illustrates continuous process control. These units, which are only part of a refinery's equipment, are large enough to be considered plants in themselves for one may cover thousands of square feet and have component parts which rise 150 feet or more in height. The process consists of heating petroleum in the presence of a catalyst to break it down to gasoline and other products. One section of the unit—the reactor—is charged with crude oil, steam, and hot catalyst. Steam and petroleum vapors are then conducted to a fractionating column where the various light petroleum fractions are condensed and trapped or bled off to undergo further fractionation and ultimately to become the raw materials for gasoline blending and other processes. Heavier oils which collect at the bottom of the column may be recycled. The catalyst is put through processes which recover the oil vapors entrapped in it and regenerate it by burning the remaining carbons out of it before it is returned to recharge the unit.

Since the temperature in the reactor influences the yield of the lighter fractions and it in turn is influenced by the temperature of the crude and the recycled catalyst, it is a critical point for control. To regulate reactor temperature, automatic controls govern the rate of cata-



lyst recycling, temperature of the catalyst, and secondary variables which affect these. Other controls regulate the flow of air and steam to the reactor. Rates of flow to the column and out of it and liquid level within it also must be controlled closely. Many other variables complexly interrelated with those mentioned require control too.

It is not surprising that several hundred separate instruments and controls may be found in a catalytic cracking unit and that nearly half of them may be for automatic control purposes. Over-all control of the unit is exercised by a half dozen or so operators, but the hundreds of individual functions which make over-all control possible are performed by automatic machinery. If operators were deprived of their helping robots and had to turn all the hand valves and read all of the instruments that would be required for manual operation of such a unit, it is unlikely that it could be operated at all. It has been estimated that if manual control were substituted for today's methods, four times as much crude would have to run through plants five times as costly to produce the same quantity of gasoline. It has been pointed out that although about 15 per cent of current annual capital investment in petroleum refining facilities is for automation and that direct labor cost in oil processing is less than 10 per cent of total cost, only about 70 per cent of the opportunities for application of automatic control have been exploited. If a representative oil refinery employing 800 people were automated as far as existing technology would allow, it is said, its operating staff (not including maintenance men) could be reduced to a dozen men. Further replacement of operator functions in this field seems to be in the cards; for example, a project involving the setting up of a computer to control the complete process of hydrogenation of oil is under way at Case Institute.

In the flow process industries generally—those producing petro-chemicals, synthetic fibers, high-polymer plastics, paints, and the like—the trend of development is toward instrumentation which makes it possible to determine internal process state automatically and eliminate indirect measures. Continuous stream analyzers, such as mass spectrometers, promise to replace cruder sensing devices and multiply possibilities for fully automatic control. Automatic logging mechanisms which do instrument reading jobs are no longer a novelty. When centralized control under operator supervision has been made as efficient as it can be in view of human limitations and when the requisite sensing devices have been perfected, the move to centralized control in which the programs of computers will specify actions to be taken in response to every situation for an entire plant will follow.

2. METAL WORKING INDUSTRIES

Manufacturing which consists of the shaping and assembly of metal parts presents somewhat different problems in the application of automatic control from those of flow processing. Operations are performed on discrete units of material by moving them, holding them in position, and fabricating them. Direct operations on materials, of course, must be supplemented by inspection operations, machine preparation and maintenance, and many other indirect activities.

Reproduction or replacement of operator functions in metal working is difficult because of the intricate series of precise operations which are so often involved. When long runs of identical parts are to be made, special setups on standard equipment or special-purpose equipment designed to perform a single operation unique to a single product component may be used. Need for operator control is reduced by use of mechanisms to position the work, start and stop the operation, and eject the finished piece. Much of metal working, however, consists of making short runs of significantly differing parts with operations and sequences altered from lot to lot. The general-purpose equipment customarily used in small lot manufacturing is designed around function; for example, the function of a drill press is to make holes, the function of a lathe is to turn cylindrical shapes, and the function of a planer is to cut flat surfaces. An operator is required to apply the machine's function to a particular job by interpreting plans, preparing the machine to perform an operation in such a way that the desired dimension will result, positioning the workpiece, manipulating the machine controls to guide it through the operation, verifying the result of the operation, and removing the work piece. Performance of a single operation may involve many repetitions of these steps, and performance of a series of operations involves numerous transfers between machines and repeated inspections.

Past mechanization in metal working has progressed along lines which avoided many of the knotty problems of automatic control. Where large volumes of material have to be handled, continuous operations replace previously intermittent ones. For example, rolling mills with several sets of rolls in series to permit working of a continuous strip have supplanted those in which a relatively short piece had to be passed back and forth through a single stand. Output rates of machine tools were increased by design of larger, stronger, more rigid, and more powerful units for high surface speed cutting employing tungsten carbide tools. For high volume production of small parts, "automatic" machines, such as screw machines, which perform a series of operations on a piece were developed. In these machines the sequence of operations is built into the machine by arranging mechanically for several tools to engage the workpiece successively or by providing for successive machanical repositioning of the work for each of a series of cuts. Unit type machines consisting of a single machine tool element and its power source (e.g., a drill head) which could be flexibly assembled with other units in any of a number of special-purpose combinations were evolved as a compromise between the high production rates of special-purpose and versatility of general-purpose equipment. Automatic handling, loading, and unloading devices with which standard machines could be linked together replaced manual handling between operations in many applications.

That it is possible to achieve a particular variety of automatic production through intensive machanization of metal working with little employment of closed-loop control is demonstrated in the so-called push-button plants of the automobile industry. One production line for the machining of engine blocks performs 555 drilling, milling, boring, reaming, countersinking, and tapping operations automatically in 53 stations to turn out 100 finished blocks per hour. Additional stations for loading, part handling, and inspection bring the total to 104 for the integrated unit. Individual machine cycles are counted automatically and when a predetermined number has been reached, the particular unit shuts itself off so that a tool set-up man can replace the dull tools with new ones preset to the proper dimensions. Chips are blown with compressed air and removed on a conveyor. The only direct labor on the line is initial positioning of the blocks in the loading station and initiation of the cycle.

Automatic operation in automobile production is not confined to machining. It has begun to appear in foundries, forging plants, stamping plants, and elsewhere. Automatic shell molding is being used to make molds from sand and phenolic resin for casting crankshafts and other parts. Only about a tenth as much sand is used as in a conventional hand assembled mold and subsequent machining is reduced because the castings are smoother and closer to desired dimensions. Automatic core making machines add still another degree of automaticity to metal founding. Semi-automatic forging presses, plating equipment with which three men can do the work of a hundred hand platers, electronically controlled spray painting equipment, sheet metal presses fed by mechanical feeders, and a myriad of other automatic and semi-automatic machines are now commonplace in automobile fabricating plants.

The kind of automatic production that is obtained by linking up metal working machines with conventional controls such as cams, dogs, template followers, and hydraulic actuators is but a first approximation to fully automatic operation. For mass production of standard components, its inflexibility is not too serious a drawback and it serves adequately. However, closer approaches to fully automatic production, particularly in small lot manufacture, will require more substantial reproduction in machines of qualities of judgment and adaptability now provided by their human operators.

The need for machines which are not limited to a fixed sequence of operations is beginning to be met. The next step is development of methods for direct translation of information from part drawings to forms in which it may be used to control machine operations. Prototypes of such flexible automation units are now in existence and scattered examples of use of production equipment incorporating advances in control foreshadow the changes to come.

Fully automatic control is being brought about by wedding the information handling functions of computers to those of fabricating machines through "numerical control," a form of control in which a tool is guided by instructions coded in numerical values on a punched paper tape, magnetic tape, or photographic film. The positions of holes, magnetized areas, or dark and light spots represent digits which can be read by a computer. Interpretation of the code by the computer results in its originating impulses which actuate machine elements to move the tool or the work. Sets of digits may stand for discrete positions in a coordinate system so that a tool, such as a punch, is moved to each of a series of selected points for performance of its operation at each point. Alternatively, the path of a continuously or intermittently operating tool may be controlled so that it traces out a curve in a plane or generates a surface. A feedback system simultaneously operates to detect and correct deviations from desired values so that variation in material or machine does not cause dimensional error.

Because many machine tools have continuous drive mechanisms, they must be controlled by continuously variable information. A profile miller in which the movement of a "feeler" over a template is mechanically or electrically converted to tool movement over a work piece is a simple illustration of what is called an "analog" set-up. In a more flexible set-up the form of a physical template would be replaced by a mathematical function (the analog) which a computer could generate as a continuously varying electrical current to serve as the actuating signal for the tool. One machine tool company already has produced a milling machine controlled by a photo-electric line tracer capable of following a line on a blueprint for the direct translation of plan information to tool movement.

3. COMPUTER APPLICATIONS AND OFFICE AUTOMATION

We have seen by now that computers play an important role in the automation of manufacturing through machine and process control. As of now, however, there probably is considerably more automation of data handling as such than there is automation of production.

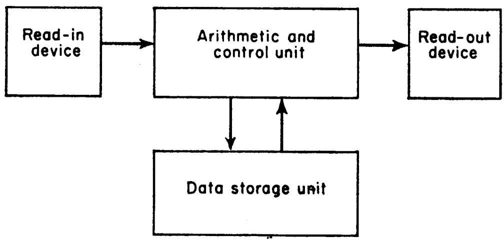
Before we look at how computers are being used to solve problems and unsnarl office red tape, we should be clear about what they do and how they do it. Computers are assemblages of electronic circuits similar to those found in the radio and television sets and telephone equipment. One type of computer, called analog, manipulates physical quantities and produces physical quantities as its output. This type of computer solves problems by "standing in" for a physical or mathematical system. For example, the parts of a complicated hydraulic flow system may be represented by electronic components (as a resistor standing for a pipe's resistance to flow) in a circuit. Conditions simulating those to be experienced by the flow system can be applied to the circuit. Values of the electrical quantities measured in the electronic analog then give the corresponding values of flows, pressures, or quantities in the system for which it stands. In a similar way, the operations of electronic elements which are analogous to mathematical operations may be linked up for solution of intricate equations. The other type of computer, called digital, with which we shall be most concerned, operates with numbers. Both types perform their functions by changing the states of their circuits—that, and nothing else.

A digital computer is, in effect, an incredibly rapid "finger counter." The usual time unit used in referring to computer action is a microsecond, i.e., one millionth of a second. Successive signals or pulses pass through the usual computer circuit in a few microseconds. During the passage of a single pulse, switches are opened and closed and signals are held, retransmitted, rerouted, or combined. Counting is accomplished by the opening and closing of circuits.

To get a general grasp of how the computer as a whole operates, let us disregard what makes up each element and identify components by function. The major components and the flows among them can be shown in the diagrammatic form of Figure 2.

The read-in device is simply a means of putting two kinds of information into the computer: instructions and data. The set of instructions given the computer is in the same form as the data which it is to manipulate, i.e., coded digits. The various instruction code words (a set of digits is called a "word") represent the basic operations the computer can perform. Provision for acceptance of instructions is built into the circuitry so that instructions are put into the "memory" accessible to the control unit. With the program (a set of instructions is called a "program") in the computer, the reading in of data proceeds as the steps in the program are executed. The input medium may be punched cards, punched tape, magnetic tape, or some other. As the medium is

Figure 2
BASIC COMPONENTS OF A COMPUTER



moved through the reader, it translates the instructions and data into circuit states in the processing section of the computer.

The arithmetic and control unit is essentially a switching center which makes connections among circuits as dictated by the instructions.

Instructions and data must be held in the computer pending their use and results must be held until they are read out; the data storage unit or memory performs this function. Information is held in a computer memory as states of the device. For example, a magnetic drum memory stores information as magnetized spots on its surface which can be detected as pulses as the rotating drum passes a reading head. Each location on the drum (by channel on the circumference and radial position in the channel) has an "address" to which the control unit may route a signal and from which it may recall it as it is needed. Thus the instruction program of a

computer contains step by step directions for the storage of data or specified addresses, recall of the data for manipulation, and storage of results.

Read-out devices operate in reverse fashion from read-in devices, translating the output data emerging from the main body of the computer in binary coded form as pulses into some physical form. The output may be punched into cards or paper tapes, recorded on magnetic tapes, or printed out as numbers and letters.

The ability of the electronic computer to hold a large amount of data and gain access to it rapidly as it performs programmed operations at high speed makes it a powerful tool for handling paperwork routines. Operations which would require man-hours, man-days or man-weeks if performed by hand with repetitive reference to record files, transcription of data, and calculation may be accomplished in computer-minutes or even seconds. The task of preparing a payroll, for example, consists of a large number of repetitions of the steps of applying the proper pay rates to the hours worked by the employee, calculating various deductions, and writing out a check and earnings statement. When this job is done by an automatic data processing system, however, no manual operations may be required after transcription of the data in machine language. A deck of punched cards containing the information on hours worked by all employees during the pay period plus "exceptions" such as special deductions, vacations, and changes of pay status is fed into the system. Each employee's pay and deductions are computed automatically by application of the proper rates previously fed into the memory of the system, recorded, and the check and earning statement printed automatically. The tedious and time consuming portion of the routine is largely eliminated.

Data processing systems may function to reduce large volumes of information to compact form as in summarizing sales information from invoices in tabular form by items, product lines, outlets, territories, or time periods. They also may operate to give practically instantaneous effect to each of numerous transactions so that current status is continuously available. In inventory control systems, for instance, the effect of each withdrawal or addition to stock is registered in the computer memory so that a particular stock balance can be ascertained in a matter of minutes in response to a read-out command. Geographically dispersed operations may be tied together by leased wire circuits feeding a central computer installation so that current company-wide information is immediately available at all points.

The early computers were used mainly for scientific and engineering calculations so voluminous that hand methods were practically impossible.

It is expected that in the future most of the functions of analysis and control in many firms will be performed by electronic equipment so that not only the routine procedures of data handling will be automated, but—by linking up process control computer elements with those programmed for analysis—a significant part of business decision-making as well. How this sort of integration may be accomplished is suggested by the present use of a computer to do production scheduling by keeping track of total production capacity and time available in each department, testing new orders against production time available, and entering them in a master schedule. Alternative schedules may be examined in terms of their cost and optimal loadings determined. If the computer were scheduling operations for an automated plant instead of a plant with relatively little automaticity, the schedule could be translated directly into signals to be transmitted to equipment controls and progress information fed back to the scheduling computer without human intervention except for the handling of exceptional circumstances.

4. ISLANDS OF AUTOMATION

While we have looked at three areas in which automation already has become important, we have not yet seen its true proportions. Increasing automaticity is not to be dismissed as a variety of technological change limited to particular segments of manufacturing industry and to office work. In every branch of industry where repetitive operations and powered equipment are present counterparts of the instances already described are to be found. Though only a fraction of the processes of many industries are as yet affected, the beginnings are there as scattered islands of automation which can grow and merge. The pervasiveness of automation may be conveyed by taking products and services almost at random and showing that because automated facilities for their production do exist, automation has begun to touch them.

The likelihood is high that the last telephone call the reader made was dialed and that his connection was through an automatic exchange where an army of robots was at work testing circuits, routing and timing calls, and recording the data from which his bill will be computed automatically. Moreover, some of the electronic components with which his call was handled almost certainly were produced on an automated line which printed, etched, and dipped the printed circuits used in amplifiers or automatically assembled tube parts.

The morning paper probably was printed, folded, and assembled with automatic equipment and the newsprint could have come from a modern paper mill in which processing, weighing, and wrapping were accomplished with a minimum of manual work or operator control of the papermaking machines. The boxcar in which the paper was shipped may have been assigned its position in the train by destination electronically and the train assembled in a recently constructed automated classification yard with the aid of an automatic "hump" which gauged the weight of each car and calculated the amount of braking to be applied as the car rolled down the hump to its proper track via switches set by a master remote control.

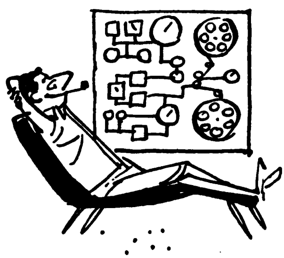
If the reader has recently built a wall or patio in his backyard with ready-mixed concrete, he could have used material which was batched automatically at the plant by inserting a punched card in a control console which followed the card's direction to select and weigh the amount of each ingredient. His form lumber may have come from a sawmill in which no manual handling of materials took place between receipt of logs and stacking of finished lumber.

The egg the reader had for breakfast may have been one of the 10,800 dozen per eight-hour shift which an electric egg machine automatically weighed, sprayed, counted, and packaged. While a human operator inspected and candled the egg and put it in the right grade slot as AA, the machine, after weighing it, remembered its grade and weight and used it in filling an order for specified quality and size.

Teen-aged daughter's latest phonograph record represents another contact with automation, for the record may have been manufactured by a new machine which feeds measured amounts of plastic into molds, cools it, and ejects records at a rate 30 per cent faster than skilled operators can attain with manually controlled presses.

Perhaps the reader likes to bowl. Perhaps, too, he misses the pinboy about whose slowness and inaccuracy he used to complain. Now an automatic pinspotter picks up and respots the pins after each ball and returns the ball. Not only does the machine display on a lighted board the numbers of the pins standing and the number of balls in each frame, it remembers the exact location of a pin knocked off its spot and left standing and replaces off-spot precisely.

The food we eat is cleaned, processed, inspected, wrapped, boxed, canned, and bottled by automation. The cigarettes we smoke are fabricated, inspected, counted, and packed by super-human machines. The cloth in the clothes we wear, the leather in our shoes, the foam rubber in the furniture on which we sit, and the tube in the television set we watch all may have undergone automatic processing. It is getting ever more difficult to find a mass-produced item which has not had contact with automatic equipment somewhere along the line. The equipment is getting more automatic and doing more of the job. Arguments about whether we are ever going to see automation on a wide scale are heard less frequently. Discussion and conjecture now turn to how far it is going, how fast, and what its repercussions will be.



III. Some Broad Implications

MAINLY BECAUSE of technological progress, man-hour productivity has been increasing in our economy at an average rate of about two per cent per year since the turn of the century. Technological changes which give improved means of production can result primarily in increased output or primarily in reduced costs. Automation now promises to accelerate the rates of both industrial innovation and productivity increase. What will be the effects?

Will accelerated productivity increase mean large scale displacement of men by machines and persistent unemployment? How will the gains from productivity be shared? What will be the effect of automation on economic stability? These and many other general questions can be answered only in terms of the likelihood of different alternatives determined by analogy with previous experience and deductions from information about the form automation is taking.

The precise impact automation will have depends on the specifics of adaptation to automation—the policies affecting rate of introduction and response to change which individual managements elect to follow; the reactions of labor unions and the bargaining strategies which they adopt; the behavior of individuals whose jobs are altered or eliminated; the measures, if any, taken by the government to control automation's impact. The particular forms that adaptation to automation will take are less predictable than its over-all consequences. How business firms generally will be affected can be said with more certainty than how individual firms and industries will be affected. The probable over-all effect on output and employment can be seen more clearly than effects on production and employment in particular economic segments. The general ways in which work force composition and employment will be altered can be judged better than impacts on particular occupations and skills.

This chapter will concentrate on those aspects of the impact of automation about which there is the least disagreement. Even here the presence of assumptions which if taken otherwise would lead to different conclusions will be noticed. The job of examining some of the details of adjustment to automation will be undertaken in later chapters.

1. HOW FAR AND HOW FAST?

Everything that is said about the economic impact of automation ideally should be placed against a time scale. The implications of X per cent of industry becoming automated in ten years obviously are not the same as those of X per cent in twenty years. Unfortunately, only qualitative estimates—such as slow or fast

—and estimates of order—such as decades versus years —can be made. Similarly, predictions of how far automation will go within a stated time, both in terms of how widespread it will be and how intensively it will be applied, must be highly qualified.

A 1955 survey of more than 1,000 companies conducted by the Research Institute of America gives an indication of what businessmen think the answer to the question of "how much automation and how soon" will be. In response to the question, "How soon do you expect automation to be extensive in your industry?" these answers were secured:

Already extensive in this industry	16 per cent
Expect it to be extensive by 1964	23 per cent
Expect it to be extensive by 1965 or later	8 per cent
Expect it never to be extensive in this industry	34 per cent
Uncertain	19 per cent

The results of course leave unanswered the question of at what point automation becomes "extensive" and the composition of the sample is not given.

When asked, "When will you use automation in your company?" the answers were:

Use it already	18 per cent
Expect to use it by 1964	17 per cent
Expect to use it after 1965	5 per cent
Expect never to use it	34 per cent
Uncertain	26 per cent

Significantly, by size of company the percentages answering that they already used automation were:

Size of company	*Per cent using automation*
100 employees or less	12
101–500 employees	16
Over 500 employees	29

Since about one-third of the respondents to the survey expected that automation never would be extensive in their firm or their industry and about one-fourth were uncertain, on the basis of the sample no more than half to two-thirds of all business firms ever will be extensively automated. Also, according to the survey, more than half of the firms and industries which expect to automate extensively will have done so by 1964. Much room could then remain for intensification of automation, however, because the range from "extensive" to "complete" automation easily could exceed that which lies below "extensive." It should be recalled, moreover, that we are dealing with forecasts here. There is automation potential today which is not known to men in industries which will employ it later. The extent to which automation actually will spread will depend also on future technical developments which cannot be foreseen completely.

Allowing for some leveling off as full automation is approached in many industries, a reasonably "optimistic" estimate would be for automation to be extensive within two decades in the sense that most of the firms which ever would use it would be using it to a significant degree by then; a "pessimistic" estimate would as much as double the time span.

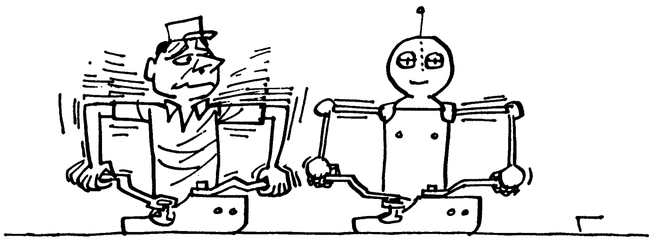
Even if automation does become extensive in ten or twenty years, it will neither affect all industries nor affect uniformly those in which it grows. Continuous process industries, mass-production manufacturing industries engaged in fabrication and assembly of parts, and industries whose transactions involve copious record-keeping can be automated readily. Those in which production is irregular and non-uniform because of the nature of the product or its vulnerability to changing fashion cannot. One writer, R. L. Meier, has roughly categorized industries according to whether they are ripe for automation, susceptible to limited automation, or relatively impervious to it. The industries he lists as ripe currently employ about eight per cent of the total labor force and those he describes as relatively impervious to extensive automation (agriculture and forestry, mining, vehicular transportation, construction, and the service industries) account for nearly 60 per cent of the total civilian labor force.

Extrapolation of trends always is hazardous, but the growth of the industries which furnish much of the hardware for automation is revealing. Between 1947 and 1954 the "electrical measuring" industry (Census of Manufacturers' Standard Industrial Classification) — which includes integrating instruments, indicators and recorders, and testing equipment—approximately doubled its sales. The "scientific instruments" field had total shipments in 1954 nearly six times those in 1947. The "mechanical measuring instruments" industry also approximately doubled its sales between 1947 and 1954.

It has been estimated that unit sales of control products manufacturers will have increased by 50 per cent over current figures by 1960. Over the past 23 years the control products manufacturing industry has increased its sales at a rate of 12 per cent per year in growing from a $100 million to a $2.5 billion industry, a rate which, if continued, would make it a $6 billion industry by 1965. The rate of increase of sales by control equipment manufacturers cannot be equated to the rate of increase of industrial automation (even at constant prices), since a part of their output has been for military applications and some part of it for industrial replacement. If even half of control equipment is going into new automation, the degree of industrial automation should be nearly half again as great by 1965 as now. It should be repeated, however, that this growth of automation will tend to be concentrated in industries which already are automated to a degree and which employ a minor fraction of the total labor force.

2. EMPLOYMENT EFFECT AND THE STANDARD OF LIVING

Some writers have asserted with little supporting arrangement that advancing automation will mean absolute displacement of workers and hence serious unemployment. At the opposite extreme others have dusted off and reused the argument of the economists who explained at the outset of the Industrial Revolution that jobs lost to mechanization in one line would be offset by employment in machine building. Competent analysts today are very cautious about predicting the effects of automation on production, employment, and the national standard of living, because they recognize that information on the rapidly evolving field of automation itself is inadequate and, beyond this, that under-



standing of our economic system is limited. What structural changes will come and what will be the effect of altered inter-industry relationships are critical imponderables.

In simple terms, if national output is not expanded and new job opportunities are not created as fast as the labor force grows, unemployment can result. If productivity increases from automation are devoted mainly to decreasing costs so that output does not increase in proportion to population growth, the standard of living will fall. That automation will displace people from jobs is indisputable. The questions are (1) whether there will be other jobs and (2) whether workers displaced can fill them. The rate of introduction of automation is crucial in any answer to the second question. To introduce automation in firms in such a way that employment is not decreased is by itself not enough, for if new employment is not created at somewhere near the rate of net new entrance to the labor market there will be general unemployment due to absence of jobs. Even if new employment is created, however, there can be transitional unemployment as workers whose jobs disappear are unable to find positions suitable to their experience and training. The more rapid the introduction of automation the more serious the problem of frictional unemployment will be. We will be concerned for now with the potential general employment level and not with "spot" unemployment which will be considered separately.

Let us take the year 1975 and make some projections to it from 1955, using the trends actually experienced during the period 1929–1955. (Our method of projection is similar to one employed by Almarin Phillips in his analysis referred to in Chapter VII.) Let us first assume (1) the average annual rates of increase in net output per person engaged in each of the major industry groups from 1929–1955 will continue until 1975, (2) the distribution of employment among industry groups in 1975 will be that secured by extending 1929–1955 trends, and (3) the 1975 civilian labor force will be 89 million (as the Bureau of the Census estimates), of which 84 million will be employed; i.e., there will be relatively full employment. With these assumptions, the 1975 gross national product (total expenditure on new output by final users) would be about $711 billion.

Now let us see what the effect of automation could be. For simplicity we will act as if automation will affect the rate of increase in net output per person in but one economic segment, manufacturing. The 1975 total net output of manufacturing in the $711 billion gross national product estimate (which we got by assuming present trends continued) would be $223.4 billion and the number then employed would be 24,400,000. If automation increases the rate of increase of net output in manufacturing from 1955–1975 over the 1929–1955 rate (which was used to estimate 1975's full employment gross national product), then either (1) total manufacturing net output can be larger than $223.4 billion if the number employed in manufacturing is held at 24,400,000 or (2) the number of people engaged in manufacturing can be less than 24,400,000 if manufacturing net output is held at $223.4 billion. What we propose to show is what manufacturing output or employment *could* be for different degrees of impact of automation on manufacturing.

In the first column of the table below, we show some alternative possible increases in the 1929–1955 rate of increase in net output per person engaged in manufacturing—these represent different degrees of impact of automation. The second column shows what the average annual rate of increase of net output in manufacturing then would be from 1955–1975. Our third column contains the alternative numbers of persons that would be engaged in manufacturing if total manufacturing net output were to be $223.4 billion in 1975 and the effects of automation on manufacturing productivity were those shown in the first column. The last column holds employment constant and shows the values of total manufacing net output with 24,400,000 employed and, again, the effects of automation on manufacturing productivity those shown in the first column.

Per cent of rise—due to automation—in average annual rate of increase in net output per person engaged in manufacturing	Resulting average annual rate of increase in net output	Number of persons engaged to reach 1975 total manufacturing net output of $223.4 billion	Total manufacturing net outputs reached in 1975 with 24,400,000 persons engaged
0 per cent	2.10* per cent	24,400,000	$223.4 billion
5	2.20	23,800,000	227.5
10	2.32	23,200,000	234.8
20	2.52	22,300,000	244.2
40	2.94	20,600,000	264.5

* 1929–1955 average.

The outcomes shown can be viewed either as threat or promise. A 10 per cent increase in the average annual rate of increase in net output per person induced by automation in manufacturing could mean an extra 1,200,000 persons unemployed in 1975 by our projected figures if manufacturing output was expanded at no more than the 1929–1955 rate. Looked at the other way, the accelerated rate of output increase could mean a 1975 manufacturing net output $11.4 billion greater than that which would obtain if productivity increased at the 1929–1955 rate. The first estimate assumes no absorption anywhere of labor displaced by automation and the second assumes complete absorption in manufacturing. Actually, neither of the estimates could be correct even if there were exactly a 10 per cent acceleration of productivity increase in manufacturing, because the effects of productivity changes will *not* be confined to manufacturing industry and three factors interact in contributing to growth of national net output: increasing efficiency in the use of resources, increasing employment of resources, and shifting of resources within and between industries from less efficient to more efficient uses.

By different choices of assumptions about the rates of productivity increase and expansion of employment in the various industry groups, various 1975 predictions ranging from severe unemployment to full employment and increased income per capita can be made. If we can presume, however, that our economy will be able to adjust to increasing productivity in the next 20 years as well as it has been able to in the past, the net effect of automation should be to raise national per capita output without causing general unemployment. If growth of the labor force is less rapid than assumed, the prediction is even more reasonable. It even may be demonstrated that an accelerated increase in productivity will be necessary to maintain or raise the national standard of living, particularly if net man-hour output is to be increased sufficiently to allow further reduction of the work week or hours of work while maintaining or increasing the living standard.

While the direct effect of automation will be to increase output per person employed and thereby provide opportunity for economic growth, it must be remembered that growth is not an automatic result of improved technology. Potential ability to supply increasing quantities of goods and services is but one side of the growth equation; if the equation is to hold, demand for goods and services must be increasing as fast as ability to produce them. The fear has been expressed in some quarters that automation may be a depression breeder which throws the growth equation out of kilter. Probably the darkest view given so far is this one of Norbert Wiener, a man who is universally regarded as one of the creators of automation:

> Let us remember that the automatic machine, whatever we think of any feelings it may have or may not have, is the precise economic equivalent of slave labor. Any labor which competes with slave labor must accept the economic conditions of slave labor. It is perfectly clear that this will produce an unemployment situation, in comparison with which the present recession and even the depression of the 'thirties will seem a pleasant joke.

It has been put many ways, but the contention that automation can lead to depression comes down to the fact that machines are good producers but poor consumers. In the next section we shall see that it really is not that simple.

3. INCOME AND STABILITY PROBLEMS

In order to say whether automation is likely directly or indirectly to cause aggregate demand for goods and services to be less than required for relatively full employment, we must consider its possible effects on the components of demand; i.e., on consumer, business, and government spending. Demand for the nation's output is the sum of consumers' demand for goods and services, business demand for inventories and plant equipment, government demand for goods and services and capital equipment, and demand of foreign purchasers.

The largest demand component is domestic consumption expenditure. In "normal" times, when the economy is not disturbed by war or depression, personal consumption expenditures on the average are about three-quarters of the gross national product. Income is the chief determinant of consumption and, therefore, if workers' incomes fall because they are displaced by machines or because the share of national income going to wages and salaries drops relative to profits as industrial efficiency increases, consumer demand is affected adversely. If this was all that had to be considered, a purchasing power problem would be looming behind automation and would be threatening indeed.

Fortunately, technological progress does not necessarily mean reduction of income and technological unemployment. Figures on employee compensation as a percentage of total income originated in all industries show the income share of employees to be remarkably stable over the years. Even in those industries in which technological change has been greatest in recent years there is no apparent tendency for employee earnings to fall. So far as employment is concerned, the industries with the most rapid rates of technological change show the greatest percentage increases in employment. While it is true that large percentage increases in employment do not imply large absolute increases and that displacement of certain individual workers may be concealed in net rates as hirings exceed firings, the progressive industries which are innovating, growing, introducing new products, and lowering production costs are increasing employment. As increasing productivity in these industries has decreased the amount of labor per unit of output, increased output has more than offset it and employment has increased.

The question next arises whether consumer purchasing power would be maintained in the face of rapid automation affecting not just a few industries but many simultaneously. Conceivably, such an improbable turn of events could set off a depression through its impact on employment and consumption expenditure, but much more stability has been built into the economy than existed when previous depressions hit and the impact of automation presumably would have to be quite large to force a cumulative economic contraction.

Investment expenditure, although typically a relatively small percentage—about 15 per cent in prosperous years—of the gross national product, has greater significance in business fluctuations than consumption expenditure. Cyclical changes in investment are much greater than variations in consumption; moreover, changes in investment have a magnified effect on output and employment because they induce changes in consumption. Since businesses construct new plants, purchase new equipment, and plan inventory accumulation in anticipation of profits, automation's impact on investment will be determined by how it affects the expected profitability of new investment.

Economists tell us that how much business will be willing to invest at a given level of interest rates (the cost of funds for investment) depends mainly on technological change which gives new products and new production methods, on the psychological state of businessmen, and on changes in the current volume of output. As a variety of technological change, automation clearly is an investment stimulus. Whether it is an adequate stimulus can be questioned in these terms: Does the fact that the ratio of net investment to increase in the gross national product has declined in the past and may decline even more with automation mean that there may not be enough expenditure on capital goods to maintain aggregate demand at full employment levels?

No data are available to show quantitatively how automation has affected capital productivity to date, but it appears that it has not had any startling influence. Initial automation installations tend to be expensive because of their experimental and custom-built nature and the stimulating effect of automation on the volume of purchases of producers' goods is likely to outrun the effect of increasing productivity for some time to come. At some point the deflationary influence of automation's productivity may become noticeable, but it is doubtful that it will be serious in the absence of other major deflationary tendencies.

It is hard to say precisely what effect automation has on the psychological element of business expectations. To the extent that the rapid advent of automation confuses businessmen and makes them less certain about the future course of their business, it may result in a "wait and see" attitude and deferred plant and equipment expenditures. On the other hand, automation may be seen as something that must be responded to quickly if its advantages are to be exploited or as a threat to established position which must be met. Most of the speaking and writing on the subject by businessmen has been optimistic in tone, however, and automation is most often characterized as something normal and necessary, evolutionary rather than revolutionary, and a way of solving business problems rather than a problem itself.

Increases in volume of output are stimulating to investment and as an output-increasing measure automation should tend to encourage investment. There is the danger, however, that if the growth rates of automated industries fall off as automation matures, rates of investment in those industries will decline unless offset by replacement needs or by the continued need for investment to avoid technical obsolescence. Unless automation grows gradually and in expanding industries, it may induce a burst of investment which is followed by a sharp drop.

The other components of aggregate demand—government expenditures and exports—should be affected favorably by automation if affected at all. The proportion of defense expenditure which is devoted to the products of automation and to automatic equipment such as missile guidance systems is likely to increase even more rapidly in the future than it has in the past few years and there is no obvious reason why other kinds of expenditure by the government should be influenced adversely, except that some reduction in personnel requirements of government agencies may be brought about by automation of their offices. As automation increases our industrial capacity and decreases the cost of output, our position in world markets should be strengthened, particularly if some new products are made available by automation which cannot be secured otherwise.

4. SUMMARY

Automation may attain its maximum growth rate within ten years and within twenty it should be relatively mature; at either stage it will directly affect but part of the nation's work force. Nonetheless, it can have far reaching economic effects through its impact on productivity.

Whether extensive automation will be compatible with full employment and a raised standard of living depends on how our economy adjusts to its advent. If the degree of industrial automaticity increases gradually enough to allow adaptation by the labor force and if the potential deflationary effects of automation are headed off by expansion of output, the result of automation should be a more productive economy and not underemployment. Without losing sight of the transition problems automation may present, it is reasonable to conclude that in the long run technological progress will be as beneficial as it has been in the past.

IV. Opportunities and Headaches for Management

IT MAY or may not comfort the outsider to know that managers of enterprises are as much up in the air about automation today as he is. John Doe would like to know when and how automation is going to hit the firm that employs him. So, probably, would his superiors. Is automation going to change John Doe's job? The company managers perhaps are asking themselves the same question about their own jobs as well as about the jobs of all the John Does.

Throughout industry there is more awareness of automation than certainty about it. This is evidenced by the numbers in which managers turn up at automation conferences and industrial exhibitions, the frequency with which articles on automation appear in business publications, the reception of the spate of books treating non-technical as well as technical aspects of automation, and the content of speeches by industry spokesmen. Managers are searching diligently both inside and outside their organizations for the answers to difficult questions. In this chapter we shall try to see what influences impel automation, what considerations deter managements from pushing ahead, what decisions management must make, and what possible consequences the decisions may have.

1. AUTOMATION PROS AND CONS

For some managements the decision for or against production automation is clear cut. Businesses which are bedeviled by rising labor costs, shortages of skilled labor, deferred deliveries due to lack of production capacity to handle customers' demands, and poor product quality may look to the extensive use of automatic equipment for a remedy. If it happens that their products already are mass produced with operations which are highly repetitive and mechanized, that demand for their output is reasonably stable and predictable, and that they are in good enough financial shape to stand the expense of considerable plant modification or new plant construction, the incentive to proceed with an automation program is practically irresistible.

In a company where production consists almost entirely of short runs of varied items, where both the volume and composition of demand are sharply fluctuating, where mechanization is at a low level and hand operations requiring considerable skill and judgment dominate, and where there is little pressure on plant capacity, consideration of even partial automation may appear ludicrous. If, in addition, the company is small, pressed for funds, and has no technical staff to speak of, an automation program probably is last on management's long list of things to do.

For most management, however, the problems of whether to automate, how much to automate, where to start, and how to proceed cannot be dismissed easily. There are both advantages to be gained and risks to be taken because the company's operations lie somewhere along a scale from "clearly amenable to automation" to "clearly impervious to automation." These managements must take a number of things into account which are of less concern to companies which must of necessity automate or to companies which are insulated from automation.

What the competition is doing may be instrumental in forcing a decision. Confronted with the prospect that competitors may automate and lower their production costs, improve their products, or bring out new products and gain a market advantage, a management may decide that it is necessary to investigate the possibilities of automation and be ready to move. Whether competitors really are serious about doing something in the field of automation may be irrelevant. Where intelligent anticipation of and response to competitors' actions leave off and guessing and straight imitation begin often is hard to discern.

The well advertised generalized advantages of automation may provide an impetus for management to try to discover how they may be reduced to specifics in their own operations. Automation, it is asserted, can do better the things people can do and, what is more, do things people cannot do—automatic equipment can work faster, work longer, work more steadily, and work with greater accuracy than operator-controlled equipment; automatic machines can work where people cannot, e.g., under hazardous conditions and where the nature of the process is such that human reactions are too slow. If automation's forte is doing the tedious, demanding, and dangerous jobs of industry, a management might well ask, what fatiguing, boring, dirty, and troublesome jobs can we find for it?

Not many managements are motivated to replace labor by machines just because they prefer machines, although the following quotation may suggest that the idea is not unheard of:

> It often has been thought that automation in its ultimate sense in any industrial plant is a desirable goal because it will reduce labor costs in the manufacture of a particular article. But reduction of labor costs is only a part of the point. Another highly desirable feature of automation, in relation to labor, is the fact that machines are easier to control than people (and this is a blessing in our democratic society). The more machines the fewer people, and therefore the easier the control problem.

Most managements seem to be more concerned with better utilization of their work force than with its reduction through automation. Management typically is sensitive on this point and the one line the reader is almost sure to find in every published case example of automation experience is, "labor requirements for this operation were reduced from X to Y, but total employment in the plant has not decreased (or has increased)." It cannot be denied, however, that managements beset by the problems of high wage rates and the tendency of wage expenses to become fixed costs through benefit programs and wage guarantees are likely to look longingly at automation as a solution.

Both real concern for the worker's welfare and uncertainty about labor's reaction to automation may cause

managements to stay out of automation as long as possible and proceed slowly when they do begin to use it. Resistance to change by unions in the shape of insistence that established incentive rates be maintained unchanged though automation will make them very "loose" rates, refusal to permit multiple machine assignments for operators, opposition to wage and job reclassification based on job analysis, featherbedding tactics, and other obstructive measures can markedly reduce the attractiveness of automation. Labor's opposition to change need not be expressed in organized fashion to hamper a company's efforts to modernize operations; declines in the efficiency and cooperativeness of individuals, poor performance in retraining programs, and other evidence of discontent can be troublesome. Even when a work force is not hostile to the change augured by automation, the management may be given pause by the prospect that some jobs will be abolished and that it will not be possible to place those who hold the jobs in other positions because insufficient openings will exist or because some employees will not have the abilities to allow their being upgraded or the flexibility to adjust easily to new jobs.

Lest we give the impression that management can expect nothing but opposition to automation from labor, let us hasten to add that it is a problem faced by particular managements, not all managements. Labor's reaction to automation will be discussed in the next chapter, but it can be said here that whether a management can anticipate difficulty in adaptation of its work force to automation depends on the climate of relations with employees that has been created in the past, the particular union it is dealing with, the timing of the steps toward automation, and the way it goes about introducing changes.

Aside from the deterrents mentioned so far, there are two reasons why little or nothing is being done with automation in some firms. One reason is that the management simply may not know what is available in the field and does not know how to find out. A management preoccupied with its daily problems may not have or may not take the time to inform itself about developments in automation. More than that, management members may never have considered company problems in relation to automation. A second reason is that management may be bound by inertia. If a company is making profits and there is no immediate competitive threat, its management may be sunk in complacency or unwilling to "upset the apple cart."

Individual companies may find strong incentives to automate or be deterred by special circumstances not mentioned here. Regardless of the source of initiation or the problems posed, however, at some point management must decide whether automation will pay and ticking off pros and cons will not by itself provide an answer. Let us shift our discussion to what management must evaluate in determining the profitability of automation.

2. COSTS AND RETURNS

Analysis of automation proposals does not differ basically from analysis of other kinds of capital expenditures for plant and equipment. Given the technical feasibility of an automated production layout, the economic question to be answered is whether the required investment (including development costs) will pay off within a reasonable time in decreased labor and material costs, increased output, decreased indirect costs, or in some combination of production advantages. What makes such analysis difficult is that some of the results resist reduction to dollars and cents terms and others cannot be forecast readily.

While the maximum advantage can be gained from automation only by complete re-examination of the production process and the products manufactured, it often is neither technically nor financially expedient to consider wholesale conversion to automatic production and a piecemeal approach must be taken. If the transition is to be made a step at a time, it is not easy to estimate the total cost of a program since what must be done at any stage depends on what has been done before and what has happened since. Economic evaluation of the alternatives of going fast and going slow involves comparing a course of action for which the costs are known because they are current to others for which the costs only can be estimated with decreasing assurance as the time span lengthens. Similarly, whether to go ahead with currently available automatic equipment which can show an immediate gain but be made technically obsolescent fairly soon by new developments, or to wait for improved or cheaper equipment and forego the immediate gain is a dilemma.

Valid estimates of market potential are essential. Automation predicated mainly on an increased sales volume which is not realized can turn out to be an expensive blunder, particularly when considerable inflexibility in the rate of operation and composition of output must be accepted as the price of increased automaticity. An increased physical volume of sales may be more than counteracted by falling prices: some knowledge of the sensitivity of demand for the products involved is vital. Installation of automated facilities for the production of new products is thus subject to a double risk and production bugs and poor market reception make a nasty team.

One may also spring an economic trap by failure to count fully the costs of change. Automation seldom can be superimposed smoothly on existing methods and more is affected than the processes which are altered. Material specifications may have to be revised, capacities of supporting operations increased, and uncontemplated indirect costs may appear from several sources such as the need to redesign products, make extended trial runs for adjustment of controls, re-engineer equipment which will not operate satisfactorily, and retrain operators. Production losses may be large during the changeover period, power requirements may be unexpectedly high, and more intensive maintenance may be required. Fortunately, unexpected indirect and intangible advantages—better product quality, safety, decreased supervision, and the like—frequently more than offset the unrecognized costs.

It is not possible to give a single method of evaluation which is applicable everywhere or to set out a list of principles complete enough to provide for every contingency, but the experiences of many managements with automation suggest the following minimum guides:

1. A complete analysis of all aspects of production is necessary to determine the need for and the applicability of automation.
2. Automation should not be justified solely on the basis of

the amount of labor saved versus expenditure for equipment; there are other significant benefits and potential disadvantages.

3. Technical feasibility should not be taken for granted.
4. Planning should be based on the worst that can happen, both with respect to revenues and costs.

3. WHERE DOES THE INFORMATION COME FROM?

In some firms the transition to automation is painless because it is a gradual and natural outgrowth of past developments. Managements of companies which have been increasing the automaticity of their operations over a long period and building up a fund of information at the same time often are surprised at the anxiety expressed by those for whom automatic production is a new concept. Managements of companies in which the use of automatic equipment will mean a sharp break with the past, however, usually find getting together information on which to base decisions a major problem.

Any number of errors can be made by organizations which lack information or get bad information, but they usually stem from focusing on the equipment of automation rather than the production system as a whole and from viewing automation as a purely technical problem which can be delegated to engineers.

Equipment-centered thinking often results in attempts to find or design equipment which will perform exactly the same operations that are done manually, but perform them automatically. It soon becomes evident that this is a wasteful approach which accepts most of the inefficiencies inherent in existing production methods and fails to provide for improvements which may come out of thorough analysis of products, processes, and materials.

Belief that an automation program is wholly a technical undertaking and not in large part a managerial problem may lead to the mistake of thinking that success is assured by assembling a staff of engineers and turning the problems over to them. Engineering talent *is* needed, but because of all the side effects which automation brings with it, other talents also are needed. Many companies have found it wise in setting up automation projects to include people who already know the business, its functions and operations, and who often can foresee the effects of operational and organizational changes better than those preoccupied with technical matters of equipment design and installation.

Companies sometimes attack the problem of getting information by setting up committees charged with that responsibility. While such committees seem to be a good device for education, they are not so good for action. Consequently, this phase of investigation is likely to be followed by creation of an automation group or department as the time for concrete planning and decision-making approaches. The automation group may be made an adjunct to the regular engineering organization, a staff unit serving manufacturing management, or an independent staff. Depending on the company and its personnel, the group may be staffed by people drawn from engineering or administrative positions in the company or outside of it.

Those drawn into an automation program find their first task one of educating themselves and those with whom they must deal. Through equipment manufacturers, other companies conducting automation programs, participation in technical and management conferences on subjects related to automation, omnivorous reading, and observation, the people who must take leadership first familiarize themselves with the new field. As their understanding progresses and as they begin to analyze the company's operations in terms of automation, they can begin to inform others and enlist their support for the program. Most essential to the success of the program, of course, is understanding and backing by top management as the program goes through its gestation period, gives birth to a new production system, and meets its inevitable early life difficulties.

Employment of consultants to assist in establishment of an organization, conduct operations analysis, and make recommendations regarding equipment is fairly common in the automation field. Valuable help also can be had from the engineering and sales representatives of equipment manufacturers. Adequate information may at first seem almost unobtainable to a company making its initial moves toward automation, but later the problem may be to avoid getting swamped with data. This is more of a danger for the management which has failed to define its objectives clearly and prepare itself to evaluate the facts it finds, however, than it is for the management which has analyzed the problem in advance.

4. AUTOMATION AND ADMINISTRATION

Automation presents opportunities, but, because it means change, it creates problems for management. Some aspects of automation have been discussed in those terms, but one aspect not touched on is so important that it should now be singled out for emphasis: in addition to the fact that automation has an impact on management because of the difficult initial decisions that must be made, it has a further impact because of the special problems of running an automated concern and because the administrative process itself may be transformed under automation.

Let us first recount the particular management problems which can be expected and the requirements they will impose when production facilities are automated to some extent.

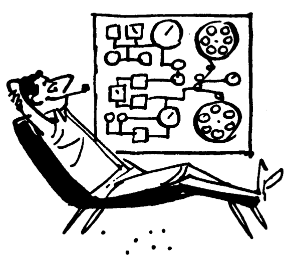
One of the most apparent results is that certain operating inflexibilities will be present. While at some advanced stage of automation it may be possible to build highly flexible production units which can be reprogrammed readily to turn out a variety of products, they will not be found in many plants for a long time to come. The typical automatic production setup will continue to consist of special toolings and single-purpose machines designed around one product. Original equipment will be expensive and revision for product change will be expensive, since changes of function, rate of operation, and process sequence will upset the balance between operations and require modification of handling equipment as well as modification and re-layout of production equipment. The fixed costs of specialized production facilities will be high in comparison to variable costs of operations, so that even if the operating rate can be slowed, costs cannot be appreciably reduced by cutting output. Furthermore, in plants designed to operate continuously at or near their maximum capacity (as automated plants must be to make a reasonable return of the heavy investment in equipment) it may be neither technically nor economically feasible to operate much above or below the designed rate. Another source of cost rigidity is that much of the labor force will consist of salaried technicians and maintenance men who must be on the job regardless of the rate of operations; labor costs will be relatively unresponsive to change in the level of output. Similarly the overhead organization of engineering and administrative personnel will be relatively large and its minimum size will tend to be fixed.

The inflexibilities mentioned will require management to place great stress on the planning function so that production variations may be avoided or at least adjusted to with minimum dislocation. Because production facilities must be operated as an integrated whole, all business functions—sales, finance, procurement, and production—must be closely coordinated. Managers who can comprehend the technical complications of automatic production and who can make decisions on the basis of reasoned analysis rather than hunches will be needed. As automation demands integration of operations and administration, so it magnifies the consequences of errors. Administrative failures in planning and execution which result in shortages of materials, inefficient production programs, excessive equipment down time, or other production interruptions or impairments will pyramid. What might have been an inconsequential planning slip causing a few hours delay in another kind of plant will be anything but negligible in an automated plant with a normally high rate of production which can drop to zero when a single process is made idle.

A multitude of new problems in the areas of sales, finance, industrial relations, and engineering research will confront the managers of concerns which place reliance on automatic production. How are large quantities of standardized items to be marketed? Where are the skilled technicians of automation to be recruited? How are new industrial relations problems created by shorter hours, changed skill requirements, and different working conditions to be handled? Where is the money to be found for continued plant revision? How much should be spent on research and how should funds be allocated to projects? We could go on enumerating problems that will have to be faced by managements *after* the beginning steps in automation have been taken, but why labor the point? Managing a business with automation is not going to be the same as managing without it.

What has gone before suggests that management is in for a rough time with more difficult decisions to make, more pressure on the decisions, and more ability needed. Is there no ray of hope? There are several to be found in the fact that automation can be an aid to decision-makers at the same time that it presents them with decisions to make. Automation in the office is certain to continue to parallel automation in the plant. Automatic data processing equipment can be a powerful tool for analysis, particularly the analysis of complex situations. Many decisions that now must be based on tedious hand analysis of data transcribed from original documents will be speeded up and be made on the basis of more complete information in firms which employ computers for managerial purposes. With improved procedures for handling business data, information will be truly current. Imagine the contrast, for example, between inventory management which provides the exact status and trend of any selected category as of the hour, within the minute; and inventory management which must comb last week's or last month's reports to find relevant figures to extrapolate hopefully in making today's decision! Ability to do high speed computing means that "100 per cent" analysis of operating figures can be performed instead of partial analysis from sampled figures. Managers will be able to have data classified rapidly in many different ways in searching for relations among operating variables. They will be able to use methods of evaluation that they could not use before because the time that would have been consumed in making the evaluations would have put them out of date before completed. They may even test the outcomes of business decisions by simulation if they can construct workable mathematical models reducible to computer programs which will run through masses of data representing different constellations of conditions.

The diffusion of decision-making through numerous management levels and among functional specialists which prevails in business firms today should be erased in large part by automation. With all operations preplanned and systems for reporting and control mechanized, major decisions can be made centrally and effected quickly. Routine decision processes for which all admissible alternatives can be predicted can be handled by machines. A management freed of the necessity for getting its information through a swarm of intermediaries and transmitting its decisions through the often distorting medium of supervisory levels should be able to do a better job, even if it has a bigger job to do.



V. Labor's Problems

THE EFFECTS of technological change are nothing new to working people. They have been losing jobs and finding jobs, seeing their jobs made easier and sometimes made harder, working under better conditions and sometimes under worse conditions, watching the power of their organizations wax and wane, and having their skill, training, and experience rise in value and fall in value in response to technological change as long as the industrial society has existed. The problems of the individual worker and the industrial relations problems raised by automation are not novel problems for the most part. But this does not make them any the less problems.

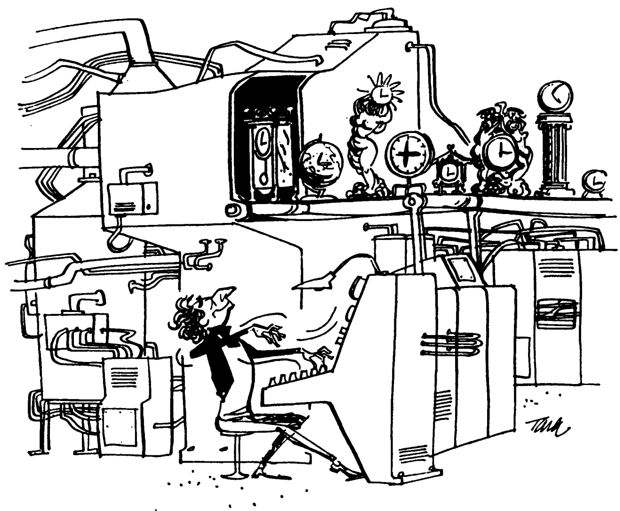
When we get right down to it, labor's reaction to automation can best be interpreted as part of an older, larger question: To what extent shall the worker be subordinated to the demands of industrial efficiency? The role often proposed for him has been described by Mason Haire in *Psychology in Management* as follows:

> Our industrial production layouts are built to utilize the production technique, the machines' characteristics, and the material's qualities to the utmost. The operator is considered the dependent variable. He is expected to (and fortunately does) bend and adjust.

Rejection of that role and skepticism regarding technology's automatic conferral of benefits, however, has been put this way:

> A new American myth is being created. High priced public relations 'experts' are saturating us with a barrage of material that sets technology upon a pedestal and pictures man worshipping at its base. Even more than free enterprise, improved technology is cited as the cause of reduced hours, higher wages, more jobs, and improved living standards. We are led to believe that technology automatically confers benefits on society. Technology is represented as the independent variable, the causal factor.
>
> But this is not true. Man is the independent variable. His customs, his habits, his desires and needs, his ingenuity, resourcefulness and wisdom determine the shape, kind and degree of prosperity he can and does wring from the natural resources of the world.
>
> * * * *
>
> This is the management propagated myth: Technology automatically determines standards of living. No one brings technology into being. It springs naturally from the ground like creations of nature.
>
> The purpose of attributing to inanimate machinery the ability to make progress automatically is clear. If machines can automatically give us higher living standards, more leisure, and the better life, then on what grounds do unions make demands for higher wages and for better working conditions? Why struggle to make progress when automation automatically provides progress?

Just as automation portends opportunities and headaches for management, so it does for labor. We have seen some of the broad implications for employment and living standards it contains and some of the decisions management must make which will have reper-



cussions for industrial employees. We shall now take a different point of view for examination of the results of increasing industrial efficiency via automation.

1. ORGANIZED LABOR'S ANSWER

In the past, unions have adopted various strategies to preserve jobs against the impact of technological change, reduce personal hardship, and maintain union strength. At different times and places unions have attempted to obstruct change by trying to prevent introduction of new equipment, refusing to let their members operate new machines, limiting production, striking against employers who used new production techniques, or by appealing to public opinion or attempting to influence legislation. Occasionally union members have tried to compete against new machines and new methods by raising output in plants where the new equipment was not installed or making concessions to union employers to enable them to compete with non-union employers who used new tools and methods. Policies of obstruction or competition, however, usually have not been followed for long and have been superseded by attempts to control the effects of change by making wages and working conditions on new jobs derived from application of new techniques a subject for bargaining. The bargaining approach has been backed up with union efforts to control new jobs by training their members to do them, by organizing the workers employed to operate new equipment, and by pushing for various measures intended to limit technological displacement—reducing hours of work, requiring higher wage rates for operators of new equipment than for other operators, requiring that displaced workers be placed in other jobs or be given severance pay, limiting the rate at which new equipment may be installed or the extent of equipment change, setting the size of work crews, or controlling entrance into the declining occupation by control of union membership and hiring.

There is no evidence that union policies with respect to technological change have appreciably influenced its nature or its rate in the long run. Union holding actions have delayed a change here or ameliorated the effects of a change there, but they have not stopped change. Unions, moreover, are as well able to recognize the need for change and the benefits of increasing productivity as are other groups and their stated policies today typically are clear on the point. To speak of "organized labor's view" admittedly is over-simplification, but the following passage which appears in a resolution adopted by the UAW at its 1955 convention probably is as good a representation as any:

> The UAW-CIO and its one and one-half million members welcome automation, technological progress, and the promise of peacetime use of the power of the atom. We offer our cooperation to men and women of good will in all walks of life in a common search for policies and programs within the structure of our free society that will insure that greater technological progress will result in greater human progress.
>
> This goal will not be achieved, however, if we put our trust in luck or in blind economic forces. We can be certain of realizing the great promise for good and averting the dangers that would result from irresponsible use of the new technology only if we consciously and constructively plan to utilize automation for human betterment. We cannot afford to hypnotize ourselves into passivity with monotonous repetition of the comforting thought that 'in the long run' the economy will adjust itself to labor displacement and disruption which could result from the Second Industrial Revolution as it did from the First.

The collective bargaining features of the specific program approved by the UAW show clearly that a strategy of control is being followed. Achievement of these objectives is called for:

1. Guaranteed employment (via guaranteed annual wage plans or supplemented unemployment benefits).
2. Shorter work week.
3. Broadened seniority units.
4. Strengthened transfer rights.
5. Preferential hiring of workers displaced from other plants of the same company or from other companies in the same industry and area.
6. Negotiation of new job classifications required by technological change with wage rates that properly reflect increased worker responsibility for costly equipment and an enlarged volume of output.
7. Protection of the integrity of the skilled trades.
8. Establishment of joint union-management programs for training and retraining of workers at company expense and without loss of wages.

Various unions naturally will emphasize different objectives and use alternative means to attain them, depending on their particular circumstances, but the general directions collective bargaining may take are clearly pointed by the preceding listing and the union responses to technological change described earlier. Our next step is to spell out causes and consequences.

2. THE SPOT UNEMPLOYMENT PROBLEM

Labor's fear of unemployment is not dispelled by talk about progress, the mobility of labor, and long run processes of adjustment. Workers are concerned about the short run, in which they live, not about the long run, in which they die. It is no consolation to the individual to know that two jobs are going to grow in place of the one he loses if neither of them is going to be for him. It is no solace to the union losing members to know that another union is going to gain some.

Several things can happen when jobs are destroyed by automation: (1) new jobs are created simultaneously in greater numbers, (2) new jobs are created in greater numbers with some time lag, (3) fewer new jobs are created than destroyed, with or without time lag, (4) all holders of jobs destroyed can and will go to new jobs, either at once or after some time, (5) some holders of jobs destroyed cannot or will not go to new jobs. We already have seen that automation, by raising productivity and living standards, well may cause more jobs to be created than it destroys. However, various general situations consisting of combinations of the alternatives above may come to pass in a firm or industry. At worst, fewer new jobs will be created than old ones destroyed, new ones will come into being only after some lapse of time, and some individuals will not be able to transfer. At best, more new jobs immediately will be created than old ones destroyed and all individuals displaced will go to the new jobs. The chances are that actual situations will tend to be intermediate so that with extensive automation some people will never be out of work, some for a short while, and some for a long while; some will get better jobs and some will get poorer jobs.

When automation hits particular firms or industries, it may create pockets of unemployment lasting for varying lengths of time. Where a firm is a major employer in a locality, reduction in the size of its work force may cause a shrinkage of employment opportunity that is not balanced by new local employment. Installation of labor-saving equipment in localized or geographically concentrated industries may have the same consequences. It may be advantageous for some firms to build new automated plants in new locations rather than expand or modify old plants; if operations are cut back in older, less efficient plants, employees who cannot or will not be transferred to another region may be stranded.

The effects of automation on employment, whether they be transitional or persistent, are likely not only to be unevenly distributed geographicaly but in other ways as well. It often is pointed out that automation will upgrade jobs as routine operations performed by unskilled or semi-skilled personnel are cut down and more technical machine adjustment and maintenance operations are created. This means, however, that the least versatile and adaptable workers probably will bear the brunt of change, for the skills of individuals are not as easily changed as the skill requirements of jobs. Unless the unskilled and semi-skilled who are displaced can be retrained, particularly older workers, they may remain unemployed while good jobs go begging. Older workers will be a problem even if they can be retrained, unless they can stay on in the same firm. Nor should it be presumed that the skilled worker is immune to the effects of technological change, for pervasive automation conceivably can eliminate the need for entire classes of skills.

It can be answered, of course, that labor mobility will erase spot unemployment. But it must be remembered that mobility has its costs. The person who must move from one job to another or one place to another may suffer a loss of income temporarily, incur expenses in moving, be forced to sell his home at a sacrifice price, lose equities he has built up in a job (such as seniority, pension and vacation rights, and other job-connected benefits), and possibly face a lessened chance for advancement. Furthermore, the disruptions of relocation cannot be measured solely in money terms and extend to the job seeker's family.

The union response to the problem of spot unemployment consists of pressure for measures to minimize the costs of change borne by workers and to make work force changes less attractive to employers. If seniority units are broadened, workers whose jobs otherwise would fall within narrow seniority classifications and who would be unable to "bump back" shorter tenure workers outside those classifications will be able to bid for more jobs in the event theirs are eliminated. Extension of seniority coverage from department-wide to plant-wide or from plant-wide to company-wide would mean that employees could transfer more easily without loss of rights. Strengthened transfer rights and preferential hiring for displaced workers would further bolster the position of the worker who must change jobs or areas to remain employed. Guaranteed wage plans are intended not only to discourage companies from laying-off and rehiring workers in response to short-term economic change, but to protect workers who lose jobs to progress or must accept reduced or sporadic employment

Labor's over-all adaptability and mobility should not be underestimated despite the probability that irritating problems may be encountered here and there by unions and managements. American labor has shown that it can adjust to the requirements of increasingly technical industry and that it is mobile in response to opportunity. Many of the difficulties sketched above can be obviated by good management planning and proper timing of changes. If the training and retraining of workers to handle better jobs is tackled cooperatively by industry and labor organizations and is attacked soon enough, many of the problems of spot unemployment never will materialize.

3. WAGES, HOURS, WORKING CONDITIONS, AND JOB CONTENT

Few will contend that automation will depress wage rates. The experience in industries where technological change has been rapid suggests the contrary. There are several wage problems that can be expected to accompany automation, however, even though its general effect may be to raise wages. One problem has to do with wage payment methods. Many incentive wage systems and piece-rate payment plans now used in industry clearly will be inappropriate under automation. The piece-rate payment philosophy is that the worker can control his output within limits and that the more efficiently or the harder he works, the more he can earn. In highly integrated and mechanized processes where the worker neither performs operations directly on the product nor controls the production rate, it becomes impossible to identify output units with individual efforts.

Industry already has met with this problem to some extent and there has been a shift to group incentive payment where teams operate processes whose effectiveness depend on joint performance by operators. Automation implies a generally higher degree of process integration than now exists and this means that more incentive systems either will have to be discarded or be revised. While it is possible to conceive of "negative incentive" methods which penalize production interruptions or incentives based on percentage utilization of equipment capacity, it is not clear how effective they would be. It would be equipment performance, primarily, that determined earnings and whether mechanical failures attributable to human performance can be separated satisfactorily from other failures is questionable.

The wage structure in firms and industries is another point at which automation's effect will be felt. The problem of properly compensating those doing jobs in automated plants for which there are no counterparts in non-automated plants without creating wage inequities will not be solved easily. Unions which have bargained out consistent wage structures will find them being warped as some firms automate and change the content of jobs. Traditional union jurisdictions may be disturbed and the structures of unions themselves may be altered as they give recognition to new groups of workers. Wage structures previously stabilized may be upset as the guideposts of "customary wage relationships" are obliterated.

A final wage problem is one of measurement. Job evaluation or work measurement methods commonly take into account the mental and skill requirements, physical factors, responsibilities, and working conditions of jobs in classifying them for purposes of wage payment. Automation will lay new stress on mental requirements and responsibilities and there often will be little comparability between existing job factors and the novel requirements of jobs under automation. How are the new jobs to be fitted into established classifications or how are job classifications to be revised to encompass them?

There is no sign that labor's approach to wage problems is going to change radically with automation. Higher wages, equitable wage structures, and bargained rates will continue to be prime objectives. While labor may look beyond wage rates and seek further enlargement of the domain of collective bargaining, those who expect automation to soften up unions and bring easier wage bargains are going to be disappointed.

As productivity increases in the economy, more goods and services can be produced with a given number of hours of labor. A choice among taking productivity gains wholly in the form of increased output, maintaining output and reducing hours of work, or devoting part of the gain to increasing output and part to increasing leisure time thereby is offered. During the past 50 years, about a third of the gain in productivity has taken the form of increased leisure, as the average work week has been shortened from around 55 hours to something less than 40. Although it has been predicted that average hours of work per week computed on an annual basis will be down to about 33 by 1970, the recent trend toward utilizing productivity gains to raise living standards rather than increase leisure (about 80 per cent of the post-World War II increase has resulted in increased output) raises doubt whether the reduction will be that great. It does appear, however, that further leisure gains are likely to come through reducing days worked per year rather than hours worked per day. Employees who have long trips to work probably would prefer to make fewer trips and have longer weekends, while employers hope that the "dual job" problem (i.e., the problem created when employees take on part-time, after work jobs in addition to their regular employment) can be controlled and that people can be kept on shifts long enough to maintain efficiency.

The reasons why unions have pressed for shorter hours have changed over time. Long hours of work were opposed initially because of their deleterious effect on the health of workers and on family life. Shorter hours were advocated later for work sharing during economic depression and as a protection against technological displacement. Currently the main contention is that increased leisure is a desirable end in itself and that the gains of productivity are adequate to allow more without reduction of pay or living standards.

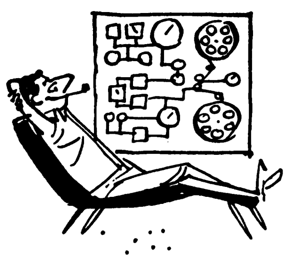
Organized labor is certain to continue to seek shorter work weeks and longer vacations, which reduce the number of hours worked during a year. Current trends toward earlier retirement and later entrance to the work force reduce the number of years worked during a lifetime. If more leisure is to be attained without reduction of the national output and personal income, it must be based on the gains of productivity to which the owners of enterprise also lay claim.

The traditional sphere of collective bargaining narrowly defined starts with wages, extends to hours, and ends with working conditions. The effect of automation on working conditions as they are viewed conventionally promises to be favorable on the whole, for the factories of the future should be even cleaner, better lighted and ventilated, and freer of hazards than those of today. If the meaning of "working conditions" is expanded a bit to take in what the job is and its psychological aspects as well as the physical conditions which surround it, however, it is seen that automation may have both good and bad effects which will require considerable adjustment on the part of the worker.

On the favorable side there is the promise that the trend of mechanization toward job routine and monotony (by reducing jobs to machine tending or virtual machine appurtenances) may be reversed. Whether automation necessarily will give rise to more satisfying jobs universally by requiring that operators perform varied and interesting tasks which fully utilize their capabilities, however, can be questioned. While it may relieve men of routine sensory and low-grade decision-making functions which have been left to them by mechanization, it can as well create situations where operators must be inactive but continuously mentally alert. Men can adjust to the tedium of machine tending where their minds are free to wander while their hands work fast and efficiently. Remaining in a state of suspenseful alertness for long periods is a difficult sort of tedium and we don't know how large a proportion of workers is adaptable to it.

Research in industrial relations has pointed over and over to connections between inter-personal relations and worker motivation and morale. What is automation's effect going to be here? Depending on the shape it takes, automation may make formation of work groups impossible or may re-emphasize their importance. Individuals satisfy needs through membership in informal groups. If workers in an automated plant are too far apart to communicate, absence of the usual joking, gossiping, and griping which goes on at the workplace may cause individuals to feel a sense of social isolation which can lead to drooping morale. If established group relationships are broken up by automation, what is to replace the motivating factors of in-group competition and group security? If, on the other hand, automation results in work arrangements which draw people together and make for teamwork, job satisfaction can be increased materially.

The nature of the relationship between supervisors and workers also may be transformed under automation. With fewer to supervise and more technical problems with which to deal, the foreman will be in a new position. Supervisory autonomy may be pared down so that supervisors will have to get results without having comprehensive authority. Production foremen in some cases may have to become operators of equipment and be forced to acquire new skills and knowledge while they work alongside those they previously directed. It takes little imagination to predict stresses and strains in the adjustment of supervisors and workers to the changed relations between them.



VI. Automation and All of Us

OUR CLOSING CHAPTER can be short, but not because everything that can be said has been said. In nine days of congressional hearings on the subject in 1955, the Subcommittee on Economic Stabilization of the Joint Committee on the Economic Report collected enough information from a parade of experts to fill a 644 page book on automation. If the reader wishes more details, the short bibliography found a few pages over will serve as a starter and the further references he finds will lead him quickly into an extensive literature. Here we have tried only to see what the shouting is about and discuss some of the issues which automation's advent will raise. In the opening chapter we said that its significance to the man in the street was not too clear, but now we have seen what automation is and one thing is plain—the lives of all of us will be touched.

Many of us who work in plants and offices will see automation at first hand. All of us, whether or not we have anything to do with automation directly, will be affected. All in all, the effects should be good. The articles we buy and the services we use which are produced automatically should be cheaper. Some petty annoyances we all find with paper work should be eliminated. There will be less physical drudgery in industry. There will be more challenging jobs in offices. Communication and travel will be easier. And so on.

There is no need for blind fear of the kind that visualizes a world in which man is dominated and degraded by his machines. The workerless factory is still a dream and the problems of partial automation—the form in which we shall see it for years to come—are not insurmountable. As is true of the other products of technology, automation is a tool to be used and not something that is good or bad in itself or that has an independent existence. We frighten ourselves needlessly when we personify automatic machines and attribute to them properties of human beings. Computers do not think and they do not even perform their awesome routines without intricate instructions provided by humans. Without men, machinery is so much inanimate junk and that is the way it is going to continue to be.

We can be optimistic about our ability to integrate automatic production into our economic system to increase efficiency and raise output and about our ability to make the necessary human adjustments to changed conditions of work. There is one question, however, that will occur to the thoughtful person: Since leisure is not the same as idleness and human welfare is not measured exclusively in material terms, are we really going to be better off with more free time and more wealth? The question is not one to be taken lightly, for as another author has said:

The mental life of the workers of the future will be much more determined by what he does during his leisure time than what he does during his working hours. As his job ceases to dominate his life, political, family, religious, and 'cultural' activities may take on greater significance. It is difficult to see how a democratic state can channel leisure time activities, except by making the facilities for them, whatever their nature, more freely available. But it is likely that the things that fill the leisure time of the average citizen will shape the future to a greater extent than any other set of factors.

Automation is but a chapter in the story of technical progress and so the last line must be, as always, "To Be Continued."

VII. Suggestions for Further Reading

THE MOST comprehensive survey of automation and its effects now available is *Automation and Technological Change*, Hearings Before the Subcommittee on Economic Stabilization of the Joint Committee on the Economic Report, 84th Congress (Washington: 1955). This review of automation developments contains statements made by numerous spokesmen for industry and labor, as well as by supposedly disinterested analysts. Statistical information and illustrations make up a considerable portion of the report. The review is valuable especially for pointing up the diversity of opinion about what automation is and what it means. Practically everyone who has had much to say about automation makes an appearance somewhere in the volume's 600 plus pages.

John Diebold, *Automation: The Advent of the Automatic Factory* (New York: D. Van Nostrand Company, Inc., 1952) is the pioneer book in the field and it has stood up well. It focuses on the business problems of automation and the economic and social consequences of automatic production. *Automation in Business and Industry*, edited by Eugene M. Grabbe (New York:

John Wiley and Sons, Inc., 1957) is based on a series of lectures which were given by prominent engineers and scientists at a University of California Extension course in 1955. The book is no superficial survey and makes frequent excursions into the technicalities of design and operation of automatic control systems. We suggest that the reader whose appetite for details has been whetted by general reading about automation or who wishes references to further sources of information look here.

Quotations in the text of this pamphlet have been drawn from:

PHILLIPS, ALMARIN. *Automation: Its Impact on Economic Growth and Stability.* Washington: American Enterprise Association, 1957.

WIENER, NORBERT. *The Human Use of Human Beings.* Boston: Houghton Mifflin Company, 1950.

SNYDER, JOHN I., JR. "The American Factory and Automation," *Saturday Review* (January 22, 1955).

CONWAY, JACK. "Automation: What It Is and What Is Coming," address delivered to Michigan State College Symposium (April 13, 1955).

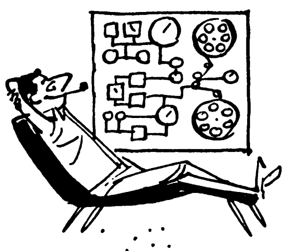
ROSE, ARNOLD M. "Automation and the Future Society," *Commentary* (March, 1956).

It is hoped that the quotations were provocative enough to initiate follow-ups to the originals.

The elements of automatic control are presented in eminently readable form in *Automatic Control* (New York: Simon and Schuster, 1955), a compilation of articles from *Scientific American.* Practical automation hints for executives drawn from company experiences will be found in *Keeping Pace with Automation* (New York: American Management Association, 1956).

Office automation and the capabilities of electronic computers can be investigated in successively increasing detail by reading Howard S. Levin, *Office Work and Automation* (New York: John Wiley and Sons, Inc., 1956); George Kozmetsky and Paul Kircher, *Electronic Computers and Management Control* (New York: McGraw-Hill Book Company, Inc., 1956); and Richard G. Canning, *Electronic Data Processing for Business and Industry* (New York: John Wiley and Sons, Inc., 1956), in the order given.

Periodicals such as *Automation, Automatic Control Engineering, Factory Management and Maintenance, Advanced Management, Dun's Review and Modern Industry,* and *Business Week* have carried articles on automation frequently in recent years. Newspapers, notably the *New York Times* and the *Wall Street Journal,* also have run feature articles on the prospects and problems of automation.



PRINTED IN THE UNITED STATES OF AMERICA
BY THE UNIVERSITY OF CALIFORNIA PRINTING DEPARTMENT
141