MACHINERY and equipment function better when the building has been constructed around them, as in the Industrial Works at Bay City, Michigan. In the erection department, the side-wall columns carry jib-cranes for local material handling. Above travels a beam crane for complete assemblies. An industrial railway brings in the parts and removes finished machines

THE FACTORY MANAGEMENT SERIES

MACHINERY AND EQUIPMENT

PRODUCING AND DISTRIBUTING POWER —HOW TO EQUIP THE FACTORY—MORE WORK FROM MACHINERY, TOOLS AND SHOP FURNITURE— MACHINE UPKEEP—MATERIAL HANDLING AND CONVEYORS—EQUIPMENT OF CONTROL

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Part I

PRODUCING AND DISTRIBUTING POWER

AUTHORITIES AND SOURCES

Where not otherwise indicated under the above heading, the manuscript of this volume is largely the work of Mr. Porter, who has also contributed much of the data from his own engineering experience and field research. Like the other volumes, *Machinery and Equipment* further represents the advice and collaboration of other members of the editorial organization, and of many engineers and manufacturers. An effort has been made below to indicate the more important of these contributions.

Chapter I. Written in collaboration with Mr. Feiker and Mr. Murphy and based on studies of power problems in a western railway repair shop, a New England plating factory, and other industries.

Chapter II. Based on material supplied by J. B. Cravath, consulting engineer.

Chapter III. Studies made by O. M. Becker, industrial engineer; William J. Lees, construction engineer; Joseph W. Hays, combustion engineer; F. Campbell Crocket, consulting engineer; Hugo Diemer, professor of industrial engineering, Philadelphia State College; W. F. Durand, professor of mechanical engineering, Leland Stanford University; bulletins issued by the United States Bureau of Mines, and proceedings of the Cleveland Engineering Society have been drawn upon for material for this chapter.

Chapter IV. George H. Cushing, Joseph W. Hays, O. M. Becker, William J. Lees, Hugo Diemer, and H. D. Jackson have contributed material for this chapter. The plants studied include those of the Commonwealth Edison Company, the Leiter Company, a middle-western ironware plant, and others.

Chapter V. Mr. Feiker and Mr. Porter jointly developed this chapter, which also includes material supplied by Joseph W. Hays, H. D. Jackson, Harrington Emerson, A. R. Cordner, Ira J. Owen, consulting engineer; Walter B. Snow, T. F. Salter, W. F. Parish, and C. R. Trowbridge of the Dodge Manufacturing Company. Among the plants investigated were those of Pawling & Harnischfeger Company, H. W. Caldwell & Son Company, Lidgerwood Manufacturing Company, Morgan Spring Company, Grafton & Knight Manufacturing Company, a Baltimore belting company, a Philadelphia shoe manufacturer, and several eastern textile mills.

I

HOW POWER UNDERLIES PRODUCTION

THREE cents out of every dollar of gross expense is a high average cost for power in manufacturing plants, according to United States Census reports. With some such figure in mind, undoubtedly, a factory manager challenged a power specialist, who tried to interest him in methods of economizing power, with this statement: "Why should power interest me? Other and more important factors in costs claim my attention. I haven't the time to bother with such a small item. Even if the cost of power could be reduced fifty per cent, the profits might not be increased more than one per cent; whereas if I increase production even slightly, the net profit will be increased in much greater proportion."

Did this executive take the right stand? Is the man dealing in trifles who has studied power, and made savings in its generation, transmission and application to work? Is it next to profitless to study power conditions in the average factory? In answering these questions, consider what the full relation is between power and the other elements of manufacturing cost (Figure I). When the statement is made that power forms an insignificant portion of gross expenditures, what is meant is power in the narrow or accounting sense—that part of overhead expense which is added in making up final costs to cover power-house payroll, fuel, water, oil, supplies, repairs and capital charges on the plant and equipment. But these items after all are only a fraction of the total cost of power. To arrive at the true figures, the manufacturer must consider the effect of sub-efficient power equipment and operation on processing and handling costs all along the line.

The engine room is literally the heart of the factory. Production follows and is limited in time, area and quantity by the circulation of power just as commerce traces a river system and ebbs or flows with the fluctuations of its current. How to equip the plant in many respects is decided by power conditions. Machines and tools must be bought and placed with those conditions in mind. The transportation of materials, supplies and products continuously involves power. The controlling devices and recorders in the offices have for their chief function to coordinate power, labor and work throughout the plant. No matter, therefore, how trivial a direct saving in coal or oil or current the management may secure by closer study of power and its application, the problem is vital and the final savings, when power agencies and other equipment have been correctly adjusted to one another, have amazed some who had taken the three-per-cent view of them.

So misleading is this narrow view of the power factor, however, that even after managers have had the possibilities of large savings conclusively proved to them, they still fail to act. The story is told of a Chicago manufacturer who was so indignant on discovering that one of his trusted workmen was regularly helping himself at the factory coal pile, taking home perhaps a few pounds each day, that he had him arrested and sent to the "Bridewell." A few months later he was shown by a firm of fuel engineers, how and why his power plant was wasting fully thirty per cent of his fuel. The fact of the loss was irrefutably demonstrated, yet the executive was not especially stirred by it. Apparently the loss concerned him less than the way it occurred.

This manufacturer's attitude is not an uncommon one. Men who make a study of such matters again and again call attention to manifest losses. Yet no action is taken. "It is easy to get business," says one consulting power engineer. "I show the owner why he is wasting fuel and how to stop it. He perhaps admits the loss and initiates measures to stop it. I write a report making specific recommendations and present it with my bill. He reads the report with great interest and tells me he pays the bill with great satisfaction.

"I visit the plant again in six months to find out what has been accomplished; absolutely nothing has been done. The measures started have not been pushed through. I have been paid for my work, but the work itself has been futile.

"This experience is not occasional; it is typical. The only way I can explain it is that managers are so hypnotized by the three-per-cent view that they can't galvanize themselves into action." Which shows what harm can be done by accepting a mere percentage too literally.

How much power affects total costs depends of course upon the nature of the industry. Where the relative amount used is small, the effect will be correspondingly small. But in scarcely

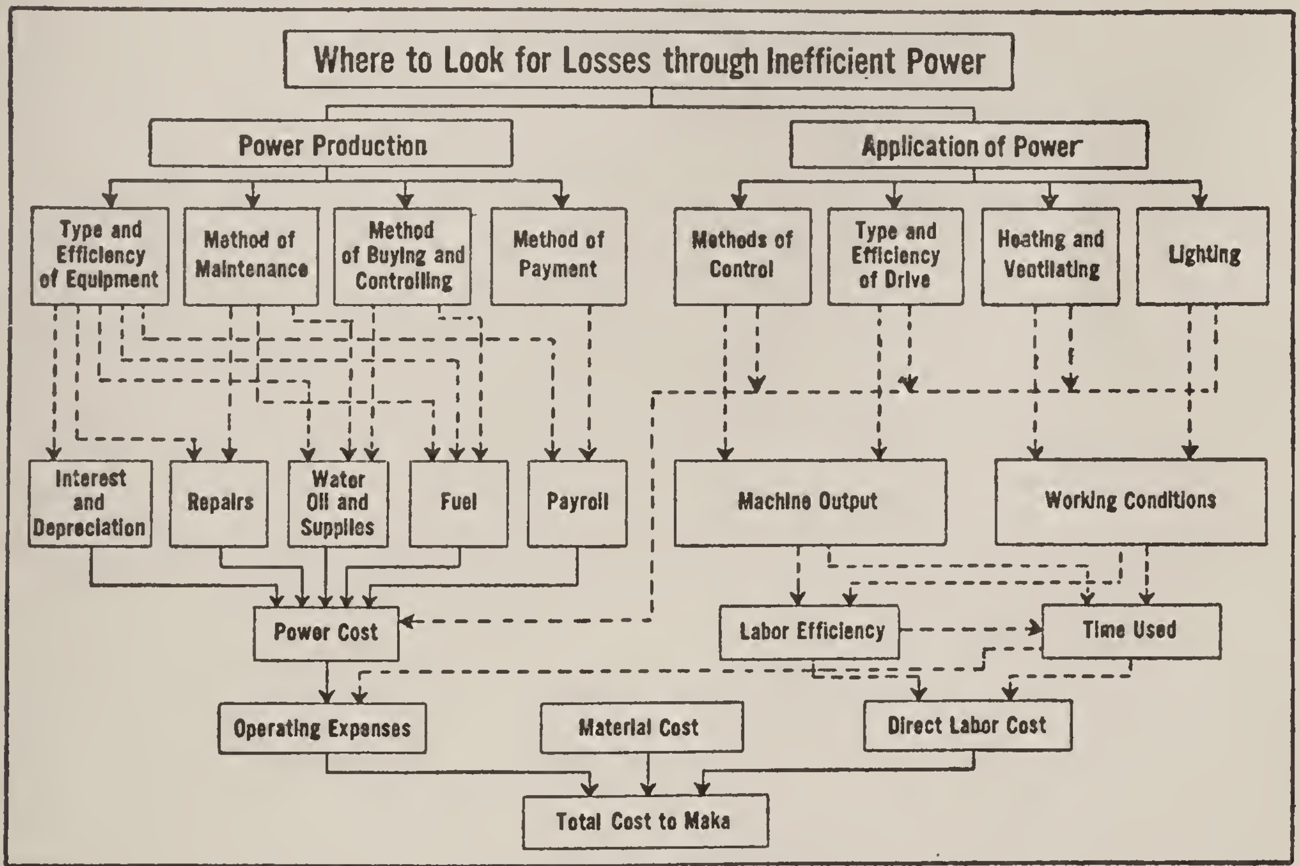


FIGURE I: How power enters costs is here charted. Greater efficiency in power production may make only a small saving in power-house items, but better use of power may, by its effect on other factors, result in a big economy. For example, by installing the latest type of lights, not only is current saved, but working conditions are improved. Labor can do more and better work, reducing both the direct labor costs and the amount of operating expense (of which power is a part) absorbed. Lines of influence are dotted, of direct cost relations, solid

any case is it so small as to be negligible. In the shoe industry, which furnishes a good example of relatively small power consumption, experience has proved that efficient power equipment pays well, and no doubt at all exists on the point in such industries as steel, cement and paper (Figure II). In these, power is one of the biggest single items of expense and no plan which has promise of reducing it can safely be ignored.

Power affects labor costs by influencing wage rates and the amount of time consumed on work. Determination of piece prices depends in some degree upon the relative output of machines. Time elapsed depends not only upon the relative output of machines, but upon working conditions and these indirectly, as light and heat, are elements in the power problem in every factory. Machine output, moreover, is directly influenced by the method of controlling the power, for this determines the time consumed in starting and stopping machines. Among other items of importance that affect the relation of power used to the cost of manufacture are the arrangement of machines and the methods of changing speeds and feeds. The experience of managers who have studied their power problem along some such lines as these, proves that it is worth the while of any factory executive to make a similar analysis in his own case.

Take the elements of power-producing cost alone—efficiency of equipment, methods of paying men and of buying fuel and supplies, plant maintenance and repairs. In the average "going factory" employing from two hundred to a thousand men, even these items offer big chances to save.

TAKING A FRESH POINT OF VIEW OFTEN LEADS TO LARGE POWER SAVINGS

IN analyzing the cost of any element—for example, making steam—it is a good plan to wipe your mental slate clean of conventional ideas. One factory man in analyzing his fuel problem listed three axioms to start with—select the right coal, buy it right and burn it right. His company was burning two-dollar coal at the rate of one hundred and ten thousand tons a year. Fuel represented eighty-one per cent of the cost of operation. A quarter of it, he found when he applied his axioms, was being wasted. By buying fuel on the basis of heat units and by making a few slight changes in the boilers and furnaces, this manager cut his fuel consumption twenty-five per cent. His outlay was covered by the first month's savings.

In a New England factory, lights in the manager's office were brighter and flickered more frequently during the last half hour of the day than at any other time. The engineer in charge of the power plant said the trouble was due to lack of power regulation; and an automatic regulator would cost several hundred dollars. In going through the buffing department late the next day, the manager found men putting away stock

Relative Position of Industries as Power Users			
Names of Industries	Horse Power Used Per		
	Employee	$1000 of Capital	$1000 Value of Product
Clothing	0.14	0.16	0.07
Boots and Shoes	0.45	0.43	0.19
Canning and Preserving	1.13	0.68	0.52
Foundries and Machine Shops	1.40	0.57	0.71
Electrical Machinery	1.51	0.60	1.41
Carriages and Wagons	1.52	0.72	0.79
Furniture	1.54	0.98	0.93
Meat Packing	1.92	0.55	0.02
Woolen Mills	2.07	0.84	0.83
Paints and Varnishes	2.55	0.56	0.45
Creameries	3.22	1.42	0.37
Cotton Mills	3.35	1.58	2.06
Lumber Mills	3.62	2.51	2.46
Bricks and Tiles	3.99	1.95	3.68
Iron and Steel Mills	8.1	2.09	2.16
Portland Cement	12.6	1.98	5.9
Flour and Grist Mills	12.9	2.44	0.97
Paper and Wood Pulp	16.0	3.19	4.86
Blast Furnaces	27.2	2.41	3.0
Calcium Carbide	37.4	12.1	14.5

FIGURE II: Industries at the head of the list are comparatively small users of power, those at the bottom very large. In the boot and shoe industry the literal power cost averages only 1.8 per cent, and in the manufacture of calcium carbide 72.5 per cent of the total. These figures are based on the U. S. Census reports and fifty dollars is assumed as the average cost of a horsepower per year

and cleaning up machines twenty minutes before the closing time. A few only still were producing.

Here was the cause of the flickering lights; machines were being stopped, less power was being used and the engineer's attempts to keep the voltage constant kept the lights flashing high and low.

This little experience brought about an entirely new inspection system. Work for the day was inspected and put in the storerooms by helpers one hour before closing time. The last hour's work was held and counted by a special man after closing time. This made it possible to work the machines at their normal output up to closing time. The department, a month later, showed an increase in output of ten per cent per man. The study of power had proved itself the key to larger economies.

HOW A NEW SUPERINTENDENT CUT COSTS BY IMPROVING POWER CONDITIONS

IN a railway repair shop, a new superintendent with a conscience stern against waste of any kind, found that the biggest single cause of lost time was the inadequacy of the compressed-air apparatus. A few years before, ten thousand dollars had been invested in new air and electric equipment. Bought hurriedly, it had not been found fit and so most of it had been put aside, to stand and rust. Inefficient pumps, a relic of the purchase, fed the air system with a tantalizing pressure of twenty pounds. Often a dozen skilled mechanics had to sit by and await their turn or odd chance at the "air," like Saturday night patrons of a barber shop. To run a locomotive in or out of the erecting room required five or more men for several hours, hard at work with their pinch bars. Or, if the case was not urgent, the foreman waited until after hours, when he could do the work more quickly with air, but on extra pay time. The value of a locomotive was conservatively figured at twenty-five dollars a day, from which item some idea can be had of the cash wasted in the hours spent "pinching."

The new superintendent went straight to the missing link in his power system. For about two hundred dollars he installed a sturdy little steam boiler of his own design, capable of withstanding two hundred pounds of steam. For four hundred dollars more he provided two cross-compound locomotive air pumps, such as his largest engines carried to control their trains. The straightening and tightening of a few wheezy joints of pipe line and the addition of some new hose practically completed the reform.

Results came fast and unexpected uses for the new power appeared from day to day. In the use of small air tools, the new superintendent henceforth had a free hand. Two men with two helpers were now able, with air tools, to accomplish in one day repair work which formerly had taken two boilermakers and four assistants four full days. The cost of this item of maintenance was thus reduced from $56.10 to $10.80, or some eighty-odd per cent. By using air rams, another large saving was made, in the amount of labor and time consumed in riveting. With only twenty pounds of air available, the use of this tool had been desultory; with ninety pounds it became exclusive. In moving locomotives, with air at good pressure available, ten minutes proved ample to connect the air hose and run a locomotive anywhere about the plant. Ten minutes against after-hours' work or five hours of pinch bars! Ten minutes as against five hours, to set to work equipment worth twenty-five dollars a day—for which perishable peaches, or cotton, corn or other freight impatiently were waiting!

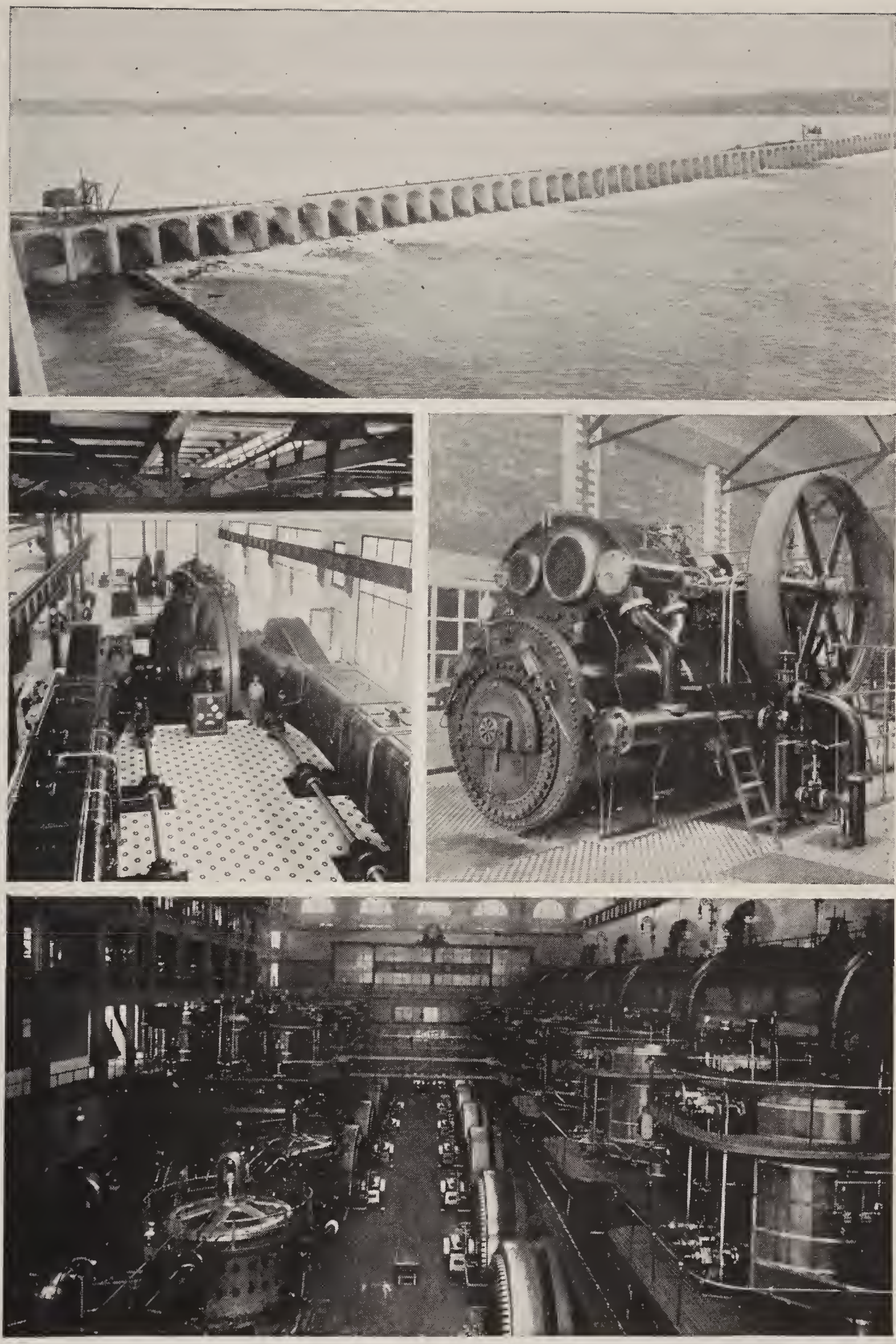
In other ways, also, large savings resulted. The payroll stood almost still, but output responded with ease to hard and heavy traffic. Direct power costs rose; but relative power costs, by reason of more efficient and continuous application, were largely reduced, and total costs dropped into their proper places.

Less tangible is the relation between power and the conditions under which men work, as these affect the time required to turn out the product. Yet dozens of examples are to be found showing that output, directly or indirectly, is affected by good lighting, heating and ventilating, all of which are power problems. Better lighting has resulted not only in a significant increase in output, but also in an advance in quality. Improved ventilation and temperature control has had the same result. Here again improvement may have the effect of increasing power consumption, but the increased returns from labor and equipment liberally compensate.

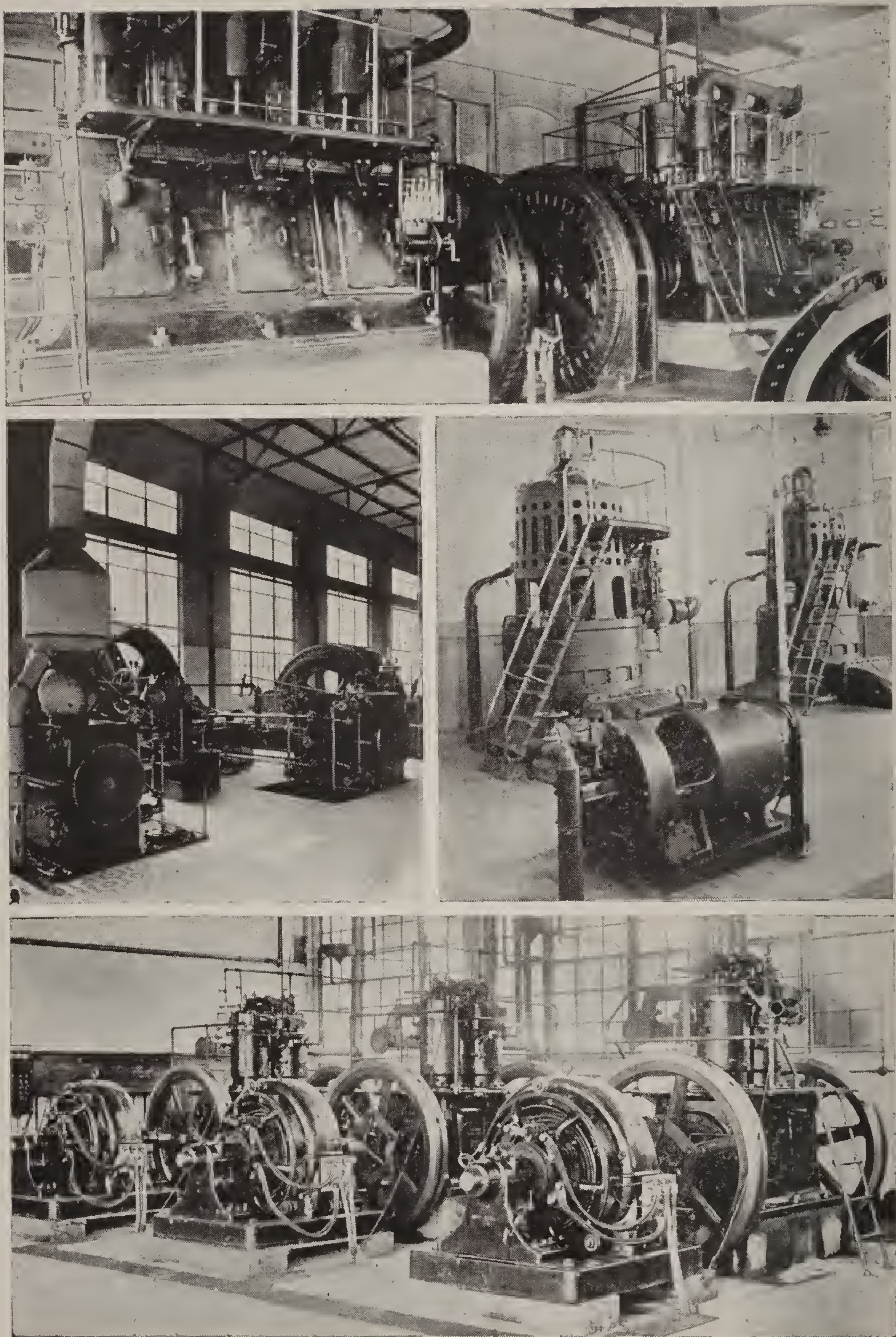
Power consumption should fluctuate approximately with the payroll. One manager who felt this to be the fact, plotted the two on cross-section paper for a number of months running. Much to his surprise, the power curve, instead of varying sensitively with the payroll, remained nearly constant. During the fall months, when business was slack, the payroll went down, but the consumption of power continued at about the same rate. The plant was one equipped with line-shaft and engine drive. The manager, on reflection, decided that his type of drive was the cause. He had been urged to adopt electric distribution of his power, but up till now had doubted that a saving could be effected. The chart convinced him. So he ordered the change made. Subsequently, to satisfy himself, he plotted the same two curves again. As he anticipated, the power curve now followed very closely the ups and downs of the payroll. For with individual motor drive, when a machine ceased to operate, power consumption stopped simultaneously. With line-shaft drive, whether all or only a few machines were operating, the shafts were turning just the same and merely to turn the shafting was causing a large portion of the load. This was one case where, by analyzing his bill for power with respect to labor costs, a manager had his eyes opened to a change in the method of drive which cut his power costs in two.

HOW AUTOMATIC RECORDERS CONTROL POWER GENERATION AND DISTRIBUTION

WATCHING the points where power enters costs has become much simpler through the recent development of automatic measuring devices of various kinds. Graphic records can now be made of almost every element in production without the assistance of clerks. In the power house efficient operation is almost impossible without the aid of recording and indicating apparatus. The amount of feed water going to the boilers, its temperature when entering and upon leaving the feed-water heater or economizer, temperature of the flue gases at the boiler breeching and at the discharge end of the economizer or in the stack, draft had, steam temperature and pressure in the main header, and carbon dioxide (CO_2) in the flue gases—all may be measured and recorded automatically, and the apparatus, if desired, located in the chief engineer's or manager's office directly



Hydro-electric developments, as at Keokuk (top), provide power very cheaply. Steam turbines coupled with reciprocating engines, as in the New York Edison plant (bottom), make the coal-burning central station a close rival. Gas-steam generators, as in the Ford Motor plant (left), achieve low cost for large isolated factories. The "locomobile" bed-rocks the cost for small installations



Four efficient types of generators for isolated plants—(top) two 225-horsepower Diesel oil engines, (bottom) vertical gas engines at the E. R. Thomas Motor Company, (left) a cross-compound reciprocating steam engine with automatic lubrication at the Dodge Brothers' plant, and (right) a combination high and low pressure steam turbine set at the Nashua Manufacturing Company under his eye. Even if it is too expensive to install such instruments at every point, the moral effect alone of a few at the more important points make their use well worth while.

One plant manager had trouble in starting men to work on time in the morning because the foreman of the department said that the room was cold. The engineer, he reported, never had steam in the room early enough to make it warm when the factory started at seven o'clock. A recording steam gage was put in the superintendent's office connecting with the steam line that fed this particular department. After both the foreman and engineer discovered that the little charts from this gage showed daily at just what time the steam was turned on, disputes between them as to the heating ceased. Accurate records arbitrated with finality between manager, steam engineer and foreman. A noticeable increase in the monthly average output of the department resulted.

More than one manager, too, has found it profitable to specialize the study of the power problem—to detail some man who has no other duty than to watch closely not only the power equipment proper, but especially the many and sensitive points where power touches costs indirectly. In some large plants this is the responsibility of the chief engineer. In one small factory the head tool-maker is the man. Whoever is given this task should for best results report to the manager directly.

Successful control of power expense in the average factory, therefore, resolves itself into three main requirements: first, a realization of where and how power enters the cost of production—what the first and final costs are; second, equipment reforms or, for the new shop, plans in which power and production shall have joint attention; third, a method of control, so that power losses from whatever source, once they have been recognized, will cease.

II

WHETHER TO BUY OR MAKE POWER

EVERY manufacturer is looking for a "worryless" source of power. Before he can assign the responsibility for keeping his plant running, several factors must be considered. Dependability and operating costs are probably the most important in the average case. But no manager can intelligently decide the question whether to buy or make his power until he understands all the factors.

He can, moreover, get plenty of free advice on the subject. The trouble with much of this is that it comes from interested sources. Unprejudiced counsel is rare. On the one side are the enterprising engineers of the "new business" departments of the electric power companies, who are anxious to show how a saving can be made by adopting central-station power. These frequently will make examinations and reports free of expense to the prospective customer. While such engineers are as a rule honest and intelligent, it is expecting too much of human nature to anticipate from them an entirely unbiased report.

On the other hand are sometimes found consulting engineers who encourage the isolated plant idea in the hope of getting a job designing and supervising the construction of such a plant. This side usually is boosted also by operating engineers of existing plants who feel that they will be out of a job if power is purchased, or at least that they will occupy a position of less relative importance in the organization if the responsibility of power generation is taken away. The sure way to get unprejudiced advice is to employ competent and honest experts who have no financial interest in the solution of the problem.

It is a fair assumption that most managers would prefer to buy power rather than to make it, if cost and reliability were equal in both cases. Of course, if the manufacturer is operating a power plant as a matter of business pride, no one can object to his doing so if he is willing to pay for the luxury. But as a purely business proposition most factory managers will agree that if the power can be purchased as cheaply as it can be made, and the service is as reliable, home-made power is scarcely justifiable (Figure III).

In order to survive, the manufacturer must concentrate his efforts as much as possible on manufacturing problems. This is a principle recognized throughout the business world—it is by specializing and concentration of effort that modern production has been brought to such a high state of efficiency. If, therefore, you can relieve yourself of the power-plant problem without too much sacrifice, you should welcome the opportunity. Furthermore, a power plant always introduces certain elements of risk which it is desirable, if possible, to avoid.

As to the fundamental reasons why a central station can, or cannot supply electricity cheaper than an isolated plant in a

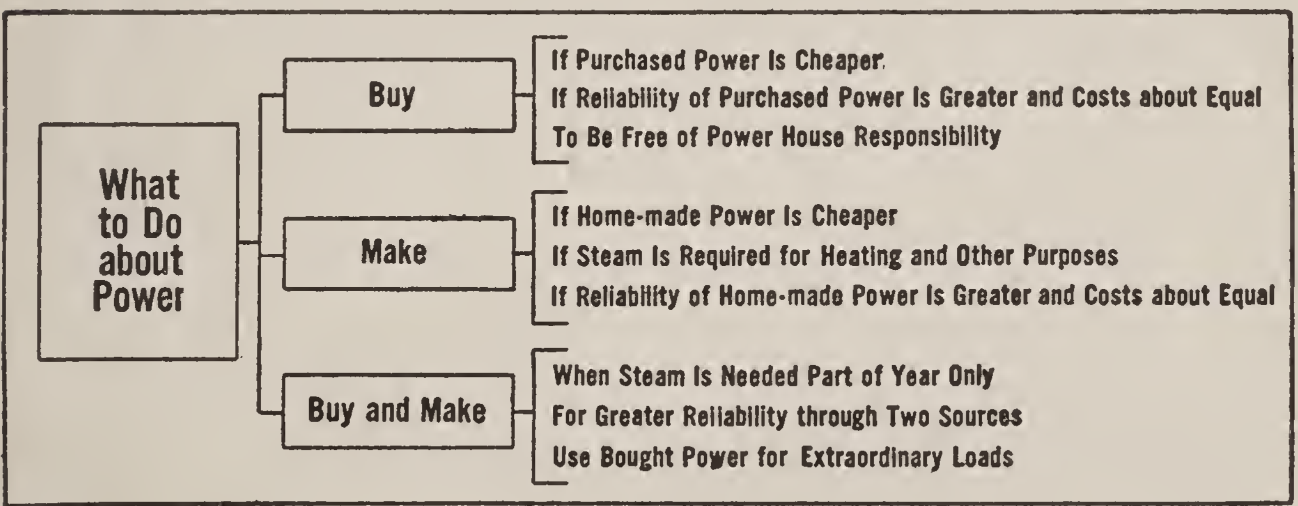


FIGURE III: The question whether to buy or make power has to be decided broadly. Cost and reliability are the two principal factors to be considered. Often to buy part and make part works out to the best advantage

particular case, many arguments are advanced on both sides; but seldom are these summarized in convenient and concise form minus prejudice. A considerable portion of the cost of producing power, whether it be central-station or home-made, consists of what are called fixed charges—that is, interest, depreciation, taxes and insurance, all of which are dependent upon the first cost of the plant. The central station has to provide not only a power plant but also a distributing system (Figure IV).

At the very outset the central station apparently is at a disadvantage because of the distribution system, the cost of which seldom amounts to less than fifty per cent of the total value of the property and may exceed seventy-five per cent. On the other hand this handicap may be offset partially by two factors: the isolated power plant may cost considerably more per kilowatt or horsepower of capacity; and *diversity* of demand may greatly increase the effective capacity of the central station. All of the consumers do not make their greatest demands at the same time. Consequently, a central-station power plant, of one thousand kilowatts, for example, may be able to serve a system having an aggregate maximum demand of one thousand five hundred or two thousand kilowatts.

Other factors may enter the problem to keep the advantage with home-made power. Exhaust steam may be required, either for manufacturing processes or heating or both. Exhaust steam is a by-product of power generation in most isolated plants. If it is needed in the factory, so that no matter where power is obtained a boiler plant has to be operated, then steam power may be obtained as a by-product in the production of steam for heating and industrial purposes.

STEAM POWER IS SOMETIMES HAD AS A BY-PRODUCT OF STEAM GENERATED FOR OTHER PURPOSES

THE correctness of this view of power will be evident from the following: Suppose your factory requires a large amount of low-pressure steam for heating and drying purposes. Assume that the coils of heating pipe are operated at a pressure of four and three-tenths pounds or less per square inch and that water at two hundred degrees Fahrenheit is supplied to the boilers. To generate one pound of steam at four and three-tenths pounds pressure with feed water at two hundred degrees requires about nine hundred and eighty-three units. One unit is roughly the amount of heat required to raise one pound of water one degree Fahrenheit. The number of heat units required to raise the water to the temperature of steam at this pressure manifestly is much less than this and the discrepancy is accounted for by the fact that to convert a pound of water into steam at four and three-tenths pounds pressure requires nine hundred and fifty-six heat units in addition to those already in the water. This is called the latent heat of steam. It is the property which makes steam valuable for heating purposes. When this one pound of steam is put into heating coils it must give out nine hundred and fifty-six heat units (plus nine heat units which were in the water before it became steam) before it can condense back into hot water.

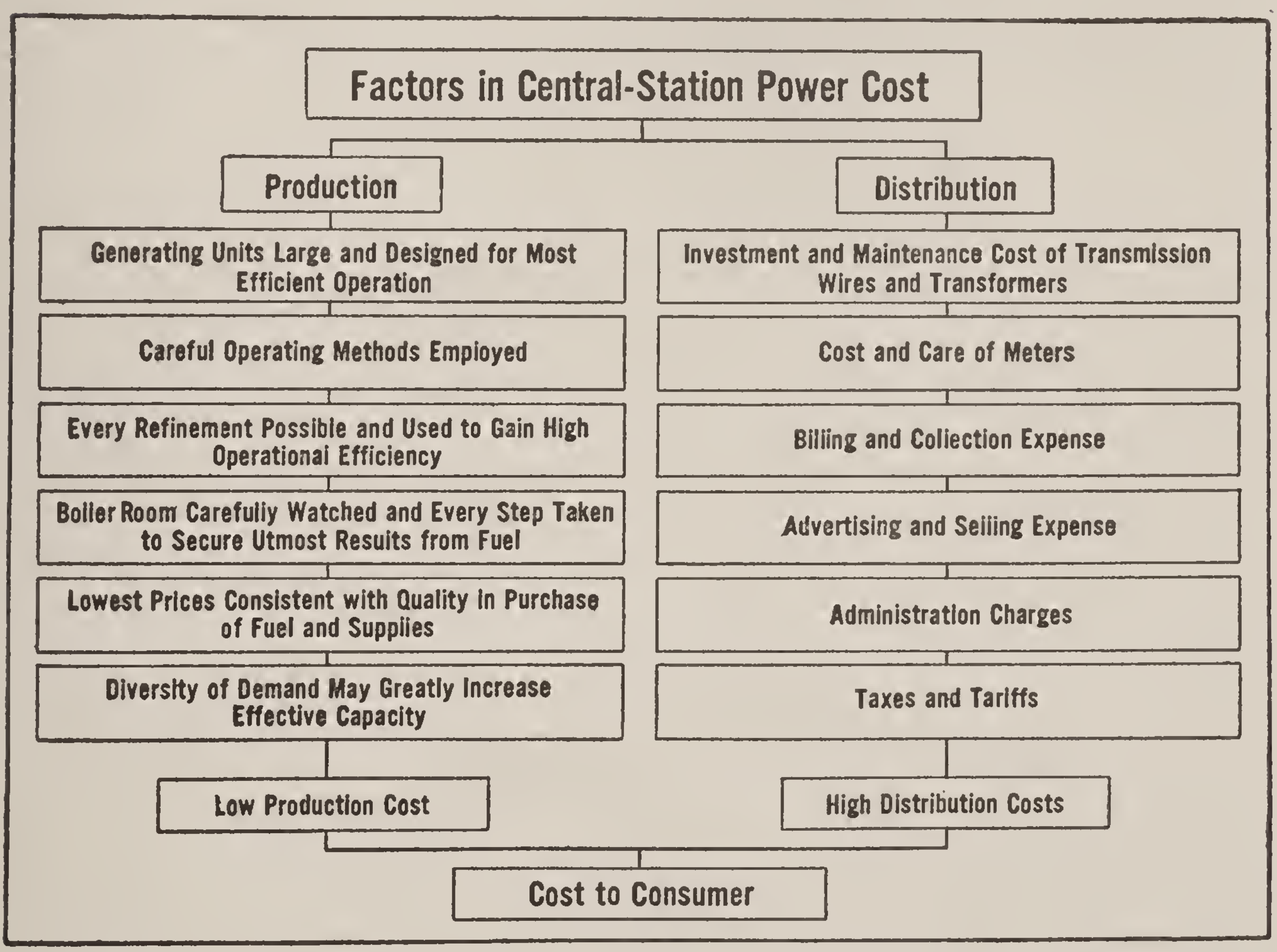


FIGURE IV: The isolated plant has only the producing cost. The central-station plant has also the distributing cost, which may greatly exceed the former. Hence, while the central station can usually produce power more cheaply than any except the largest isolated plant, the delivered cost may or may not be less than home-made power, depending on the size and efficiency of the isolated plant and whether or not steam is required for other than power purposes

Suppose now, instead of generating low pressure steam for the heating coils, the steam pressure is raised to one hundred pounds to operate a steam engine. To do this it is only necessary to add thirty-five heat units to the nine hundred and fifty-six required to convert it into steam at four and three-tenths pounds pressure. If this steam is put into an engine exhausting at about four and three-tenths pounds pressure thirty-five heat units only are taken out of the steam, leaving nine hundred and fifty-six in steam and water available for heating purposes in the process of condensing the steam into water at two hundred and twelve degrees Fahrenheit. The amount of extra heat required for operating the engine would then be only thirty-five nine hundred and fifty-sixths of the amount required for heating—an amount so small that in the practical operation of a boiler plant it would scarcely be noticed. When steam is generated for low-pressure heating and drying, it usually has to be throttled down anyway. A steam engine will take the place of a reducing valve with little or no extra expense for fuel.

BOTH TO MAKE AND TO BUY POWER IS BEST UNDER SOME CONDITIONS

WHERE the demand for exhaust steam is only for a part of the time, or perhaps insufficient to utilize all of it, choice involves a nice balancing of one set of conditions against another, and a study by men who understand all the factors. Conditions may be such that in winter the entire supply of exhaust steam is required for heating; whereas in summer it all has to be wasted. Under these circumstances it might be cheaper to operate the factory power plant in winter, when the exhaust steam is needed, and to buy power in summer providing it could be obtained at a reasonable rate. And frequently it would be to the central company's interest to make a low rate on business of this kind, because the maximum load on the central station usually comes during the winter months, whereas during the summer months the equipment is idle or operating far below capacity much of the time and might better be earning something in this way.

Another of the principal factors to consider is *reliability*. The manufacturer who operates his own power plant always assumes certain risks which are in no way covered by insurance. If the plant breaks down, compelling cessation of operations in part or all of the factory until repairs can be made, the business incurs a loss against which no form of protection exists. To be sure, with purchased power the same contingency is present in greater or less degree, although the larger the scale of power production the less likely is a breakdown seriously to impair the service. The risk obviously is greatest in case of the smaller isolated plants which cannot afford to carry spare units for just such contingencies. A close study of local conditions will usually show which is the more reliable—purchased or home-made power—and thus offer a basis for deciding the question. As two independent sources of power naturally are more reliable than either one alone, it may be the wise policy to buy as well as make power, even though the conditions in your case enable you to produce more cheaply than the central station can deliver. Ordinarily use the bought current for lighting and irregular overtime work only, but have feed-capacity and connections such that in emergency the entire factory can quickly be shifted to the outside source.

To what extent direct current is needed also is a consideration. Central-station current is usually alternating, which is better for constant speed machines. If there is much variable speed equipment, then it might pay, on account of the cost of transforming, at least, to make your direct current.

In this comparison, it is assumed that you are getting the limit of economy out of your present power equipment. Even if home-made power with the present outfit appears upon careful analysis to be more expensive than purchased, and if the requirement of steam for heating or manufacturing purposes is not a factor, you still may find it to your advantage to investigate other kinds of generating equipment before finally deciding the question. To substitute fuel-oil or gas for coal, change over your furnaces to burn a lower grade of fuel, adopt internal-combustion generators or install the locomobile type of steam engine may solve your problem as regards both cost and certainty of supply.

III

SELECTING YOUR POWER UNIT

NOT many years ago, the choice of a power producer was a simple matter. Such has been the rapidity with which new sources of power have made their bids for favor, however, that the manufacturer who would equip his plant with the most reliable and economical power unit today must compare item by item a half dozen different types of producers.

Closely following the highly developed reciprocating steam engine, operated in connection with a condenser, came the cross-compound type, direct connected to an electric generator. This combination had scarcely established itself when the steam turbine was perfected to such an extent that, in the words of one authority, it became not the engine of the future but of the present. Before the turbine had secured a firm foothold, the gas engine demonstrated its superiority for many kinds of service.

Roused to the utmost by the inroads of its rivals, the reciprocating steam engine put forth still another effort to hold the lead, in the "locomobile," or superheated-steam unit. At about the same time, oil-burning units reached a stage of development which put them to the front for many purposes. More recently still, improvements in valve design and arrangement have greatly increased the efficiency of simple engines, making possible the fuller use of the steam without resorting to multiple cylinders or subsidiary turbine sets. To find, therefore, the most efficient power unit for a given plant, with its local advantages and disadvantages, and the peculiar requirements of its work, has become as intricate a problem as that of factory location.

Flowing water as a source of power presents an almost ideal efficiency which other sources have not yet approached. As much as ninety-five per cent of the power available in a waterfall can be developed. But "white coal," as the Swiss term it, is not so distributed as to be available wherever needed. Blast-furnace gas, too, so widely adopted as a power source in steel plants, is not generally available. The power producers generally available, therefore, are of two main types: the steam engine—reciprocating or turbine; and the internal-combustion generator burning oil or gas.

For some time to come, the "old reliable" reciprocating steam engine doubtless will continue to be the standard for all-around

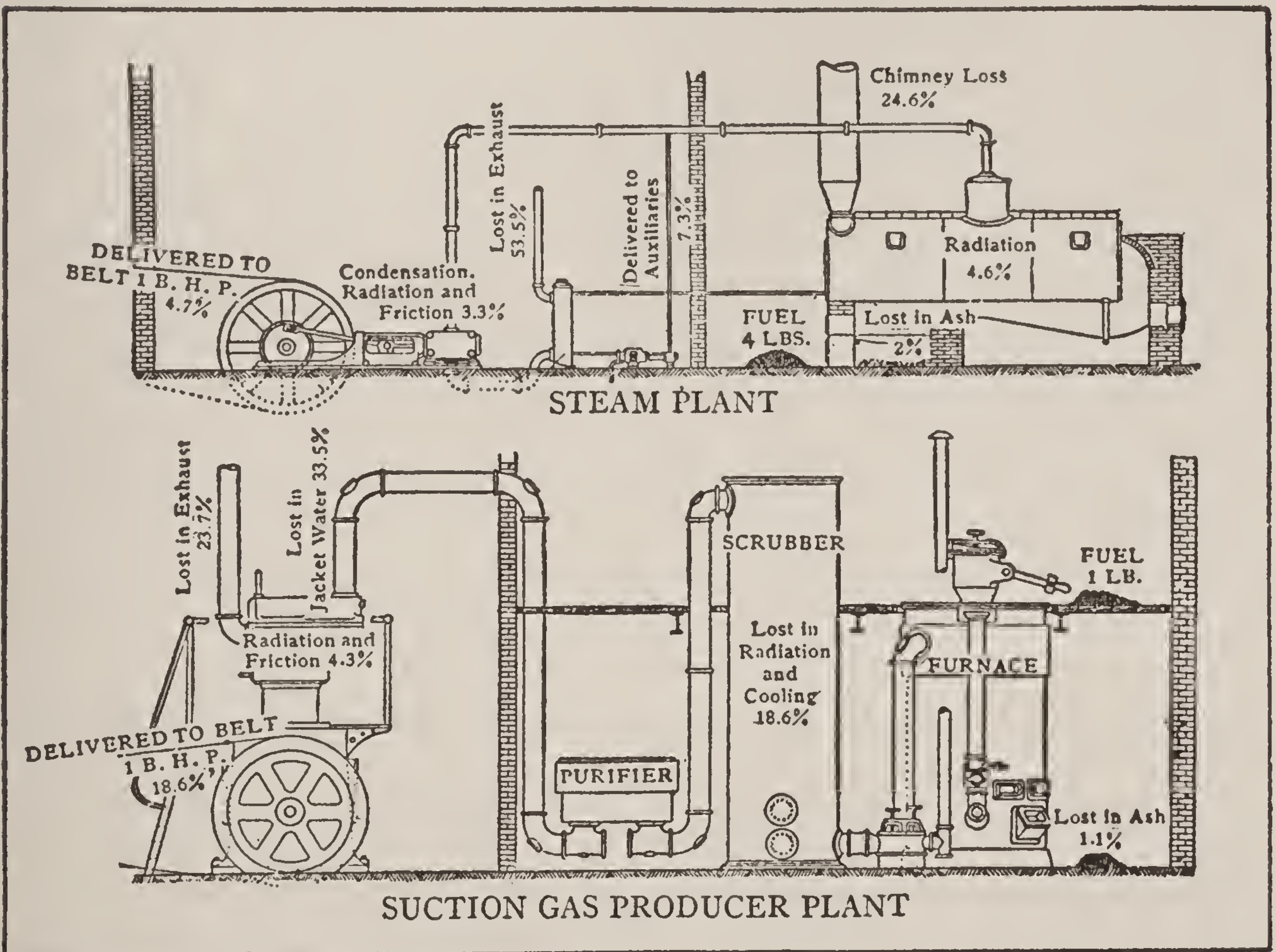


FIGURE V: Why producer-gas plants are more efficient than steam plants, from an operational point of view, is shown in this diagram, drawn by Dr. R. H. Fernald, professor of engineering, University of Pennsylvania. Gas plants have only heat losses in furnace and engine, while steam plants have in addition the loss in boilers and connections

service. So highly perfected is it that it is the most dependable and in many respects the least troublesome of all power producers. And it is so thoroughly understood that many an old engine man "stan's or fa's wi' Jemmie Watt" despite the claims of the turbine and internal-combustion types. When with time, however, these become equally familiar to the practical operator, they may be expected to take their true rank. They are not more complicated—on the contrary are if anything simpler in mechanism; but they are different. Both management and men, therefore, have to be educated to a proper understanding and appreciation of them.

In the locomobile type of steam engine conventional ideas are boldly disregarded, with a consequent economy of fuel that is remarkable. The engine is superimposed directly on an internally-fired tubular boiler and the cylinders are housed within the smoke box. Between the high and low pressure cylinders the steam passes through superheating coils. All steam-carrying parts are thus kept at high temperature and condensation practically is eliminated. Even in the final cylinder, the steam remains dry until the end of the stroke. So short are the steam connections, too, that friction losses are inconsiderable. More power from each pound of coal is the result. A horsepower an hour on a pound and a third of coal is guaranteed for this generator, and abroad, where over fifty thousand of the units are in use, a record of a horsepower on seven-tenths of a pound is cited. This equals the best showing made by gas engines. Economy of space is another advantage (Figure VI).

CHECKING UP THE EFFICIENCY OF OIL-BURNING GENERATORS

OIL-BURNING generators list as one of their chief advantages the convenience of oil as a fuel. Handling costs are reduced, space is saved, perfect combustion easily secured, ashes are eliminated, temperature regulation becomes a matter of exact control and attendance is reduced to a minimum. So great is the economy in this type of prime mover that several countries, notably Great Britain and the United States, have adopted it for vessels of war. Where fuel gas is available, it presents practically the same advantages as fuel oil. Powdered coal offers possibilities along the same line, opening up to usefulness large quantities of low grade fuel which are practically worthless otherwise.

These generators still produce power indirectly; that is, steam-making remains with them the intermediate step to power. Other types of oil-using producers exist, however, which follow the principle of the internal-combustion gas engine and burn their oil directly in the piston chamber. The oil is sprayed into the cylinder under high pressure. The temperature induced thereby ignites the atomized oil and it explodes with great force against the piston-head just as does the gas in a gas engine. The best known of these direct oil-burning producers is the Diesel engine, which, like the locomobile, has met with more recognition abroad than in the United States. As with the other types, the direct oil-burning engine has its limitations. But in its special field, with logical development, it gives promise of wide application.

Of other internal oil-burning types, the alcohol engine is still in the future and the gasoline or kerosene engine is best suited to very small plants, where not more than twenty horsepower is required and this only intermittently.

From the standpoint of efficiency, the producer-gas engine is, perhaps—for large plants at least, second to none. Two variations exist—the pressure producer, so called because the gas is generated by forcing air, or air and steam through a bed of incandescent fuel; and the suction type, wherein the engine-piston or an exhaust fan creates the necessary draft. Both types have given excellent satisfaction. But generally speaking, the pressure producer, because it makes possible the storage of an ample supply of gas for all contingencies, is to be preferred. The suction producer is practically limited to fairly uniform conditions of load, for it is almost automatic in action and the fires die down as the demand for gas falls; then if a heavy load suddenly is thrown on, the engine is likely to be stalled owing to the deficiency of gas supply. The pressure type has another advantage in that it permits the use of a by-product, water-gas, for heating purposes. Moreover, it is successful with the cheapest grades of fuel, even lignite, while the suction type works well only with anthracite (Figure V).

If the locomobile be excepted, producer-gas generators utilize a much greater proportion of the power in coal than any other producer based on the use of this fuel. Commenting on the merits of the gas producer over the steam engine for quickened combustion and the prevention of smoke, the United States Bureau of Mines, after a comprehensive investigation of various types of gas producers burning different kinds of fuel, says: "The gas producer reduces fuel consumption, not ten or fifteen per cent, as claimed for the smoke consuming devices ordinarily

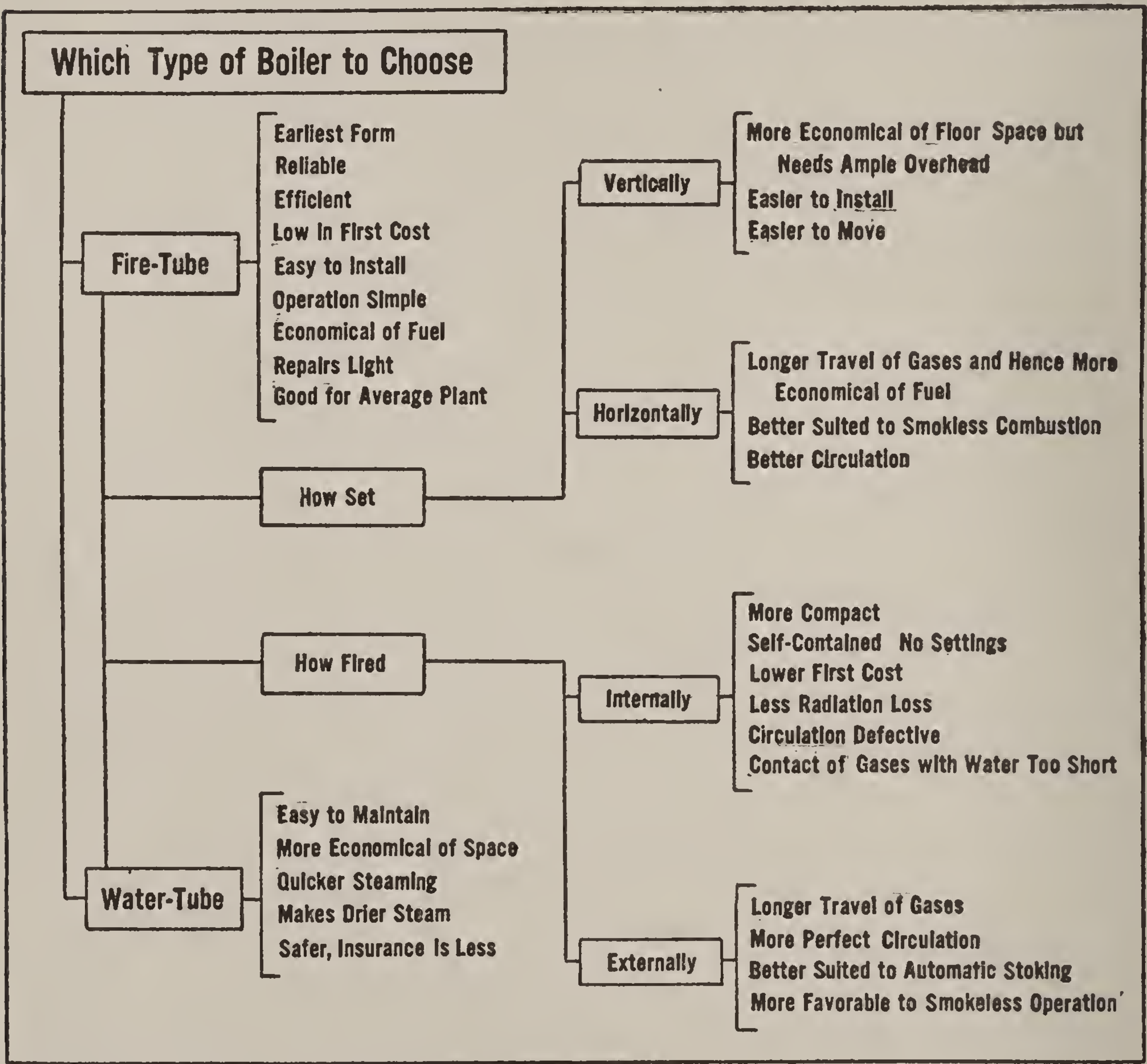


FIGURE VI: Boilers are classified (1) according to how the water and hot gases come in contact—as "fire-tube" when the gases pass through tubes surrounded by water, as "water-tube" when the gases pass around tubes filled with water; (2) according to the direction of the tubes—as "horizontal" or "vertical"; and (3) according to location of the furnace with reference to the boiler—as "internally fired" when the boiler surrounds the grate, as "externally fired" when the grate is below and separate from the boiler. Both the fire-tube and water-tube types may be either horizontal or vertical, and either internally or externally fired with either setting. Each combination has its field

proposed for use in a steam plant, but fifty or sixty per cent." The economy is still further increased if the heat of the engine-exhaust and the jacketing water is fully utilized. At the Ford Motor plant, this waste heat, together with that of the producers, is used to make steam for driving pistons connected in parallel with the gas cylinders. The reclamation of tar as a by-product of the producer, too, offers attractive possibilities of increasing the resultant economy.

While producer-gas installations are cheaper to operate, they are usually slightly higher in first cost than equivalent steam plants. On the other hand, the gas containers often are erected in the open and only the generators and engines housed. When this cheaper housing, together with the reduced amount of space necessary and the savings in accessories are taken into account, the difference in first cost often lies the other way.

Close to the gas engine in point of efficiency is the steam turbine. This statement is pretty well substantiated by the evidence of general experience, though it is true that the turbine is available only for electric driving, while the gas engine, like the reciprocating steam engine, is suitable for any kind of drive. Where it is possible to drive a shop on a line shaft in a straight line, without intermediate miter gears, mule stands and the like, the electric drive cannot, as a rule, compete in cost, whatever may be its desirability in other respects. Such direct line-shaft driving, however, can be done economically only in small plants. The tendency is distinctly towards the more general distribution of power electrically, not only because of its economy in large plants, but also because it is convenient and eliminates the belt losses formerly so much in evidence. In large plants, therefore, the turbine has a very important place.

Among the advantages of the turbine is the relatively small space it requires. In the case of a certain large central station, turbines saved ten per cent on the new building cost on account of their economy of floor space.

This feature of turbines and the fact they can be designed to work on extremely low pressures, permits them to be fitted in compactly with engine units of the reciprocating type already installed. In a number of plants, therefore, this combination has proved very effective. After the steam has done its work in the cylinders, instead of being exhausted into the air, it is worked out against the blades of the turbine. The condenser at the other end, in which a good vacuum is maintained, adds power by pulling the exhaust steam along. Dynamos directly connected to the turbine shaft convert this energy into useful form. With the engine exhausting at atmospheric pressure and a condenser vacuum of twenty-eight and one-half inches, some twenty-six per cent greater electric output is obtained without any increase in boiler capacity or fuel consumption. The combination of turbines with gas engines, using the waste heat of the latter to generate steam for the turbines, offers even greater possibilities and at the same time overcomes the inflexibility of the gas plant alone.

The manager of even the small plant will plan to keep his units so divided that an accident will not close the whole shop until repairs can be completed. The larger the factory, the more important this strategic choice of units becomes. When a thousand horsepower boiler goes out of commission temporarily—a not unlikely contingency—the large plant is seriously crippled. Even when maintenance is at a high standard, the safer and, in the end, more economical policy generally is to keep the unit capacity fairly low. With the exception of the very largest plants, capacities not exceeding three hundred and fifty horsepower for boilers and engines, and fifteen hundred kilowatts for generators are recommended as reasonable working standards. For central-station and water-power developments, of course, much larger units are feasible.

Thus, while no one type of generator has undisputed sway, and the manufacturer needs to base his choice upon the net of advantages and disadvantages, each of several types shows, under certain conditions, some special fitness. Even the old-fashioned Corliss engine sometimes proves adapted in a unique way to the requirements of a particular plan. Laboratory-rated efficiency and economy are on the side of the producer which, using the cheapest fuel available, converts it into usable power by the most direct line.

IV

SECURING MORE POWER AT LESS COST

SCALE an eighth of an inch thick in boiler tubes has been known to cause a waste of fuel value equal to three pounds of coal in ten. Soot on the outside of the tubes is an even greater foe of economy, rated as a hundred times more resistant to the passage of heat than the steel of which the tubes are made. Improper firing, faulty baffling, leaky valves and fittings and poorly wrapped steam pipes are some of the other causes for the preventable loss between the mine and the engine, which, according to one authority, in the average plant amounts to 13,272,123 B.t.u., or nearly forty-six per cent of the theoretical twenty-nine million B.t.u. in the original ton of coal. Engine losses, preventable and non-preventable, bring down the number of heat units actually converted into useful mechanical energy to a little more than a million B.t.u., which is only about four per cent of the quantity started with and less than ten per cent of the 10,837,302 B.t.u. converted into steam. When it is realized that fuel constitutes approximately one-half of the total power cost, it is evident that the practical elimination of preventable losses means a large financial saving (Figure VII).

No matter what type of prime mover the manager installs, he will find underneath these various losses, certain principles of power generation on which engine efficiency hinges. Whether his engines are direct or indirect, whether they burn solid, liquid or gaseous fuel, this fuel must be purchased by scientific standards, stored to protect it from deterioration, handled and fired properly, burned with the most perfect combustion chemistry knows and the resulting steam or gas so utilized that the energy-loss between the fire-box and the crank-shaft shall be a minimum.

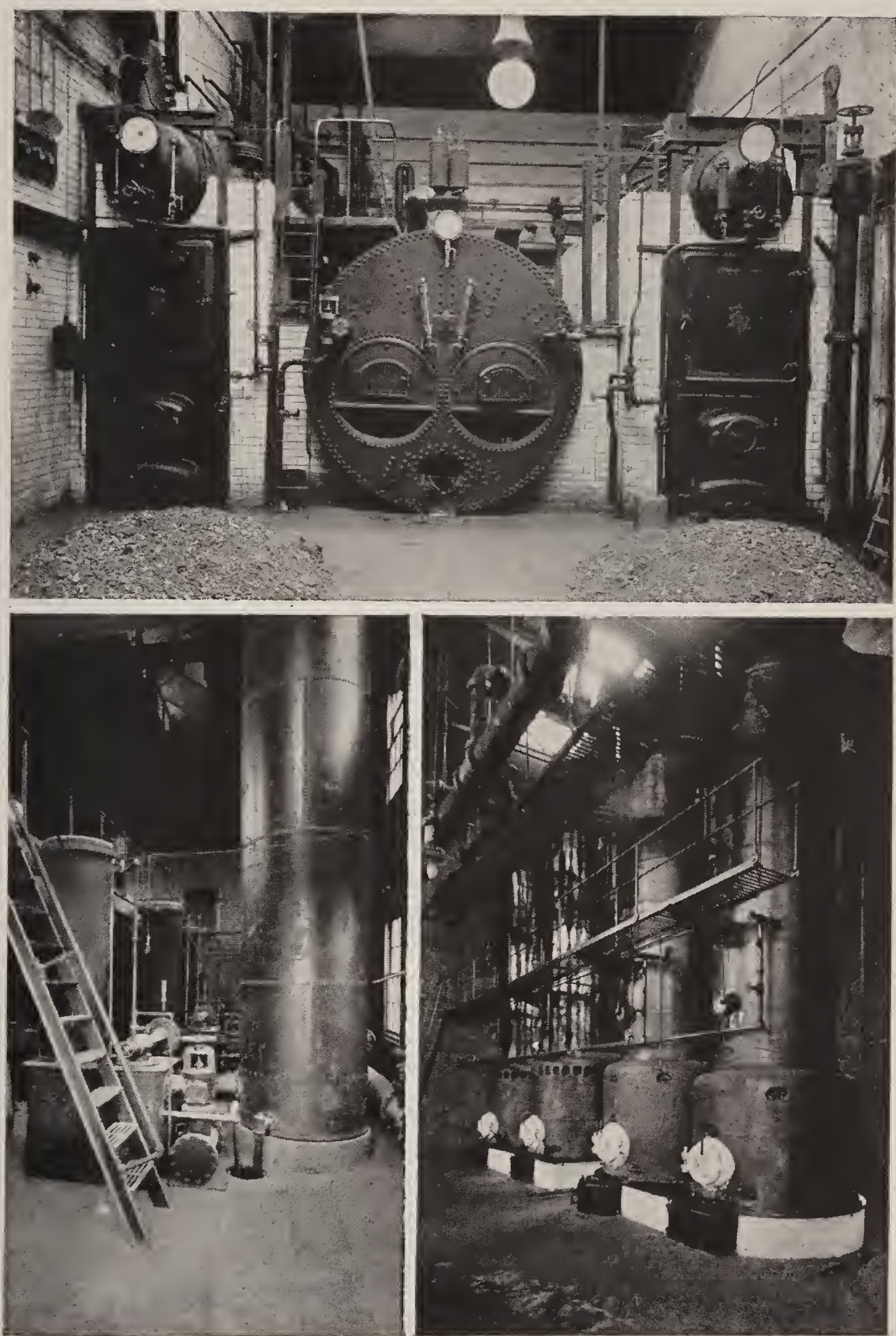
Coal still dominates among sources of power and will probably continue to do so while a cheap supply is available. Coaling and steaming practice is therefore of almost universal interest. Moreover, the same principles which managers and fuel engineers have employed to make coal-burning units more efficient, when taken in connection with the technical detail of any other type of generator, will usually solve that problem also.

Coal supply is one of the most important of the purchasing agent's concerns, on which he must cooperate closely with the power chief in order to insure the right heat-producing value, size of lump, shipping cost and price. When the coal is in the bin, responsibility shifts and it is for the management to get full value from the cash invested.

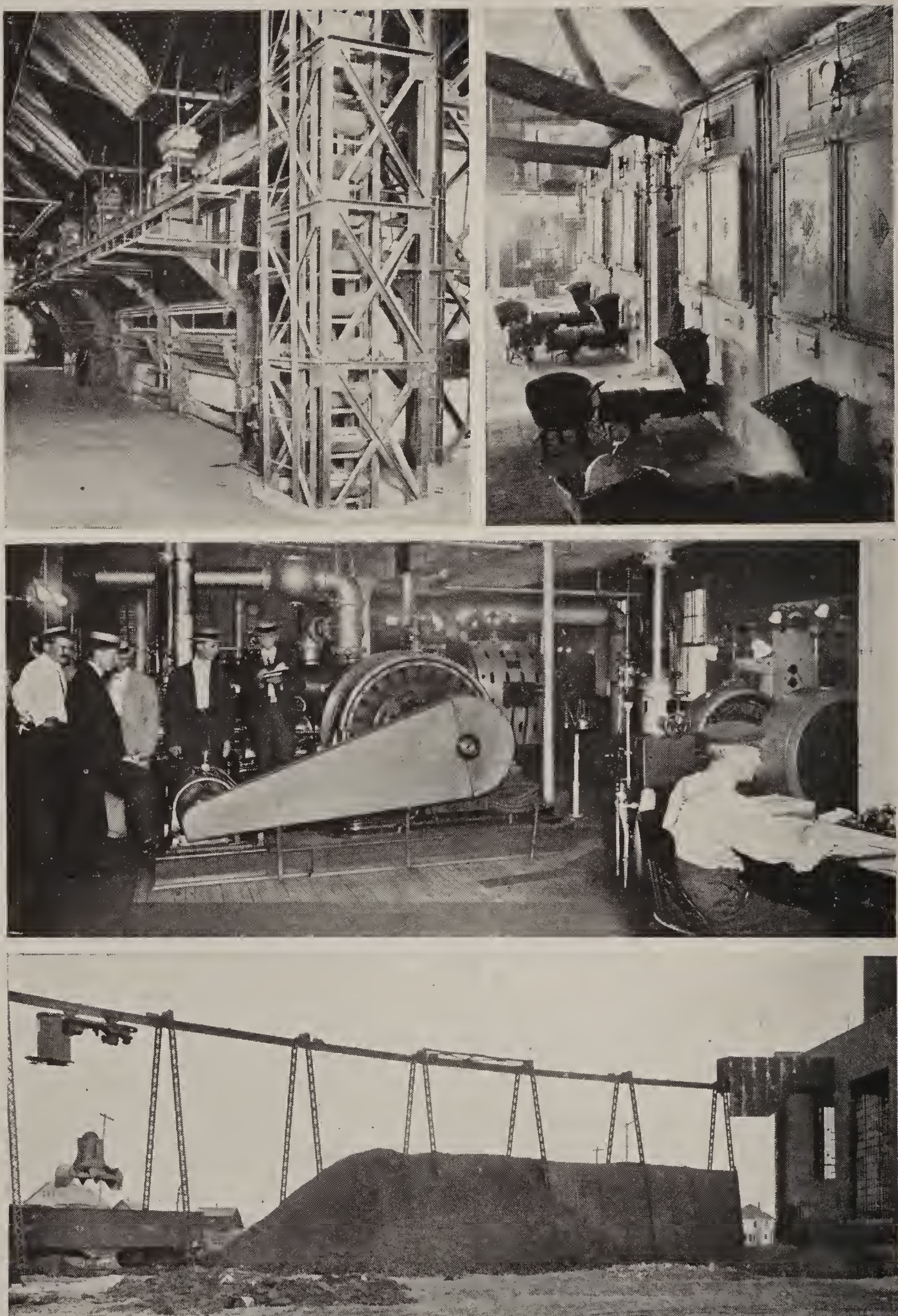
Of any fuel, the prime question is one of chemistry—to tear down the old chemical combinations and facilitate the new ones which give off the most heat. Fire and intense heat are phenomena that attend the rapid union of the oxygen in the air with the element, carbon. Coal is the largest ready source of carbon in compact form, hence its great value for fuel purposes. Moisture, sulphur and volatile matter also enter into its make-up, together with certain incombustible minerals which constitute the residue or ash. That coal will usually prove most economical, under proper firing practice, which on analysis shows the greatest quantity of combustibles to the dollar of delivered costs.

The volatile matter in coal—made up mostly of hydrocarbons—begins to distill at about 450 degrees Fahrenheit. Ignition, however, does not ensue for another two hundred degrees, while the carbon itself does not take fire until the temperature reaches 850 to 900 degrees. And for free and complete ignition at these points, an adequate volume of equally hot air must be available.

So far as providing a properly sized chamber above the fuel bed in which the coal gases and air may mix, proper air supply is a problem for the furnace designer. The thickness and distribution of the fuel on the grate, however, and the volume of air admitted, which after all chiefly determine the efficiency



Internally-fired, horizontal boilers are compact and take little headroom (in middle, above); externally-fired boilers (on either side, above) stand higher, but give longer travel of the gases. Vertical boilers (right, below) require ample head-room, but are space-saving. Producer-gas furnaces (left, at American Graphophone Company) are space-saving, but require a high roof



Coal-unloading equipment (bottom), is indispensable in large plants, and with bucket and bins (top, at left), gives low-cost coal-handling. Automatic weighing scales and automatic stokers (above) aid scientific coal-burning, Periodic inspection of the engine-room equipment (middle) promotes efficiency. Stokers at left are of chain-grate type; at right, underfeed of combustion, are in control of the operator. Without knowing in advance the grade of fuel and the precise method of firing, moreover, the furnace designer cannot even proportion the mixing chamber perfectly. In an existing installation, therefore, the problem is to adapt your method of firing to the size of the present chamber. Experiment alone can decide this.

Too little air to the amount of coal means incomplete combustion and a smoky chimney, for smoke is merely a cloud of minute particles of carbon which have not found oxygen molecules right in amount and temperature for combination. Too much air, on the other hand, means that colorless carbon

Fuel and Heat Losses between the Mine and the Crank-Shaft

Stage	Character or Cause of Loss	(1) Preventable	(2) Non-preventable	Total (1) Plus (2)	Net B. T. U.	Per cent
	Theoretical Heat Units (B. T. U.) in Original Ton of Coal				29,000,000	100
Mine to Furnace	Handling and Weathering	290,000	290,000	580,000		
Furnace	Unconsumed Coal in Ash	1,136,800	284,200	1,421,000		
	Radiation from Furnace	852,600	284,200	1,136,800		
	Chimney Loss Due to CO	204,908				
	Chimney Loss to Maintain Draft		3,410,400	3,615,308		
	Air Leakage Due to Bad Settings	2,842,000				
	Air Leakage Due to Poor Firing	2,842,000		5,684,000		
	Moisture in Coal and in Air		426,300	426,300		
	Total Furnace Losses	8,168,308	4,695,100	12,863,408		
				Delivered to Boiler	16,136,595	55.7
Boiler	Unabsorbable Heat in Flue Gases		1,280,907	1,280,907		
	Soot on Outside Boiler Tubes	1,126,561		1,126,561		
	Scale on Inside Boiler Tubes	1,452,293		1,452,293		
	Short Circuiting of Gases	322,732		322,732		
	Improper Draft Regulation	1,116,800		1,116,800		
	Total Boiler Losses	4,018,386	1,280,907	5,299,293		
				Converted into Steam	10,837,302	37.4
Pipes	Leakage of Water and Steam	216,685		216,685		
	Friction and Radiation	866,742	216,685	1,083,427		
	Total Pipe Losses	1,083,427	216,685	1,300,112		
				Delivered to Engine	9,537,190	32.9
Engine	Exhaust		7,627,331	7,627,331		
	Condensation and Radiation	715,068		715,063		
	Friction in Engine	59,588	119.177	178,765		
	Total Engine Losses	774,651	7,746,508	8,521,159		
				Converted into Power	1,014,030	3.5
Total	Grand Total Losses	14,046,774	13,939,200	27,985,974		
	Per Cent	48.5%	48.0%	96.5%		

FIGURE VII: Figures, where not directly calculable, are based on the judgment of long experience and may be taken to represent conditions in the average industrial power plant today. Were all the preventable losses to be eliminated, 14,953,226 B. t. u. of the original 29,000,000 would be converted into power. The possible increase in efficiency thus is close to fifteen hundred per cent

monoxide (CO), rather than carbon dioxide (CO_2) will be formed. A smokeless chimney, if carrying large amounts of this gas, would represent a great fuel waste, for carbon monoxide has three-quarters of the fuel value of pure carbon. The admission of cold air, or any influence that tends to chill the intermingling air and distilling gases above the fuel bed, means a loss of both unconsumed carbon and unoxidized gas. The only safe test of complete combustion, evidently, is not the

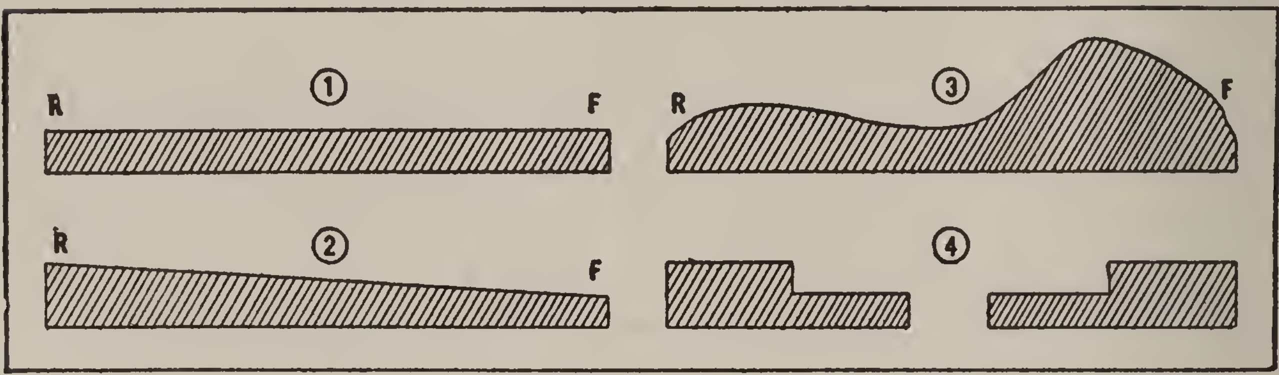


FIGURE VIII: Several methods of hand-stoking with bituminous coal are shown: (1) Even bed; (2) sloping bed, thickness increasing toward rear; (3) "coking method;" (4) uniform thickness, but only half of grate is fired at a time. The "coking method" (3) is effective as a smoke preventer, but requires a great deal of skill and is impracticable if the load fluctuates much. An even bed (1) fired alternately (4) is probably the most satisfactory

total absence of smoke but the proportion of carbon dioxide in the chimney gases. This should be roughly fifteen per cent.

Until this percentage of carbon dioxide is found in the stack, the thickness of the fuel bed and its distribution, the frequency and manner of firing, the baffling, the tightness of the settings and the air supply all need investigation and adjustment. Even then, with manual regulation of the draft, which is necessarily irregular and approximate, it still may be impossible to avoid heavy losses intermittently. However, let the load on the boilers automatically control the air supply, fire the furnace light and often, avoid thin spots in the fuel bed, shut off all air leaks and have plenty of travel for the gases, and the kind of smokeless operation which spells economy becomes a reality.

Examination of the ash, too, is valuable not only as a check on the effectiveness of the stoking, but on the quality of the coal. The ash evidently should contain a minimum of unignited or incompletely burned carbon, although it is better to waste a little fuel this way than, in trying to burn it all up, to have large air leaks through the fuel bed. A percentage of incombustible matter in excess of that figured on in the chemical analysis by which the coal was purchased is an indication of fraud or carelessness on the part of the supplier.

One of the greatest obstacles to proper firing is often the fireman himself, filled as he sometimes is with old stoking traditions and predisposed to carelessness (Figure VIII). The mechanical stoker was inevitable. The two types that have come to be generally accepted are the underfeed and the overfeed, or chain-grate stoker. One, as the name indicates, is constructed so that the fresh fuel is fed under the bed. The gases distilling from it are thus compelled to rise up through a white-hot mass of coal, by which they are raised instantly to the ignition point. Air is supplied under pressure through tuyères at the sides. A hydraulic or steam plunger forces fresh coal in from a hopper feed, and both the plunger and the blower are controlled automatically by the load on the boilers.

The chain-grate type is designed to give a front-to-the-rear movement of the coal and the idea is so to regulate the speed

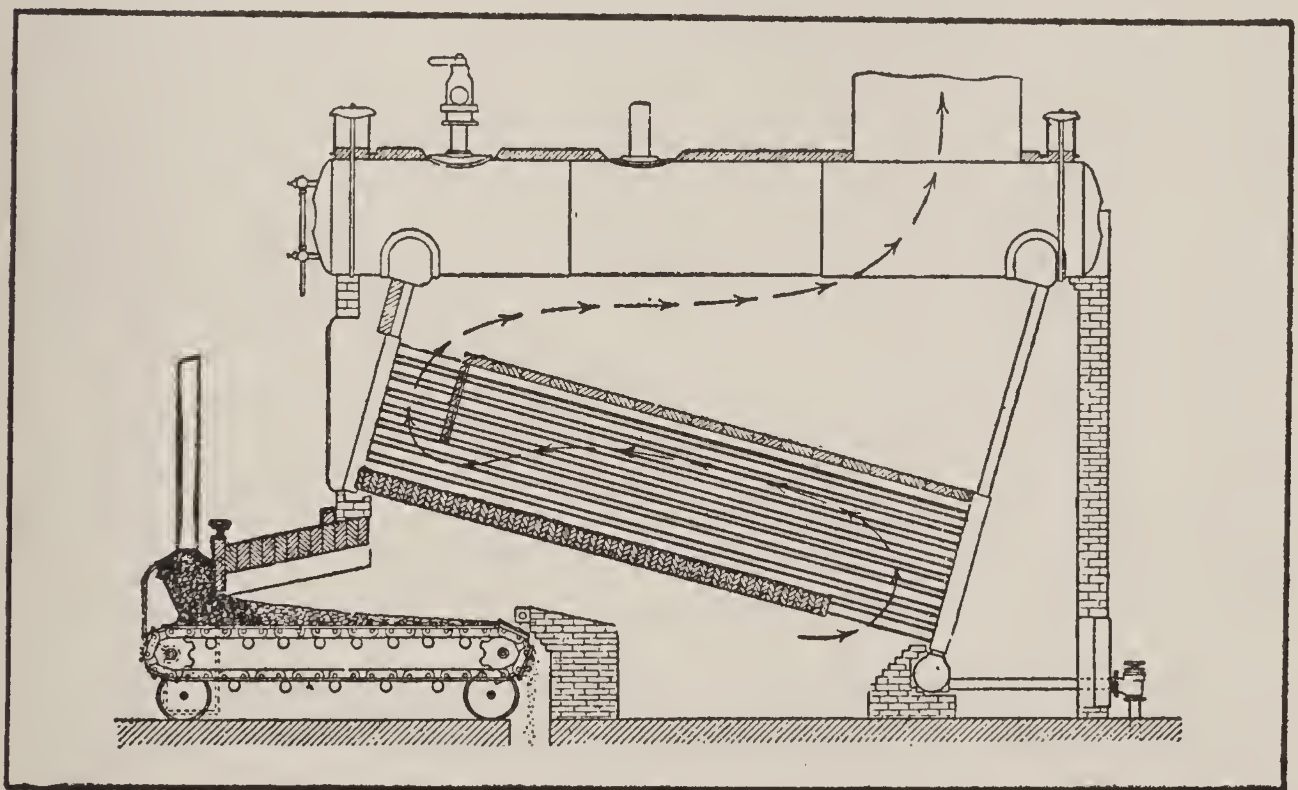


FIGURE IX: To obtain a "Dutch-oven" effect at the International Harvester Company on a furnace (similar to the one at the Leiter plant), fired with a chain-grate stoker, a short roof of special fire-tile was set up in front, together with an arch under the boiler tubes. This gives the long travel of gases necessary for complete combustion. Baffles as shown compel the gases to travel the full length of the boiler tubes. The vital importance of a tight arch and tight baffle plates is evident

of the moving grate that by the time the fuel reaches the back end it is completely burned. The theory is always to have a certain amount of coal in various stages of combustion on the grate surface (Figure IX). Side and front-feed, inclined rocking-grate stokers are other types that have yielded good results. A stoker that mechanically sprinkles the coal over the grate surface has also made its bid for favor.

Practically all these types employ a hopper or magazine feed. An attendant may still be relied on to keep the hopper full, but usually an automatic spout-feed from bins overhead is provided. This arrangement saves both operating and handling labor, and is moreover far more reliable. Coupled with an elevating bucket conveyor, it places coal handling on a truly scientific basis. Where the quantity of ash produced is large, too, it pays to remove and bin it in the same manner.

While automatic stokers are capable of giving high satisfaction, they are by no means fool-proof devices, nor are they superior to hand stoking under all conditions. Intelligent supervision is quite essential. The grade and size of fuel commercially available also have a bearing. Underfeed types will operate with almost any kind of uniformly sized coal. With chain-grate stokers, however, unless screenings or small nut are available, a crusher must be employed; and the extra process may tip the balance of economy the old way. This type consequently finds its application in large plants—of five hundred horsepower and above—convenient to a supply of low-grade and hence low-priced fuel, which does not have to be crushed.

The small plant is not, however, shut off from economical coal burning. A conscientious, well-trained fireman, stimulated by proper checks and incentives, is worth many costly fittings. And automatic stokers need to be watched more carefully than hand-fired furnaces for costly air-leaks through the bed.

HOW TO IMPROVE AN EXISTING INSTALLATION TO SECURE BETTER COMBUSTION

PLENTY of travel for the elements in combustion has been mentioned as of prime importance. Even though ignition over the bed is complete, the hot gases must not be brought in contact prematurely with the relatively cooler boiler tubes, at the risk of arresting combustion and causing a large fuel waste. In a new installation the simplest way to insure a proper travel of the gases is to place the boilers at a liberal height above the fire grate, if the head-room does not prevent. Where overhead space is limited, or an existing installation is faulty in this respect and raising the boilers would be difficult, two effective solutions, at least, are available. An application of one is seen in the Fisk Street plant of the Commonwealth Edison Company, in Chicago. Here the front of the boiler has been elevated and that portion directly above the mixing chamber lined with fireproof tiling. By this means the gases in their flow are forced slightly downward, so that by the time they reach the boiler tubes they are completely ignited.

The results of these simple changes have been striking. Emissions from the stack are imperceptible in any kind of weather, and the decrease in the fuel consumption has been in almost direct ratio to the amount of volatile matter in the coal. Admittedly, this remedy may be applicable to water-tube boilers only and so be not of general utility, but the principle is clearly established that coal gases must have sufficient room to "digest."

Of more general application is the second method, which is independent of the kind of boiler. This consists in placing a "Dutch-oven" in front of the fire-box, through which the gases are compelled to travel and be thoroughly mixed with air, and their temperature raised to the proper point, before coming in contact with the boiler tubes. It is significant that in the Leiter plant, at Zeigler, Illinois, by this device the gases are completely burned in a length of five and a half feet. With a different grade of fuel, the gases would of course need a different length of passage. For this reason, it is important to design the plant to suit the grade of fuel and to stick to this grade.

Old boiler attendants, skilled in the practice just outlined, usually bungle the job when transferred to the operation of a gas producer. Efficiency in this case is measured by the amount of *burnable* gases generated—not by the volume of gases completely oxidized. Too good a fire robs the gas of its richness before it reaches the explosion chamber. A clear understanding of these facts is essential if the saving possible by firing coal to make gas rather than steam is to be realized.

Nor does economical boiler operation end with proper firing methods. Combustion may be perfectly regulated and yet the power plant may record low efficiency. Boilers in good order with proper firing should roughly show an evaporation of ten pounds of water, from and at two hundred and twelve degrees Fahrenheit, to every pound of coal burned. A less amount than this usually is a safe indication of a wrong condition some-

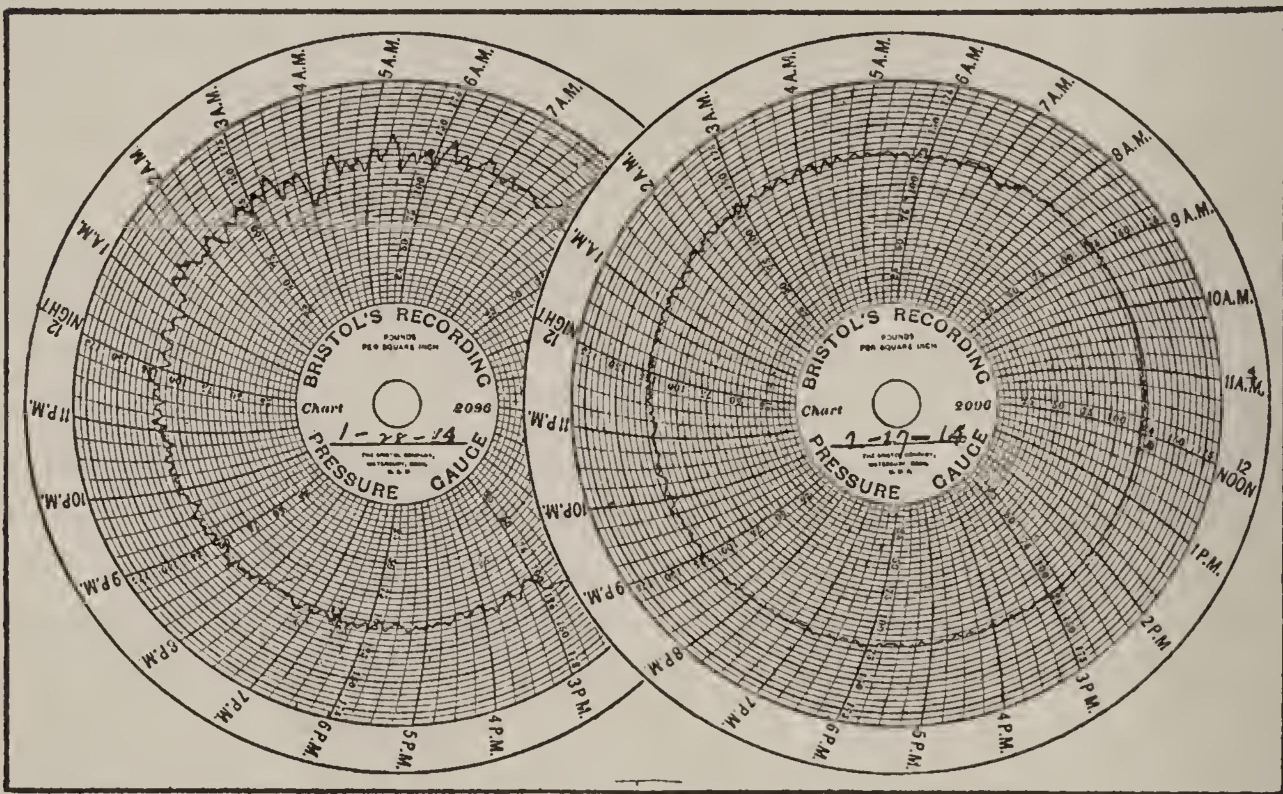


FIGURE X: What the fireman can do when his enthusiasm is aroused by a graphic record of what he is doing ever before him, is plainly indicated in these two charts. The chart dated January 28th shows a record made within a day or two after the recording pressure gage was installed. Three shifts of firemen operated the plant. The pressure fluctuations between midnight and 7 a. m. are clearly indicated. On the twenty-seventh of the next month, the remarkable improvement in firing economy, induced by the firemen's knowledge that they were going on record, is indicated

where. It may be an accumulation of soot on the outside or of scale on the inside of the tubes. The baffling may be broken down, the settings leaky, or the feed water too cold. To check up the efficiency of evaporation, it is necessary to weigh the amount of water used, as well as the amount of coal, and to figure the ratio between the two.

Scale is one of the largest sources of loss. A layer one-sixteenth of an inch thick may cause a loss as high as twenty per cent of the fuel value, and one-eighth of an inch nearly thirty per cent.

Soot may cause an even greater loss, as it turns heat more effectively than any ordinary substance except only loose wool and goose feathers. According to one authority the waste of heat due to soot deposits in the average plant will amount to seven per cent of the total fuel cost, and it is entirely preventable. The remedy is frequent blowing out of the tube spaces with live steam or compressed air, and it usually pays to have the boiler permanently piped for this purpose.

The adverse effect of cold feed water has been noted. The idea is to have the water enter the boiler as close to the steaming point as possible. Every heat unit required to raise the water to this degree after it is in the tubes leaves just that much less for actual steam making. Water at sixty instead of two hundred and twelve degrees may entail a fuel loss as high as twenty per cent. Fortunately heat otherwise wasted is available for preheating the water. The engine exhaust, if not needed for heating the factory or for manufacturing purposes, is one means. The heat wasting up the stack, some of it at least always may be captured and utilized. Condensation from the engine or returns from steam lines in the plant, when strained of their oil and dirt, are sources of hot water to begin with.

Preheating the feed water has the further value, if the water supply is "hard," of precipitating many of the mineral salts carried in solution at normal temperatures, which otherwise would precipitate in the tubes, forming scale. Dissolvents, or "boiler compounds," intelligently prepared, also are helpful. By a combination of the two, coupled with regular cleansing of the tubes, the scale nuisance can be practically eliminated.

HOW HEAT LOSSES BETWEEN THE BOILERS AND THE ENGINE MAY BE REDUCED OR ELIMINATED

BETWEEN the boiler and the engine are many other possibilities of heat loss. Among these may be mentioned leaky traps, valves and fittings, improperly and insufficiently insulated mains, rambling connections and abrupt turns in the piping. No thrifty plant engineer tolerates steam leaks, but too commonly the apparatus is not accessible, so that leakage goes on unnoticed and is difficult to correct when found. All points of possible leakage should be easily get-at-able and supplied with good light and ventilation.

Proper insulation of the steam connections is more important than might be thought. At one plant, in a main sixty feet long, the steam was found to contain thirty-one per cent of moisture. By covering the pipe with a good heat-insulating material, this percentage was reduced to 3.6.

Hair-felt, slag-wool, magnesium, gypsum and asbestos are among the best of the substances available for insulation. Hair-felt is unexcelled as a non-conductor, but quickly chars unless protected from actual contact with the piping. An inner wrapping of asbestos paper or other non-burnable material furnishes the necessary protection. Slag-wool, on the other hand, is fireproof. A compound of which asbestos fibre is the base is popular because it is easy to apply and re-usable.

At the engine, too, serious power losses which are preventable often are found. These may pass unnoticed for months. Then as output increases and greater demand is made upon the power plant, the engine balks short of its rated load, even under a full head of steam. In a plant where this actually occurred the manager first had recourse to an indicator. The card taken showed nothing wrong, but the engine still lagged. After quite a time the trouble was located. Several years previously, when the steam valves had been renewed, a set of valves of a wrong design had been put in. The port opening was about seven-sixteenths of an inch too late. Proper valves were substituted and the trouble ended.

An unusual case, you say, yet it is only one of a great number of a similar character that have come to attention. While greater opportunities for loss may lie between the coal pile and the boiler, and between the boiler and the engine, the possibilities of waste at the engine itself are by no means so small that the management can safely ignore them until something goes wrong. Systematic use of an indicator, careful attention to the lubrication and packing, prompt renewal of worn and pounding parts, and thorough cleaning daily are necessary, if the equipment is to give high class service and have long life.

Economical operation also takes for granted a thorough policy in power-plant maintenance. Maximum efficiency can be attained only where furnace, boiler, and engine are all kept in first class physical condition. A spare boiler is a wise provision, not only to facilitate regular cleaning and repair of all units, but to guard against a shut-down due to breakage. When the plant or any portion of it is idle for any length of time, it should be cleaned and overhauled, and the proper measures taken to prevent corrosion. All contacting surfaces of the engine need a thorough coating of engine oil. If the shut-down is in cold weather, it is particularly important that all valves and bleeders be opened wide, to insure against damage and delay due to freezing. Renewal of gage glasses is another important matter. An idle power unit is always an opportunity for inspection and rehabilitation.

Again, power-house location may have much to do with the resultant power economy. Two principles govern: the site shall be favorable for getting in the fuel supply; and so centered with regard to the points of power application as to minimize both transmission expense and chances for waste to occur.

Fifteen dollars a day, or forty-five hundred dollars a year—the interest at six per cent on seventy-five thousand dollars—is what a Wisconsin manufacturer is paying for a mistake in placing his power house. Some years ago the plant burned down. Before rebuilding, he worked out a plan that would give him straight-line production and permit of the easy expansion of any department. He picked an admirable spot for the power-house, at the focal point of the plant as it ultimately would shape up. For appearance's sake, however, he built it to front the bordering highway, with fuel storage in the rear. As a result every pound of coal has to be transported by wagon from the nearest siding some seventy feet away.

The same manufacturer further erred in not providing permanent fuel storage. His reserve fuel must lie in the open, where heating value is lost steadily by "weathering." Nor can he realize the advantage of gravity feed which overhead bins make possible. What he is paying for weathered fuel, loss between the coal pile and the furnaces, and extra labor in transporting and firing would wipe out the capital charges on an installation of bins and elevating conveyors several times over.

V

CUTTING DOWN TRANSMISSION LOSSES

LINE-shafting about fifty feet long was required to drive a band saw in the shipping room of a machine-tool plant. The saw was used only two or three hours each day. About as much power was required to drive the shaft as was necessary to operate the saw. During seven hours of the day, consequently, the idle shaft was consuming in friction as much power as the machine and shaft together took during the three hours of use.

By placing a clutch at the end of the shaft nearest the main drive, the manager cut out the friction loss in the simplest manner possible. Instead of shutting off the power at the machine he shut it off at the other end of the line-shaft.

This is but one example of the wastes in power transmission found in practically every shop, which can be stopped or much diminished by proper attention. Where losses in fuel, heat and steam stop—at the crank of the engine—friction losses begin. Between this point and the smallest use of power in a plant, opportunities for "lost motion" trail along in profusion. Study of the transmission equipment and of the application of power at the machines seldom fails to prove profitable.

The average factory manager would declare that to increase output ninety per cent without increasing the load on the power plant would be a physical impossibility. In at least one plant, however, this increase was made and, like so many savings which are possible in factories, this one was discovered by accident.

Electric drive had just been installed. Soon it was found that the motors were too small to carry a load that had been carried by belts for years. Each motor drove a group of machines; and while these drives were under test in one department, an unusual power leak was disclosed.

In this department a large number of small machines were driven from counter-shafts. One-half of the machines were driven by crossed belts. On investigating the amount of power used by the machines, the manager found that practically one-half of the total was being absorbed in friction by the crossed belts (Figure XI).

Although the machines were similar, it was necessary to use a number of different methods to overcome the trouble. Still, the total cost of the changes was more than offset by the power saved in three months.

Under the original method of driving the machines with crossed belts (Case I), the belt was tight on the outside so that it was drawn against the clutch shoulder. This friction loss was eliminated by driving the counter-shaft and clutch through the medium of a binder pulley (Case 2).

Another method that cut the friction loss where crossed belts still were necessary was to reverse the direction of the cross (Case 4) so that the tight side crowded the belt away from, rather than toward the collar on the idler pulley, greatly reducing the friction. A third scheme was to arrange the drive as shown in Case 3. Here an open belt was used for the main drive from the main shaft, while the crossed belt was used from the counter-shaft to the machine. The friction losses due to crossed belts, instead of being constant, now occur only when the machine actually is running.

As in so many instances of like character, the saving in this case meant not only a dollars-and-cents reduction in the cost of power, but also a saving in the wear and tear on the complete equipment. The additional drive equipment, thought at first to be needed, proved unnecessary; rather, it became possible to drive several new machines with the existing equipment.

In another instance, where group-electric drive was the practice, a large saving was effected by rearranging the motors and shafting so that the drives practically were at the middle of the shafts, instead of at the ends as originally. Smaller shafting, better alignment, more balanced operation of the motors and in general more satisfactory conditions were thus made possible. Each shaft, moreover, was connected on either side with a detachable coupling, so that either half could be run as needed. In certain cases, too, when the use of power was more or less intermittent, individual or unit drive was substituted to advantage, affording ideal flexibility, eliminating loss through driving of superfluous shafts and counter-shafts with attendant belting troubles and losses and obstruction of the overhead space and shutting off all power consumption with the stopping of the machine. Centralized control and practically unlimited ability to vary speeds were further facilities afforded. These advantages, of course, were partially offset by the higher initial cost of installation and lower operational efficiency of the motors. The net decrease in power consumption over the old arrangement, however, exceeded fifty per cent.

Cumulative effects of little wastes in power are much in evidence in textile plants where thousands of high-speed cylinders and spindles are rotating constantly. By minimizing the friction on all these small parts of machines, the total power used may be much reduced.

In one mill, power was wasted by driving the spindles with larger bands than necessary. The bands weighed seventy-five to the pound, while those that weighed one hundred to the pound were found to do as well. Since ten per cent of the power was consumed by the bands alone, it was important that this loss be minimized. The increased power required to drive the larger bands was not due so much to the extra weight, as it was to the increased friction these met in moving through the air.

IMPROVEMENTS IN LINE-SHAFTING MAY MAKE NEW MACHINERY UNNECESSARY

THE possibilities of power saving at machines are equalled by the savings accruing from a reduction of line-shaft losses. What can be done by substituting roller and ball bearings for the ordinary types was brought out in a very interesting way in the discussion of a paper on line shafting before the American Society of Mechanical Engineers:

"A Pennsylvania shoe manufacturer, with an electrically-driven shop,'' related Mr. T. F. Salter, ''found himself compelled to add new equipment in departments where the motors used already were overloaded. He concluded that new and larger motors were necessary, but before taking action, consulted engi-

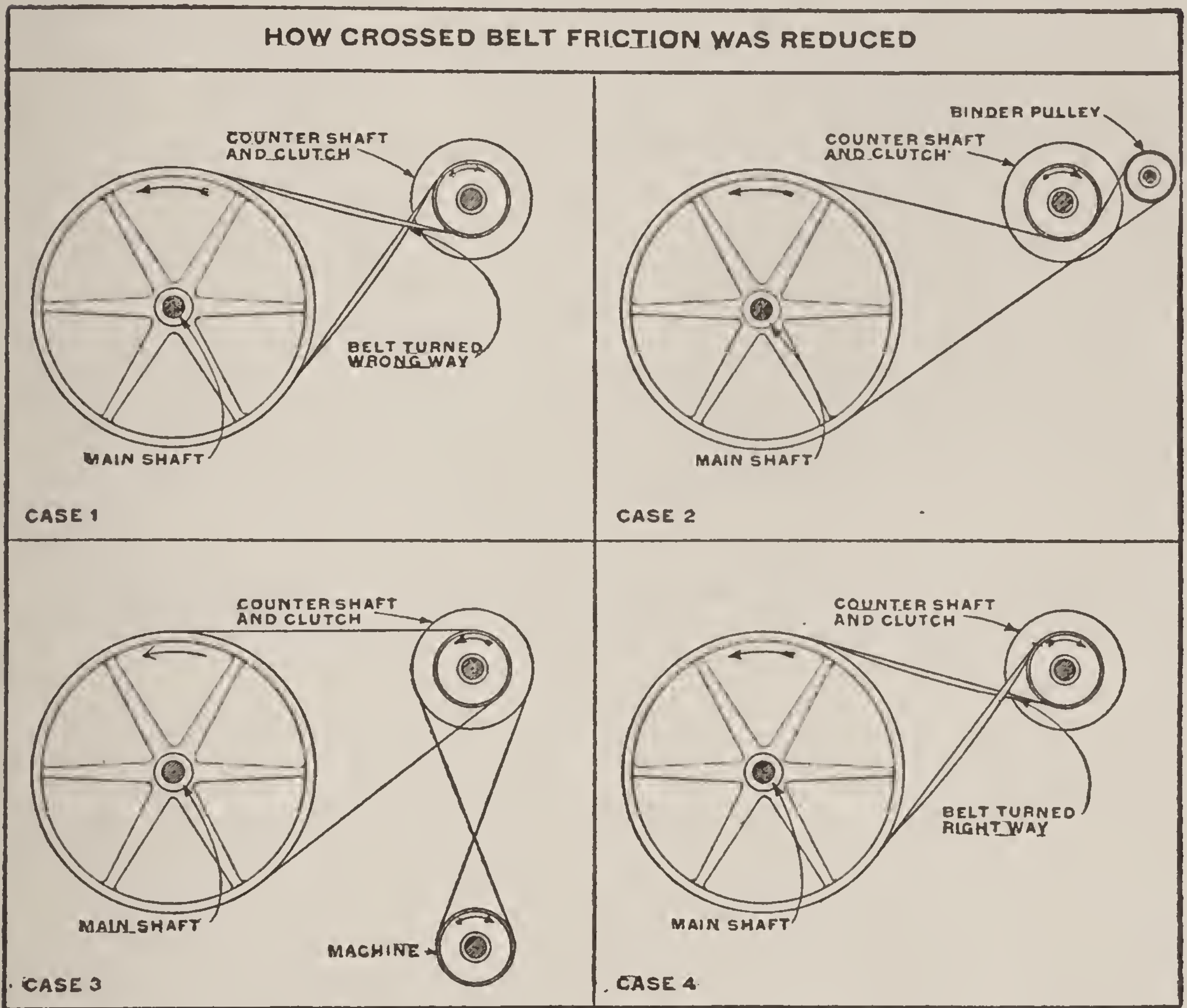
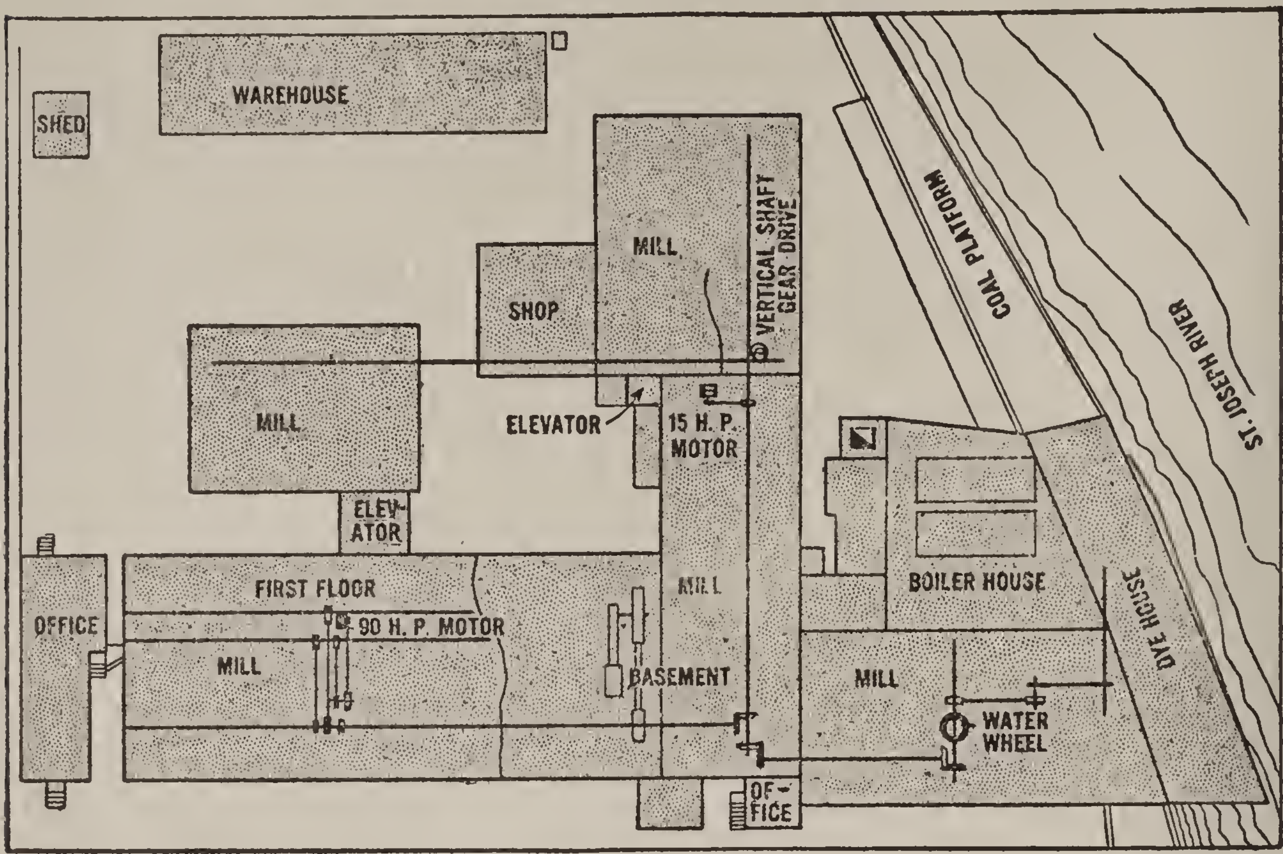


FIGURE XI: In an electrically driven machine shop one-half of the total all-day load was absorbed by crossed belts. Changes in the relation of belts to the driven machines made it possible to save this loss. A wattmeter on the electric circuit was the divining rod for waste in this case

neers. After investigation, these recommended that roller-bearing hanger boxes be purchased and the old motor equipment retained. With babbitted boxes, one department required sixty-eight horsepower. With steel roller-bearing hanger boxes the amount was reduced to fifty horsepower, a saving of eighteen horsepower, or nearly twenty-four and five-tenths per cent. The old motors thus were enabled to drive the new equipment with a small reserve for future additions.

''A Baltimore belting company had a four and seven-sixteenth-inch bearing which gave a great deal of trouble through over-

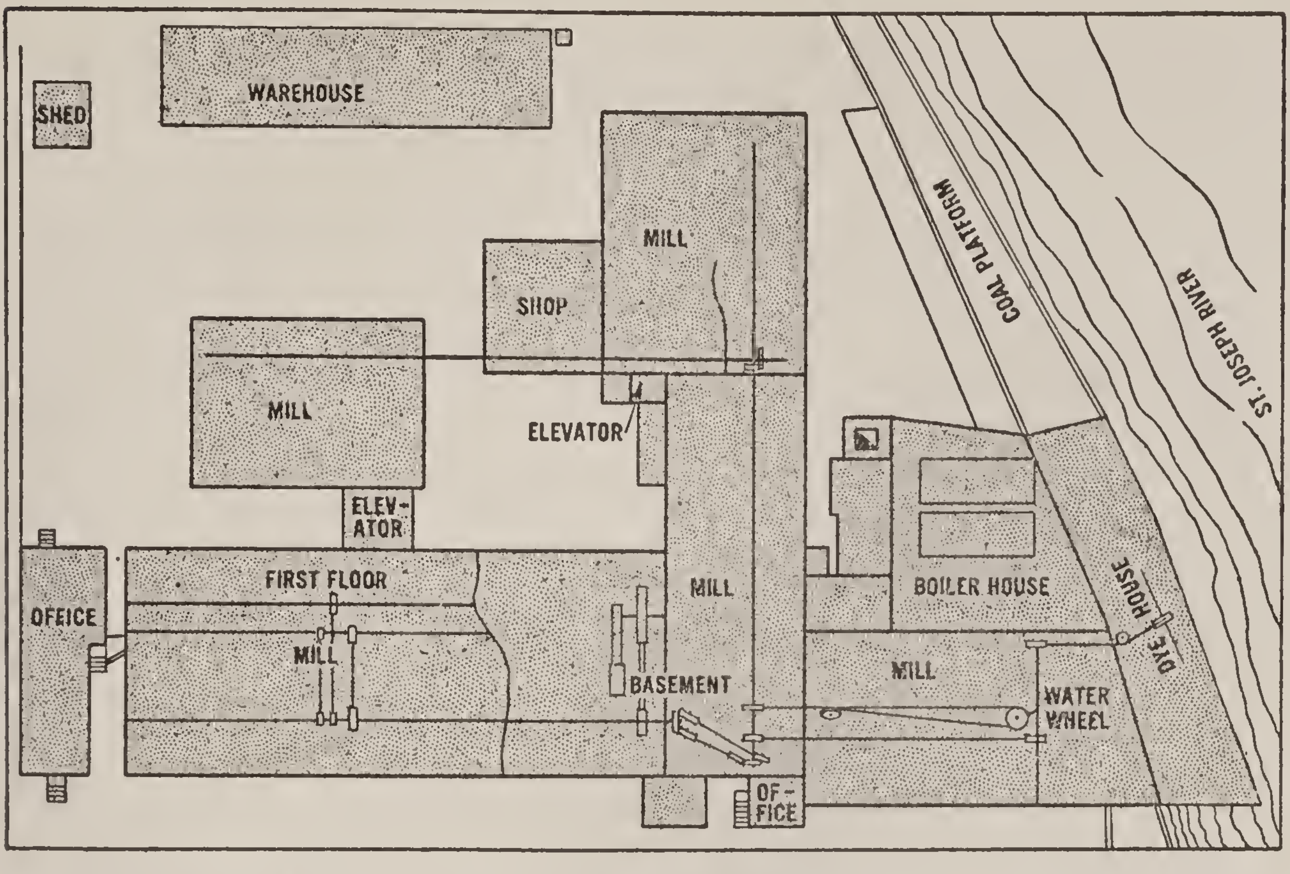


FIGURES XII and XIII: In the Mishawaka Woolen Mills three sources of power were combined—water, steam and electric from outside. This combination proved wasteful and was changed from the arrangement shown above at left to that illustrated at the right. The bevel-gear drives were replaced by a rope drive and other changes made, as the drawings show. Before the changes the

heating. Oil bath and water jackets were tried with some success. Roller bearings, at length, were fitted. So successful did these prove that forty additional units of various sizes were similarly equipped. A wire company in Worcester, Massachusetts, also equipped their entire plant with roller bearings and realized a sixty-five per cent reduction in the friction load."

That simple changes in belts, too, often result in large savings, was made clear by Mr. W. F. Parish, Jr., in the same discussion. An English firm some years ago found themselves with a cotton belt on their hands. Bought for a certain purpose, it had been found unsuited. Finally they decided to try it on one of the main mill drives, heretofore served by a leather belt which, under the damp conditions there, had not been very satisfactory.

As the belt hung low and in a dangerous position, a casing had been built under it. The allowance for sagging proved insufficient and the belt was chafing against the casing continually. The cotton belt proving too short, some of the old leather one was spliced in. Now moisture affects cotton and leather oppositely, and in this instance the net result was a belt of unvarying



water wheel had to be helped out by the steam engine. After, it carried all the load until about 60 horsepower in new machines had been installed, when the help of the engine again was required. The rearrangement saved $300 a month in electric power. Steam is required for other than power purposes, and less than $100 per month for coal is required for power alone

length and therefore constant efficiency. The trouble from sagging ceased and it was never necessary to change the casing. As it was a main drive, the power-saving effected was especially large.

Again, a study of the general conditions of drive frequently reveals chances to save power. Sometimes the remedy lies in a complete readjustment of the method. A belt drive in a saw mill gave trouble. The mill was driven by a six-hundred horsepower engine which ran at eighty revolutions a minute. The drive-pulley was eighteen feet in diameter. From the center of the fly-wheel shaft to the center of the main mill shaft the distance was sixty feet. This drive had been very hard on belts. The company could rarely get a belt that would last more than twelve or fourteen months and give good service.

Finally it was decided to substitute a rope drive. To make this change the pulley had to be fitted with a hardwood lagging, which was grooved to take eighteen inch-and-a-quarter ropes. With the lagging the pulley diameter was increased to nineteen feet. To receive the rope at the other end, an iron sheath sixty-one inches in diameter was placed on the main shaft. Under the very severe conditions imposed upon the drive in this instance, the rope proved extremely effective.

WHERE ROPE DRIVES CAN BE USED TO BETTER ADVANTAGE THAN BELTS, CHAINS, OR GEARS

ROPE drives often present opportunities for better service in difficult situations, if not for evident money savings. When the drive is very long or very short, ropes are superior to belts and approached in efficiency only by motors in the one case and by chains or gears in the other. For vertical drives, for transmitting power around corners, and for situations exposed to the weather, they are superior to belts. Then, too, they are easier on bearings, take up less width, are simpler to repair or replace, and are almost wholly free from slippage. Hence they deliver a

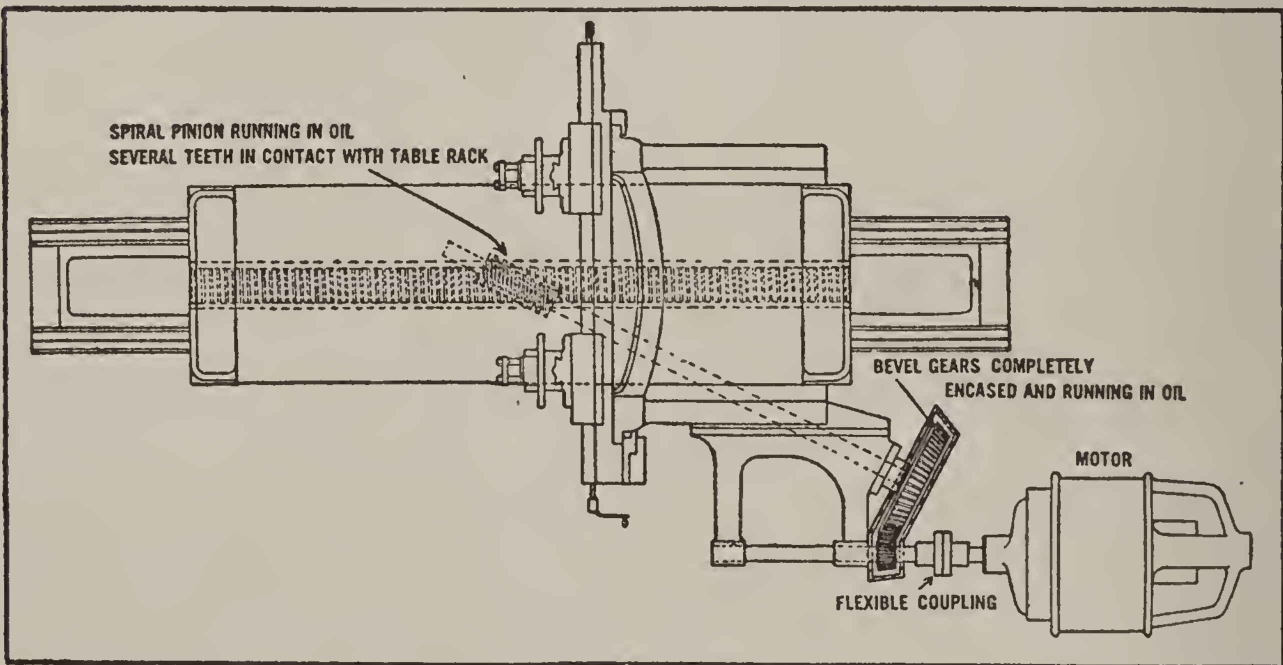
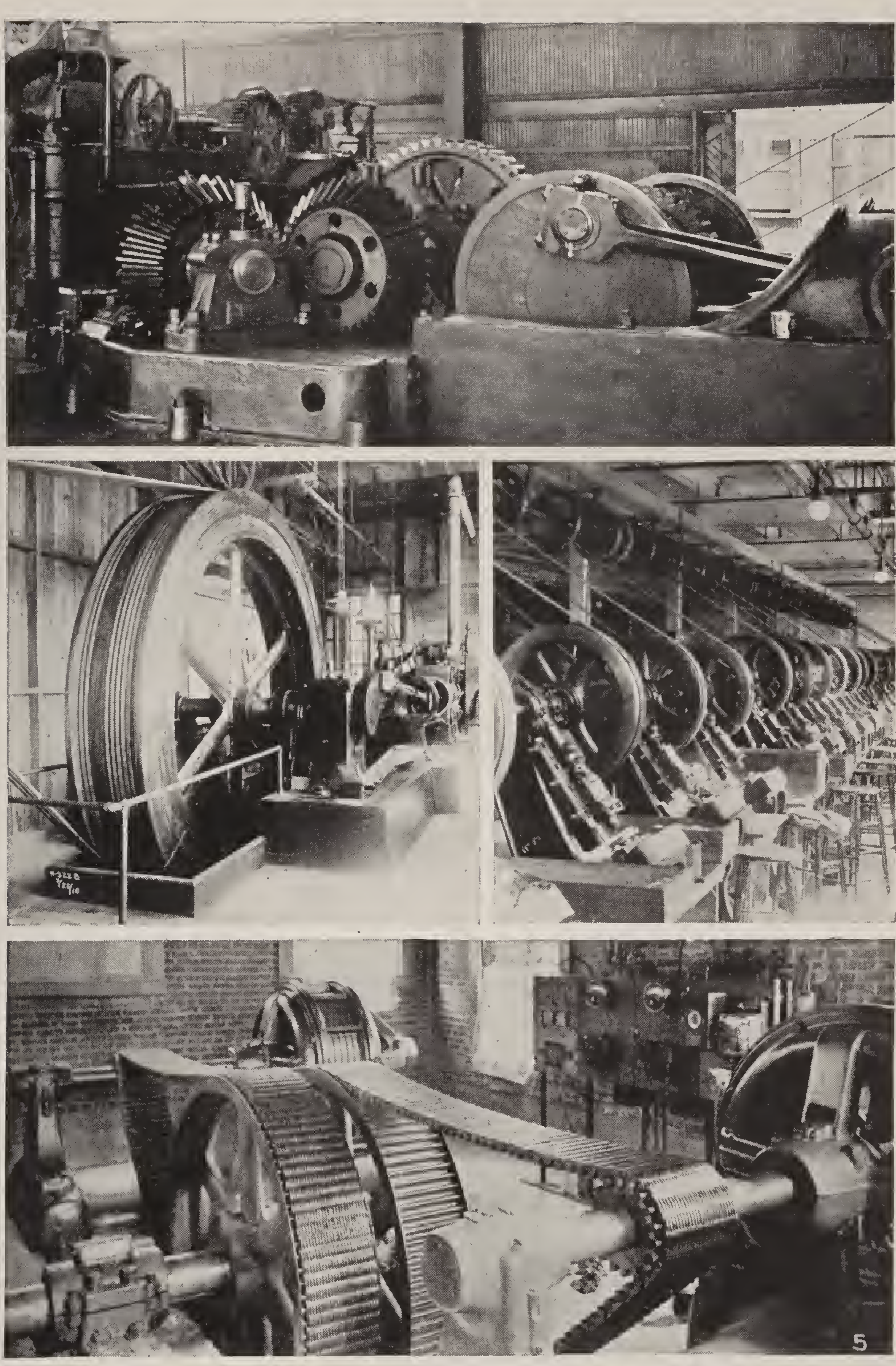


FIGURE XIV: Special gears often meet specific needs. A smooth motion is given to this plane bed by the semi-rolling, semi-sliding action of a spiral pinion

larger percentage of the horsepower. Moreover, unlike leather belts, they do not generate static electricity. (See Figures XII and XIII.)

From this it is not to be taken that leather belts, the good old standby, are a back number. On the contrary, for many purposes of drive they are unexcelled, if properly proportioned and installed, and maintained with care.



The four principal types of power transmission, each uniquely efficient in its place—engine driving steel rolls through gears in Schwen Works of Carnegie Steel Company (above); main rope drive in a sawmill, run on wood waste (left); belt-driven punch presses at the E. W. Bliss Company (right); and two 250-horsepower chain-belt drives at the Converse Rubber Company (below)

Types of motor drive are here shown. Machines above are individually motor driven. In shoe and garment factories, group motor drive is the practice (left, arrow indicates chain-belt connection). Group motor drive, overhead (right) is often preferred for floor machines. A combination of the two (below) shows the larger machines individually driven and smaller ones group driven

To get satisfactory service from leather belts, only the best parts of the best oak-tanned hides should be purchased. Narrow, thick belts pull better and are longer-lived than wide, thin ones. Proper tension and speed are very important. The speed for maximum economy should be between 4,000 and 4,500 feet a

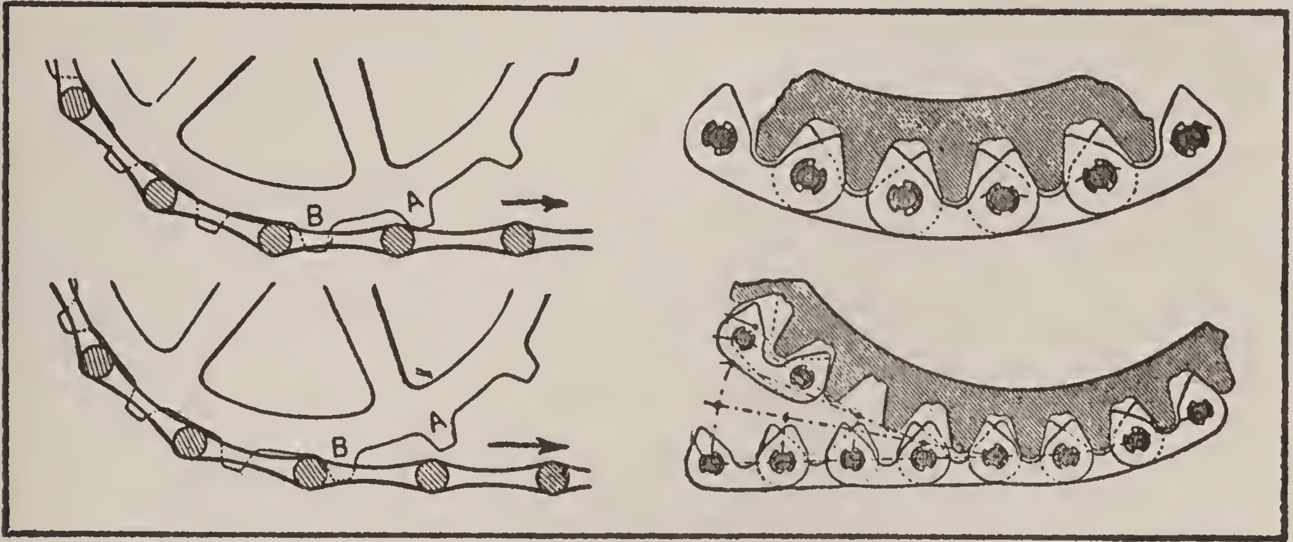


FIGURE XV: Why worn and stretched chains jerk under the strain of transmission is shown by the diagram at the left. When the chain link leaves tooth A the next one jumps to B. In the diagram at the right is shown a type of chain largely without this fault

minute, according to one authority. For main drives it can be even higher than this. The facing of the pulleys is also important. Tests made on a pony planer in a Chicago planing mill, before and after covering the iron pulleys, resulted in a reduction, on one operation, of from seventeen to eleven-and-a-quarter seconds, or a saving of over thirty per cent. Cast iron and wood facings are inferior to paper. Canvas is still better, while a leather facing gives the maximum friction and hence the fullest delivery of power. Belting compounds are a makeshift remedy and unneeded if the pulleys are right, the belts maintained at proper tension and run at the best speed.

Conditions of drive, however, are found which make belts and ropes unsuitable, if not impracticable. Chains and gears here find their special application. Short centers with these are no obstacle. Gears, moreover, make possible an absolute speed ratio, should this be necessary. Gears formerly were objectionable because of the vibration and noise they gave out on wearing. The development of rawhide and cloth pinions, however, has eliminated this trouble to a large extent. Special types of gearing, too, have been brought out which engage in such a way as to minimize slippage and lessen wear. Means of easy adjustment to take up wear, and running in oil baths have further increased the desirability of such drives (Figure XIV). Good gearings show an efficiency of ninety-two to ninety-six per cent. This cannot be approached by belts or ropes. But the efficiency falls off rapidly once the gears begin to cut. Hence, except where a constant ratio of speed must be maintained, gears are apt to prove less satisfactory than the modern chain drives.

The earliest chain drives utilized the ordinary chain fitted over a specially shaped sprocket. They were necessarily limited to slow speeds and their efficiency was low; still for certain purposes they gave good satisfaction. A step forward was the ordinary block, or bicycle chain. This was further improved by substituting rollers for the blocks. The wear and tear on both the rollers and the sprockets, however, is severe and the chain tends to lengthen under heavy load and become jerky and noisy.

By using better material for both sprockets and chains and by submerging in oil, many of these troubles were alleviated. But the most pronounced step forward was taken when teeth were provided on the chain itself, to interlock and mesh with the sprocket teeth all around. These distribute the strain and thus reduce the wear and tear (Figure XV).

Among other items to be watched in the campaign for transmitting power with less loss, are the arrangement and grouping of machines to reduce to a minimum the number of counter-shafts and belts required; the proper speeding of machines; the use of good lubricants and timely and regular application of these to all running parts; the avoidance of heavy end-drives on shafts, which cause severe tortional strains and render difficult the maintenance of perfect alignment of shafting; and the replacement of pulleys which are too small and which therefore, to prevent slipping, require belts so tight that they occasion undue strain on the bearings and shafting.

Part II

MACHINERY AND TOOLS

AUTHORITIES AND SOURCES

FOR PART II

Chapter VI. Based on studies made in the plants of the Kohler Company, Cowan Furniture Company, Cincinnati Milling Machine Company, National Acme Company, Hart-Parr Company, Western Electric Company, General Electric Company, Hays Manufacturing Company, a Michigan motor car company, a New England textile mill, and others.

Chapter VII. Contributed chiefly by J. A. Furer, Naval Constructor, U. S. N. Supplemented by material based on studies by Mr. Porter of methods practiced in the Ford Motor Company, Cincinnati Milling Machine Company, National Acme Company, Jones and Lamson Machine Company, Rochester Railway Signal and Switch Company, United States Steel Corporation, and several other machine tool companies.

Chapter VIII. Developed from studies made in the plants of the Ford Motor Company, Hart-Parr Company, Thomas B. Jeffrey Company, Niles-Bement-Pond Company, Root & Vandervoort Company, Rand McNally Company, United Shoe Machinery Company, and others.

Chapter IX. Based on studies of the investigations made by Carl Barth and Harrington Emerson. Material was also obtained at the plants of the Westinghouse Electric & Manufacturing Company, Kohler Company, Thomas B. Jeffrey Company, Cleveland Automatic Machine Company, Western Electric Company, Packard Motor Company, Taft-Pierce Company, and Brown Hoisting Machinery Company.

Chapter X. Developed from studies made at the Kohler Company, Tabor Manufacturing Company, Bethlehem Steel Works, Link-Belt Company, Nonotuck Silk Company and of methods followed by Frederick W. Taylor.

Chapter XI. Written in collaboration with Mr. Thomas, and from methods practiced by the Rathbone, Sard and Company, Seymour Manufacturing Company, Waltham Watch Company, Western Electric Company, William Jessop & Sons Company, England; H. Black & Company, Postum Cereal Company, Kohler Company, a Michigan chair manufacturer, and others.

Chapter XII. Written from material supplied by J. A. Furer, presenting methods followed by Frederick W. Taylor, Tabor Manufacturing Company, American Blower Company, New York Edison Company, Douglas Shoe Company, and others.

VI

HOW TO PLAN EQUIPMENT CHANGES

GREATER output from the same floor space is achieved in two ways chiefly: by utilizing present equipment more intensely, and by replacing hand labor with machines. In the early years of any industry, progress is measured largely by the development of labor-saving devices. Eventually the time comes when to many no further progress in this respect seems possible. Then attention shifts to better layout and arrangement, to higher speeds and more efficient cutting tools, to saving time between and eliminating delays at machines. Of course, much of this involves improvements of a labor-saving nature—the substitution of cranes and hoists, conveyors and chutes for hand lifting and trucks; of push button and pedal control for laborious hand-actuated levers; of magnetic and air chucks for the old kind, and so on. But the emphasis is not on the development of new devices.

Then the pendulum swings the other way again, and the straight substitution of machines for hand work and the replacement of semi-automatic machines by more completely automatic types again get attention. This alternation seems to be the natural course of industrial development.

How improvements come is well illustrated by what has taken place in the simple art of coating articles of wood and metal with a protective or decorative film. Paint was probably applied originally with the hand or a stick. A great step forward was taken when the brush was invented, and for centuries a brush continued to be the only aid to applying liquid coatings. Then someone conceived the idea of applying the paint by dipping.

Not only were time and labor economized, but a more uniform covering with less waste of material secured as well. At first, articles were dipped singly by hand. But presently mechanical aids were contrived by which articles could be dipped automatically in quick succession or dipped in lots. This process has its limitations, one of which is that only articles which require coating all over lend themselves readily to it. So for many purposes, hand brushing still continued to hold sway. Then the air brush was invented. This replaced almost immediately the dipping process for many purposes, and made hand brushing practically obsolete.

Paint, varnish, enamel, even cement and metal coatings are now applied by this method. Not only is the labor-saving great, but a superior quality of work is possible. The spraying devices are still used largely as hand tools and for many purposes probably will continue to be so employed; but already attention is being directed to the possibility of automatic handling of work before gangs of spraying nozzles, much as castings are now cleaned in an automatic sandblast chamber. Then the proportion of direct labor will be still further reduced and the workman made still more a controller and director of mechanism and less an artisan.

Progress, in fact, lies strictly along this line. As wages rise—and they rise as human wants multiply—hand labor becomes increasingly expensive. Then, too, as industries grow in size and complexity, hand labor becomes more and more difficult to control. Moreover, as the intelligence of factory workers increases, they become less contented and physically less able to do heavy and monotonous labor. Competition, on the other hand, and the desire for large output operate to keep prices down. All these forces combine to place a sharp premium on the continual development of new labor-saving devices.

Some manufacturers naturally take the initiative in bringing out equipment improvements; others are open-minded and are prompt to fall in line once the demonstration has been made; while a large class succumb to changes only when competition leaves them no alternative. Few deliberately organize their plants for mechanical development.

Upon the manufacturer-user obviously it devolves to take the lead in the improvement of machinery and the development of new labor-saving devices. Special equipment he must always design, and build very largely himself. How far he can adapt standard machines—which are designed to fit the average need—depends upon the peculiarities of his business. If he wishes a standard product modified to suit his conditions he must bring pressure to bear on the builder. For departures from standard are costly, and machine builders out of self-protection naturally incline to discourage them. There are conspicuous exceptions to this rule—builders who gladly couple their genius with the user's necessity in bringing out new inventions, and who are constantly making structural improvements to keep ahead of competition. But the initiatory impulse for

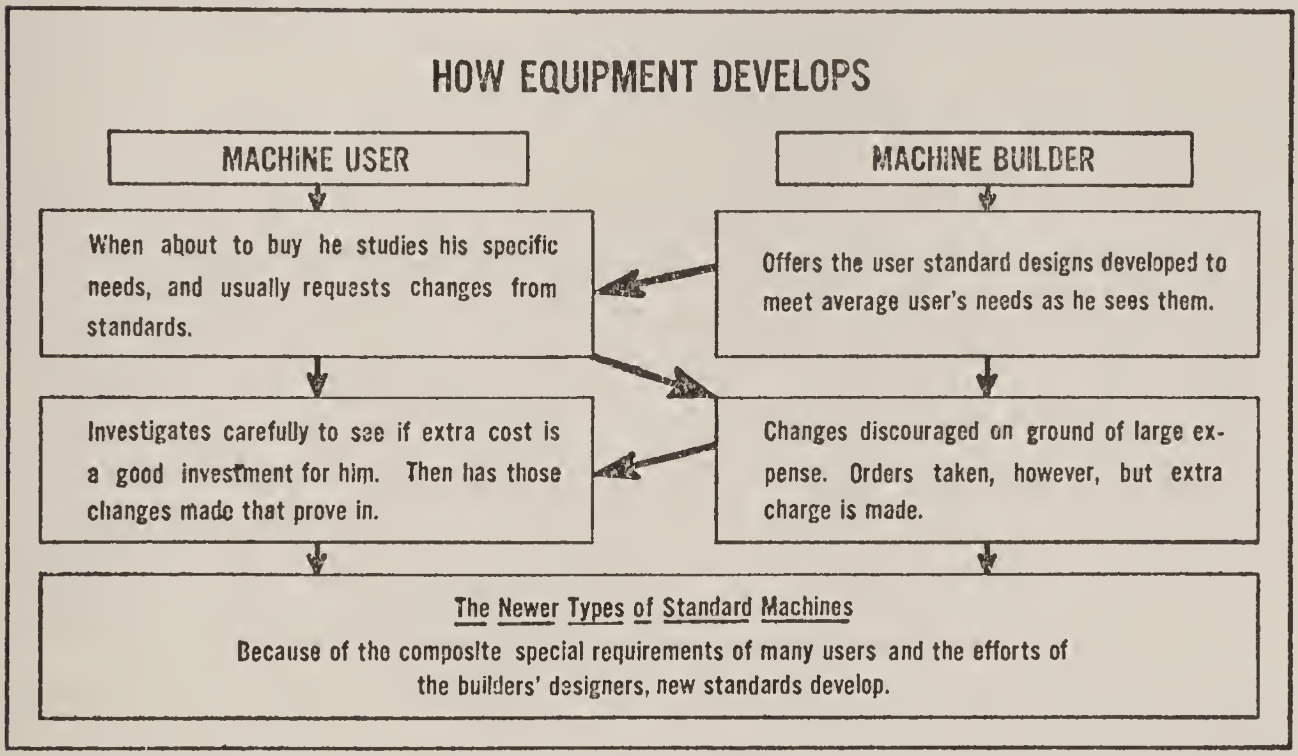


FIGURE XVI: How the special machine of today, born of some user's need, becomes through the builder's cooperation the standard machine of tomorrow, is here charted. Because standard types must reflect the average requirements, it devolves upon the user to lead in developing improvements

changes must in general come from some user. If an invention meets a widespread need, vigorous exploitation follows until the new device is accepted as a matter of course and all plants use it or an equivalent. The user who is last to fall into line, as a rule, benefits the least. For generally by this time the more progressive manufacturers have developed something still better (Figure XVI).

A large motor-car plant was reorganized several years ago.

One of the principal reasons disclosed for its inefficiency was that much of the machinery was old-fashioned and many operations were still being done by hand or on semi-automatic machines which elsewhere were being performed by machinery or on fully automatic types. Accordingly the reorganizers established a department of mechanical betterment whose task it henceforth became, not only to devise new and better tools, but to keep posted on the latest developments outside and to make periodic recommendations for the purchase of new equipment.

Every factory, if it has not already done so, needs to take a similar step. Only the largest plants, perhaps, can afford the expense of maintaining a regular department for this purpose. But the smallest shop can delegate some one man—a foreman or a high class mechanic—to have this in his charge. Medium-sized establishments can well afford to retain a mechanical engineer who has nothing else to do but study the equipment problem. An ironware plant employing eight hundred to a thousand men, and a garment factory employing about the same number are two that follow this plan, and both have found it extremely profitable. Large concerns like the General Electric, Westinghouse Electric and Manufacturing, Western Electric, and the United States Steel Corporation, maintain large experimental and research laboratories for the express purpose of keeping their plants ahead mechanically.

TAPPING VARIOUS SOURCES OF NEW IDEAS FOR DEVELOPING MACHINERY

NO one man or organization, of course, can think of everything first. Besides its original research work, every plant needs to keep definitely in touch with developments elsewhere. With this in mind, one manager consistently cultivates the good will of visiting salesmen, whether he is in the market for their wares or not. "I have found them mines of information, and some of the tips I have thus secured have been extremely valuable," he says. A large Milwaukee concern has its secretary, a ten-thousand-dollar man, make it a point to see every new salesman, and has likewise gained many benefits. On the other hand, many owners are like the Chicago furniture man, who, when he was approached by an air-brush salesman, ordered him out of the place, declaring it preposterous that varnish could be sprayed on. But his next superintendent installed the equipment unsolicited and it proved its worth by saving four two-and-a-half-dollar painters. So the thing that can't be done in the way of new equipment, somebody is usually doing.

Another source of mechanical progress often neglected is the shop itself. High-priced engineers are not the only ones who can conceive new labor-saving schemes. Sometimes opportunities which totally escape the eyes of the chief and his experts are seen quite naturally by the workers. A New England textile mill for years had been using a bellows as the quickest and most economical way to clean off the woolly lint that collects on the strings of spinning frames. The superintendent happened to notice that one of the operatives, a comparatively green hand, was regularly cleaning up in half the time of the rest. Curious, he watched her and found that she was using a piece of felt wrapped about a bit of stick. She inserted this under the strings and in a few quick strokes deftly removed the accumulation of lint. Taking his cue, he had felt cleaners made for the entire room.

Suggestion systems often bring out time and labor-saving devices. When the workers feel that their brains are valued as well as their labor they usually can be depended on to do their part in originating improvements.

Because many of the suggestions made by shop men are impracticable or impossible from the cost viewpoint, and because to turn down suggestions offered with the best of intentions is a delicate matter, some plants, however, have discarded the suggestion system. Instead, Mr. Hart, of the Hart-Parr Company, for example, picked a young man of a practical turn of mind from his drafting force, and providing him with a sketch pad, sent him out into the factory to "dig up" ideas. This young man has nothing to do but to "browse around" and talk with the foremen and workers, learning their problems and getting their ideas for improvements. Then he retires to an out-of-the-way corner and works up rough sketches. These Mr. Hart himself inspects; if he finds them workable he turns them over to the drafting room to develop.

An effective way also of enlisting the inventive cooperation of the shop is, if piece rate largely is the vogue, to allow any man who originates an attachment, device or method which saves labor and cuts the time of an operation, to retain, for a period of perhaps one year, the benefit in increased earnings thereby made possible. This plan where tried has proved most effective. Moreover, it helps to solve the problem of rate adjustment, for then the men clearly understand that when an improvement is made the rate is due for a change in accordance. Furthermore, it does much to allay their opposition to new devices.

Occasional trips to other factories—in other lines as well as your own, for equipment ideas are interchangeable and the woodworker can often learn more from a metal man than he can from another in his own line—attendance at the meetings of manufacturers and engineering associations, the systematic reading of government and technical society publications, of trade and management journals—all these, too, are indispensable for the man who would keep up on equipment problems and the progress in science and invention.

HOW TO TELL WHETHER AN IMPROVEMENT IS JUSTIFIABLE OR NOT

"BUT it costs money to be making changes and additions to our equipment continually," say some managers. "We wish sometimes that improvements would cease for a period, so that we could get our money's worth out of what we have."

Whether a new piece of equipment is justifiable or not is capable of fairly certain mathematical proof. To save the labor of a dollar-and-a-half man you can afford to lay out three thousand dollars. Four hundred and fifty dollars, the wages of a dollar-and-a-half man, on the basis of three hundred working days in the year, is the interest at fifteen per cent on three thousand dollars; and fifteen per cent will, in the ordinary case, easily cover the capital charges on an investment in equipment. This is assuming that there are not other economies. But it is a poor machine which in addition to saving the labor of one man does not afford output capacity considerably more than equivalent. A machine, besides, is ready to do service twenty-four hours a day three hundred and sixty-five days in the year, if necessary, at little additional expense. When all the savings are weighed it is easy to decide whether to invest or not.

An ultra-conservative board of directors sometimes stalls the introduction of meritorious labor-saving devices, of the wisdom of which the manager himself is fully convinced. So resolutely do some boards set their minds against spending money which adds to the capital investment, that it frequently is easier to get an appropriation of five thousand dollars for repairs than five hundred dollars for a new machine, as many factory men can testify. If, however, the manager will take pains to arm himself with the proper figures and has any knack of presentation, he usually can win his point. A good plan is to induce the directors to appropriate a certain sum annually for improvement purposes. Spent wisely, even a small sum of money will enable the astute executive to do wonders. An ample depreciation reserve also is a source of help, for many times the improvement can easily and justly be construed as a replacement.

An obdurate labor situation often is the reason for an unprogressive equipment policy. "We can't install new machines because the men wouldn't have it," say the owners. Yet labor has always opposed the advent of labor-saving devices and if manufacturers in the past had not had the courage and the tact to overcome such opposition, we still would be in the handicraft stage of industry. How some managers secure the cooperation of the workers in this respect is told elsewhere in these pages. The story of the introduction of the Northrup automatic loom also is full of suggestion.

Northrup was an Englishman. Meeting no encouragement in his own country, he came to the United States. He was successful in persuading several mill owners to try his machine. One after another failed and threw the new loom aside, chiefly because of their inability to deal with labor opposition.

Finally the heads of a concern which had a special equipment man decided that the Northrup invention was the coming machine. So great was their belief in it that they changed over their entire spinning department. But they said absolutely nothing to the men about operating more looms each. After the men had become accustomed to the new machines, the superintendent picked out a certain operator, over whom he had influence, and said: "Jean (the man was a French-Canadian), I believe you can run twelve of these looms just as easily as you can run six. I want you to try." He slipped him a twenty-dollar note and continued: "If you don't do it, why the sooner you pack up and put yourself on the other side of the border, the better for you."

Jean, needless to state, made good. The same process was repeated with other operatives and soon the entire room was on the new basis. Each man, of course, was given a substantial raise in pay. The bonus was unnecessary after the first few cases, for when the men learned that they were to get more pay and that to operate the additional machines really did not work them any harder than formerly, they actually asked to be changed. Opposition was allayed, too, by giving the displaced hands good jobs elsewhere in the mill. Good operators eventually came to run as many as twenty of these looms.

Similar stories attach to the introduction of many noteworthy labor-saving devices. Consequently, when you hear a manufacturer say: "I can't, because my men won't stand for it," put it down as an indictment of his ability to manage.

On the other hand, a manufacturer in his enthusiasm over labor-saving devices, may err by adopting an innovation on immature consideration. A Wisconsin maker of plumbing fixtures, for instance, invested one hundred thousand dollars in a sand-handling equipment to facilitate molding. A fifty per cent labor economy was indicated at the very least. But when the interest on investment, the depreciation charges and repairs were considered, this saving was more than wiped out. It was shown that the new equipment would not prove its worth until the foundry was put on a two or three-shift basis.

VII

GETTING THE RIGHT MACHINE

MANUFACTURERS who pay good money for machines that do not exactly fit their production needs have, so to speak, bought shoes that pinch. The problem in either case is to tell beforehand whether the purchase will fit.

A large number of misfit machines are sold and installed in shops every year, partly due to the ignorance of the buyer as to just what he should have and can get by perseverance, and partly due to the ignorance and indifference of the machine builder as to the purchaser's needs.

That the buyer should know just what he needs before he goes into the market for a new tool is self-evident. The natural comment will be, "Of course, the buyer knows what he needs, otherwise he would not be in the market." A buyer may know, for instance, that he needs a machine to punch fifteen-sixteenth inch holes through five-eighth inch plates. Perhaps he even has a more or less definite idea as to the depth of throat which is called for by most of his work. The chances are, however, that he will not be within twelve inches of the most suitable depth. It is probable, also, that only a small proportion of the plates which he proposes to punch, are as thick as five-eighths inch. Many times, too, he may not know what kind of lubrication he ought to have for the machine, what operating mechanism is best, whether the height of the die-block is of particular importance, what speed is most desirable, whether the nature of his work makes a variable speed desirable, and many other points which can be more or less definitely prescribed if the buyer has investigated his own needs with sufficient care.

If a machine is to be used only intermittently, it may pay to invite bids on the simplest possible specification, so as to obtain prices from all manufacturers who make a standard machine that approximates your requirements. If, however, it is to be used day in and day out on reasonably similar operations, the buyer who does not insist on getting a machine that exactly fits his requirements is buying a shoe that will pinch his foot.

Just one road exists to exact knowledge of a shop's requirements in machine equipment—that is, the most painstaking analysis of conditions in each case. The manager who thinks that he can find out in ten minutes whether the additional equipment for the forge shop should be a twelve-hundred or an eighteen-hundred-pound hammer, will either suffer a disappointment or get deceptive information.

He can arrive at suitable characteristics for the machines which he contemplates buying, only after a very careful study of his needs. Machines of standard design, such as are commonly catalogued by builders, usually will not in all respects fill the requirements so ascertained. When requests for alterations from standard designs are discouraged by the machine builder, on the ground of the extra cost, the purchaser who has made a thorough investigation can quickly say whether or not the extra cost will be a good investment. Having a sound basis of this kind to work on, he can always find manufacturers of machines who will make changes in designs to suit his needs, at a small additional charge.

RIGHT AND WRONG METHODS IN SELECTING NEW EQUIPMENT

MANY manufacturers, however, when they are in the market for a new machine, go at it very much like this eastern manager. Without knowing save in a general way what he needed, he made up a list of builders of equipment and to each of these he sent a somewhat hazy description of his requirements and asked for prices. In the course of a few days he received replies from the greater part. A number said, "We are sending our engineer to call on you." But the majority answered, particularly the concerns at a distance, "We have referred your inquiry to Messrs. Blank and Blank, our local representatives, who will call upon you at their earliest convenience.'' Few responded with definite specifications, accom-

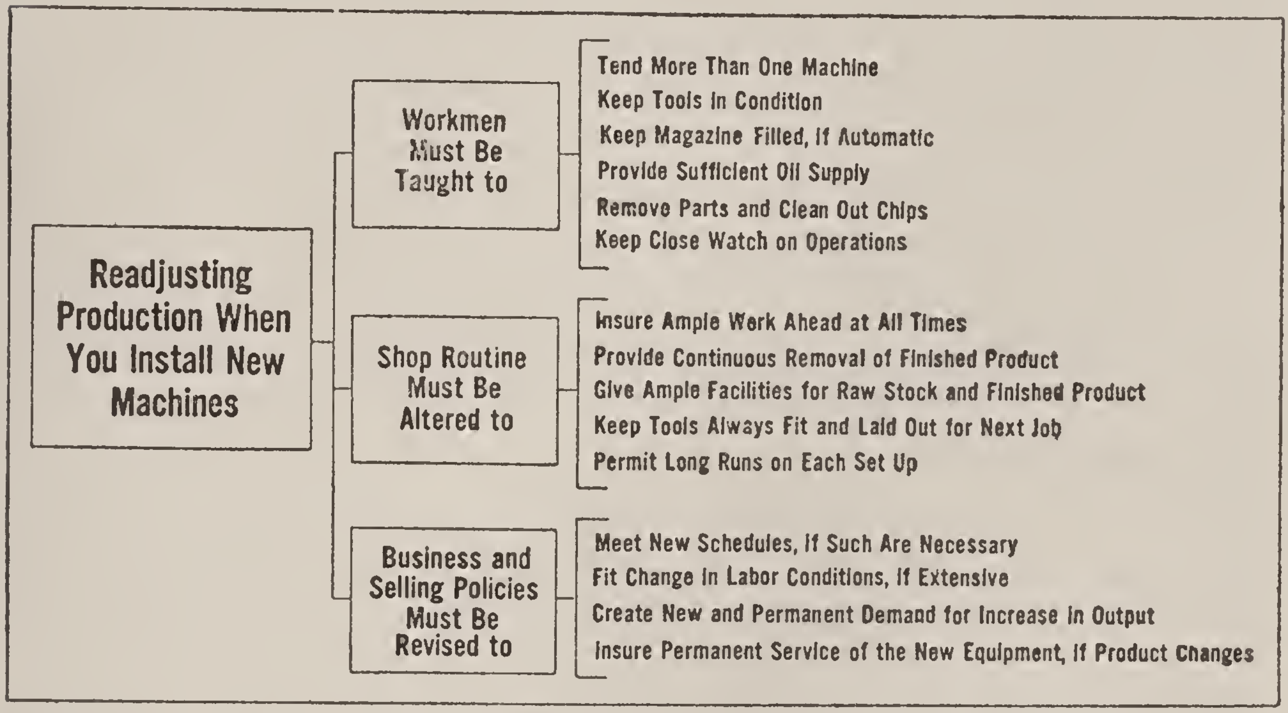


FIGURE XVII: New machines, especially automatics, force a complete readjustment in the enterprise. For successful operation, workmen's habits, shop routine and business policies must be altered to suit. These changes the manufacturer should thoroughly appreciate in advance. Even wage payment must be especially adapted to get best results

panied by a well-illustrated description, precise quotations, and a promise of delivery.

The various local agents, most of them, represented several concerns in different lines and were thoroughly conversant with none. Consequently, when they called they were unable to go into the details. One of the concerns at length, however, sent an engineer-salesman who was really qualified. He sized up the manufacturer's needs in a hurry, got down to essentials in short order, and landed the business. But it was nearly two months before negotiations were brought to a definite head.

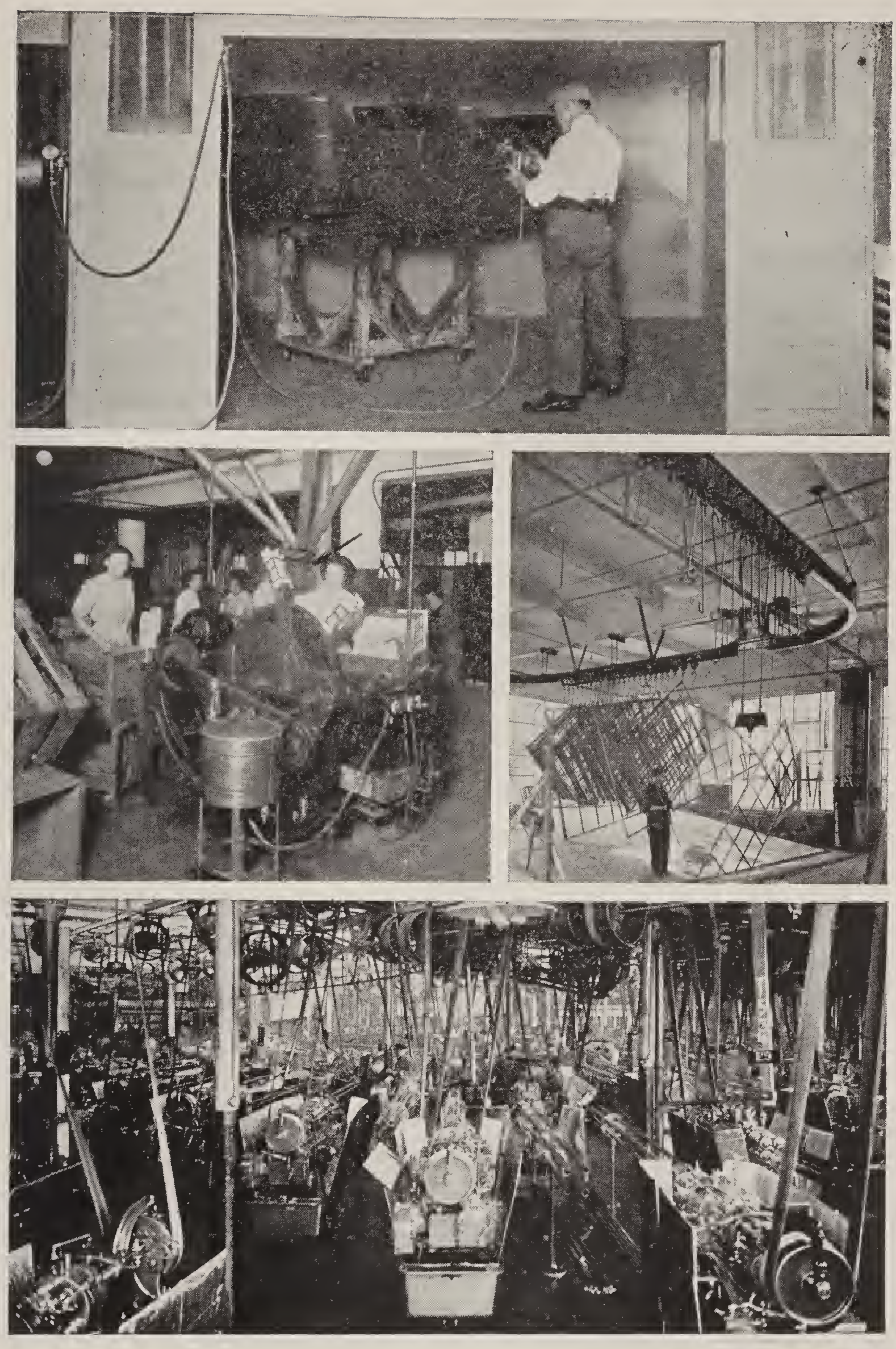
This experience is almost typical—except that the engineer-salesman who can decide the manufacturer's problem for him, doesn't always happen on the scene. It is a case usually of groping in the dark.

Suppose, on the other hand, that the manufacturer is approached by the representative of a progressive builder who endeavors to persuade him of the advantages of his particular make of machine. Or perhaps the manufacturer learns that a competitor, who is pushing him hard, is producing at less cost or turning out a superior quality of article because of the possession of a new type of machine. Naturally, if the money-saving possibilities are big, he will incline to see only the advantages and perhaps buy hastily or start building special equipment to equal his trade rival in efficiency. If he acts precipitately in the matter, the chances are excellent that he will likewise be disappointed. A painstaking analysis of conditions in the shop and an appreciation of all the factors involved are even more necessary in this case than when the need for special equipment originates with the user. New equipment spells new opportunities—sometimes; but it also often means confusion unless the routine of the shop is, or can be altered to suit the requirements for best operation of the new apparatus, particularly automatic machinery. It sets the pace and shop methods and business policies must be altered to suit (Figure XVII).

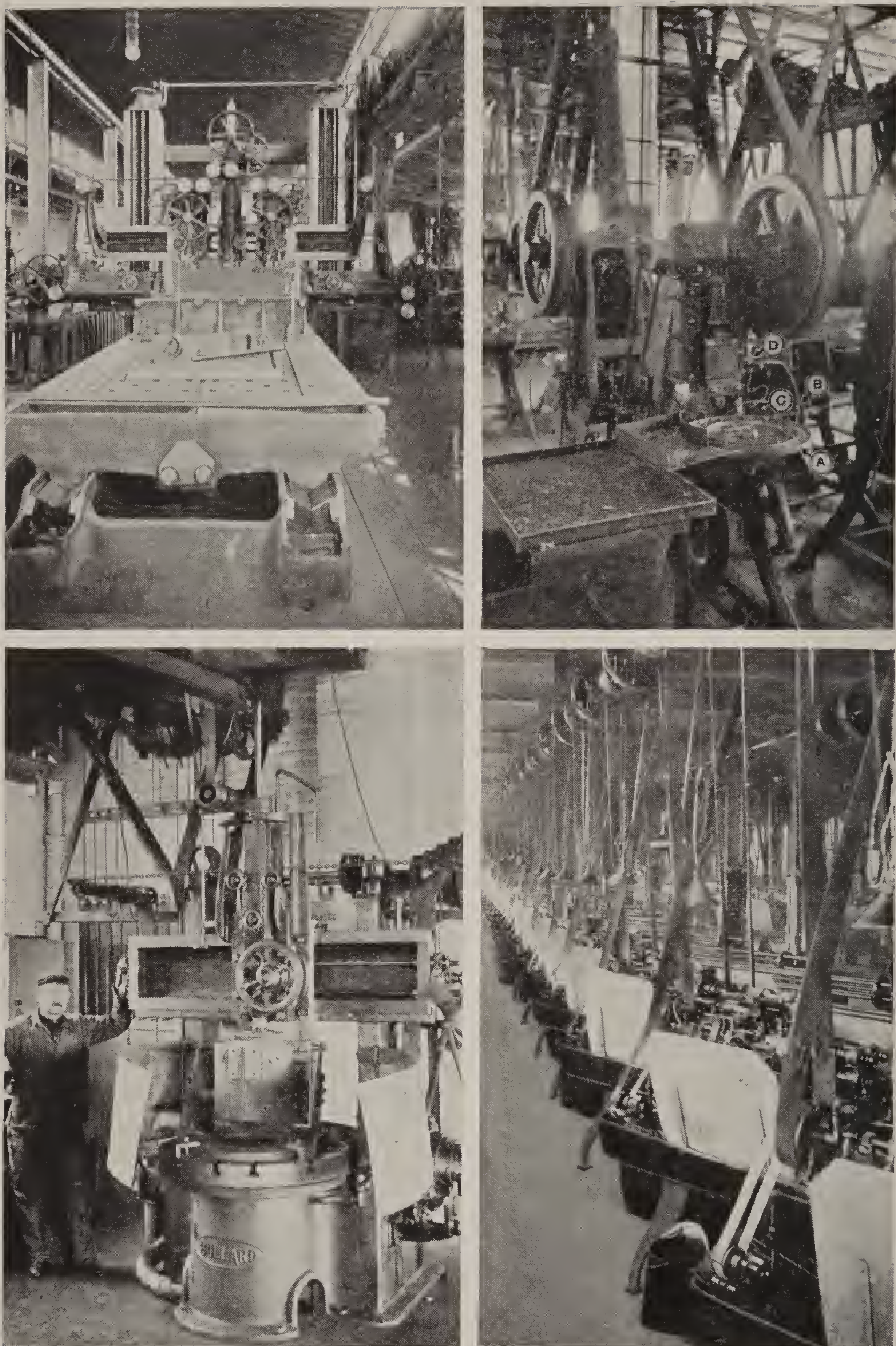
HOW AUTOMATIC MACHINERY DISTURBS TRADITIONAL SHOP POLICIES

A MANUFACTURER was led to install a battery of costly automatic machines. Choice had narrowed down to two types, one combining more refinements than the other. In consideration of the one promising a reduction in labor costs of over ninety per cent as against some seventy-odd for the other, it was selected. First costs of the two types were about equal. However, in order to realize the economy of the new machines, it was found necessary greatly to increase the size of lots and this affected the amount of space necessary for finished-parts storage. To be exact, three times the storeroom space was required. When the expense of this was weighed in the balance, the net saving was small. The type, moreover, because a highly specialized design, proved exceedingly inflexible, lending itself to a variety of work only with great difficulty. To cap the climax, the particular work for which these machines were bought, ceased after a year or two, owing to a radical change in the demands of the trade, and the stockroom was left loaded with many thousands of dollars' worth of useless parts.

Highly specialized and automatic equipment is a product to



The airbrush for spraying on liquid coatings (top) has replaced handbrushing for many purposes, while for painting articles like steel window sash (right), dipping economizes labor still further. Pneumatic weighing devices make automatic carton-filling machinery (left) effective. Automatic screw machines for producing small parts in quantity (below) enable one man to operate many machines



Equipment fitted to the business—home-built planer-bed, rotary milling machine (upper left), punch press with horizontal dial safety-feed (A), compressed-air ejection device (B, C), valve automatically controlled (D), vertical boring mill with grinding fixture (lower left). Using his own make of automatics to turn out product (lower right) gives the builder a test of design and workmanship

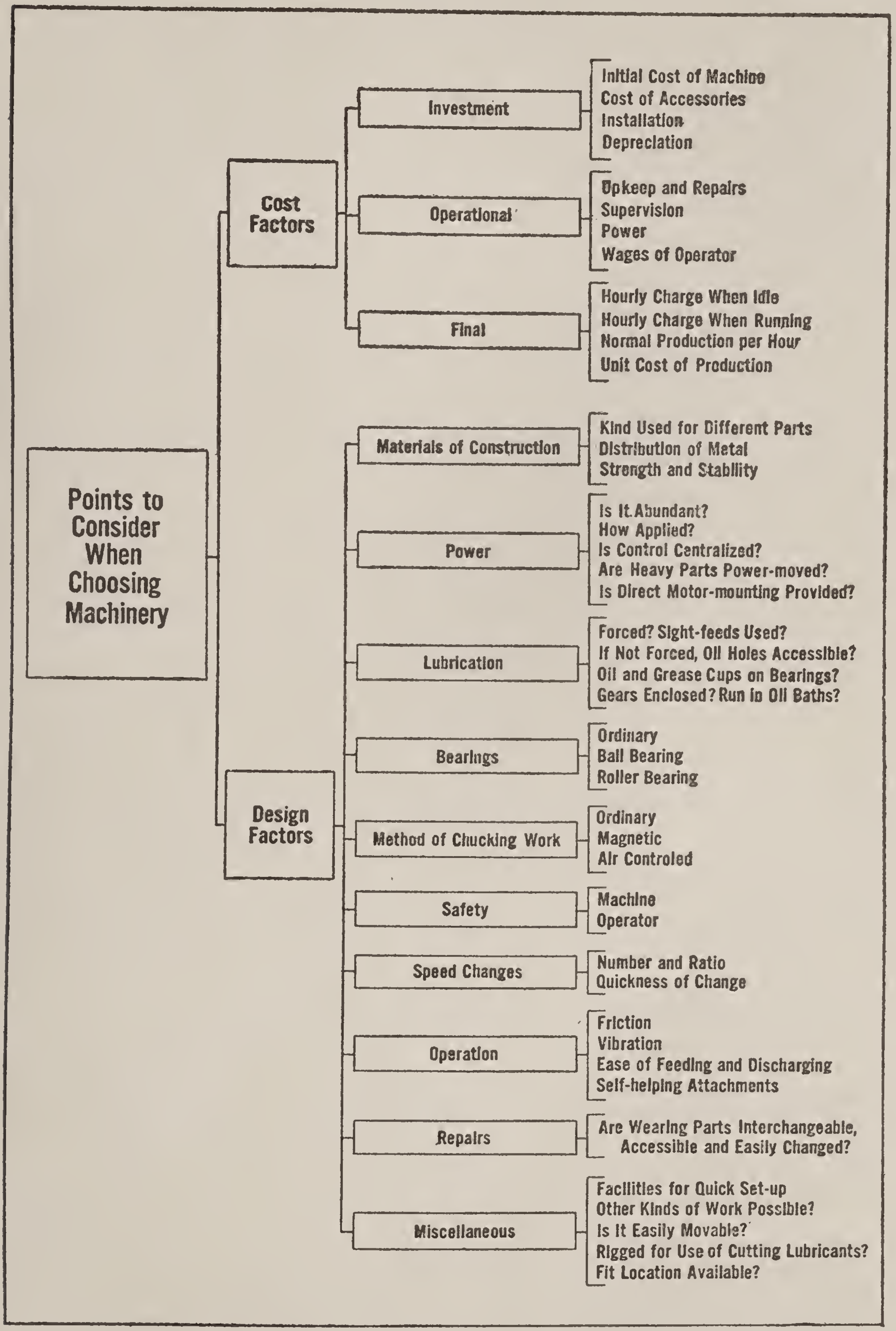


FIGURE XVIII: Keep these items before you and apply them rigorously to every proposed purchase of equipment. Then you will be less liable to be swayed by such claims as low initial costs, for instance. Rate competing machines under consideration according to some such list, and if you weigh the various points carefully, your decision can scarcely fail to be sound and wise the development of which America owes much of her industrial supremacy in many lines. The tendency to install it without making certain that its service is the thing needed is, however, common among factory men. The sound preliminary of any important installation is thorough investigation, followed by a cool, calculating, but broad weighing of all the factors (Figure XVIII).

Another manufacturer had this experience. He was expanding his business. For one of the new departments a battery of special machines was needed. He took up the matter with various builders of such equipment and finally, after several months of negotiation, placed the contract. The machines proved faulty. In fact, he was compelled with his own force almost entirely to redesign and rebuild them, and when he needed additional units he designed and built them himself. These home-made machines, while doing the work in a way, are still short of the mark. Now he is hard at work experimenting on a new design. Eventually, he will work it out—find the one best type and standardize it. But it is expensive standardization.

The correct procedure, in case of special equipment, is more nearly indicated by the method of another manager. He first builds a single machine, as well adapted to the purpose as his engineers can devise. Then he tries it out thoroughly under actual working conditions. He keeps on improving it, perhaps rebuilding it entirely before he is through, and not until satisfied that he has the "one best thing" worked out, does he sanction the building of additional units.

This same manufacturer, when his need can be met by standard equipment, takes the precaution to send his equipment engineer and his shop superintendent on a tour of inspection to see various makes at work in other shops. They report upon their return, and the purchase is decided in conference.

Into this conference enter the purchasing agent, the methods engineer, the safety man, and the foreman of the interested department, as well as the equipment engineer and shop superintendent. Requirements for new equipment are also determined by the same committee. Thus, a balanced judgment is obtained, and as a result equipment purchases in this shop usually "fit."

Many concerns, particularly the largest ones, now maintain elaborately equipped testing departments, especially for the purpose of determining the fitness of new equipment and supplies. Here the various makes are thoroughly tested out under actual working conditions and the order is placed with the firm

> **HOW HENRY FORD STANDARDIZED INSTRUCTIONS FOR EQUIPMENT PURCHASING**
>
> Place original requisitions for machinery required after determining suitability of machine for operation intended.
>
> Eliminate excess cost by proper specifications which cover only such equipment or attachments as are absolutely necessary.
>
> Maintain complete record of breakdowns, thus locating weak points and preventing recurrence by insistence on proper changes when buying more equipment of the same type.
>
> Prevent excess purchases: (a) by keeping record of equipment made available by changes in design of product, (b) by properly timing and determining actual capacity of machines, and (c) by distributing machinery so as to secure full-capacity operation of each unit at all times.
>
> Keep a complete record of all machines purchased: (a) date purchased, (b) supplies, (c) date delivered, (d) where put, (e) description of special features and attachments.
>
> Go carefully over all changes made in design of product and anticipate machinery required by such changes. Eliminate machines if they cannot be adapted to other uses, or sold or otherwise disposed of.
>
> Follow up all machinery orders, thereby seeing that builders receive formal order promptly and that production does not suffer through unnecessary hold-ups.
>
> Follow up builders to see that machinery is shipped and received on time and installed without delay.

whose product, other things being equal, satisfies most nearly the specification and the claims made for it.

Several machinery builders, moreover, realizing the necessity for "making good" in every case, and realizing, too, that most of their customers, particularly the smaller ones, are obliged to buy largely on what the builder tells them, have established their own service-tests departments. Here the machines they manufacture are thoroughly tried out under actual working conditions and every practicable effort made to perfect them. Often a side line is developed to furnish work for these machines, which makes the test productive as well as eminently practical.

An example of this combination is seen at the plant of a middle-western manufacturer of automatic screw machinery. Part of the plant is given over to the production of the machines. The rest is busily occupied turning out product with automatics of its own make. Thus one section of the plant is, to all intents and purposes, the testing laboratory of the other, and a more practical laboratory could scarcely be imagined.

Again, some builders are large users of their own machines. The product of such shops naturally can be expected to show a higher development than that of factories which are not so situated. Desirable changes are thus brought forcibly home to them and can be judged on their merits, rather than by the standard of whether it will pay to discard certain old patterns.

When in the market for considerable equipment, the tendency is to lump purchases with a few reliable firms. This has its advantages, but also its drawbacks. Because a manufacturer is noted for one type of machine, it doesn't follow necessarily that his entire line is equally choice. Pick the best from each, therefore, is a safer rule to follow.

So, in fitting equipment to the business, whether it is a case of buying a standard machine, as it is catalogued or modified the better to suit your need, or whether your requirements demand special machinery, the most important preliminary is to ascertain exactly your needs. The next is to insure, by equally careful investigation and test, that the machine you propose to buy or build exactly fits the requirements. Lastly, ask yourself whether the work in sight for it will return the investment, otherwise some machine of more general utility may be more profitable.

VIII

PLACING MACHINES FOR TEAM WORK

WHEN a manufacturer buys a new engine or boiler he usually has in mind a definite location for it. More than this, if his power house has been laid out with expansion in view, not only is the site predetermined but a foundation often is in waiting. With regard to his heaviest processing machinery, perhaps, he exercises equal foresight. But so far as the general run of equipment is concerned, the chances are he has no plan. And what is more, he leaves it to the shop to decide where to put the new unit when it arrives. All goes well if the superintendent or master mechanic has a properly developed sense of location and is not hampered by the dictates of expediency and haste. Many shops, however, seem to be unfortunate in this respect, if the numerous examples of improperly positioned machines is any criterion.

Nor can the production chief alone be indicted. He may be capable in this respect and yet be so restricted by a faulty arrangement to begin with and by the unwillingness of the management to stand the expense of any sweeping changes, that the best he can do is to put a machine wherever he can find a bit of space. No, the fault mainly lies with the management, for failing to work out a logical grouping in advance which anticipates the need for growth and development (Figure XIX).

Because the cost of a machine does not exceed two figures is no reason why it should be slighted in the least. It may occupy a relation to other and more costly units that makes careless or incorrect positioning a matter of serious moment from the standpoint of operating expenses.

A helpful analogy in this connection is a team of horses. Given a proper driver, both animals exert their pull simultaneously in the same direction and the load moves forward. If two horses are not enough, a third is added or one or more pairs are hitched on ahead. So in the factory; the output is the burden to be moved, the machines are the beasts of burden and production will progress most smoothly and at least cost if all the machines exert their effort in the forward direction.

How machines should be located depends chiefly on the character of the production scheme. The manufacturer who is equipping a new factory or extensively altering an old and faulty arrangement, must first decide on this. Two general plans are found. In one all similar machines are grouped together. In the other, machines performing successive operations on a part or article are brought together in the same department. Which scheme will be better adapted depends largely on the nature and size of the business. The second gives the shortest transfers of material, but is only economical in case the volume of business is such that the most rapidly producing machine is kept constantly busy. A Michigan automobile plant, in reorganizing a few years ago, adopted this plan with highly gratifying results. At the Ford plant, neither arrangement is adhered to rigidly—some departments are organized on the one basis, some on the other. In general, however, the aim has been to keep similar units together, but this has been secondary to the consideration of continuous forward travel of each item of the product with the shortest practicable intervals of space between successive operations. The shop has the appearance of being crowded, so closely together are the machines located. And the crowding is real to the visitor who departs from the main aisles to make his way across the floor. Each man has ample room for the necessities of his work, but so little to spare that piling up of product in front of or behind a machine literally is impossible. There is no alternative but to keep moving. Ford thus secures practical continuity of operation in a non-continuous industry.

Another point to consider in determining the general scheme of layout is the most effective utilization of operating labor. As automatic operation becomes more general, the duties of labor

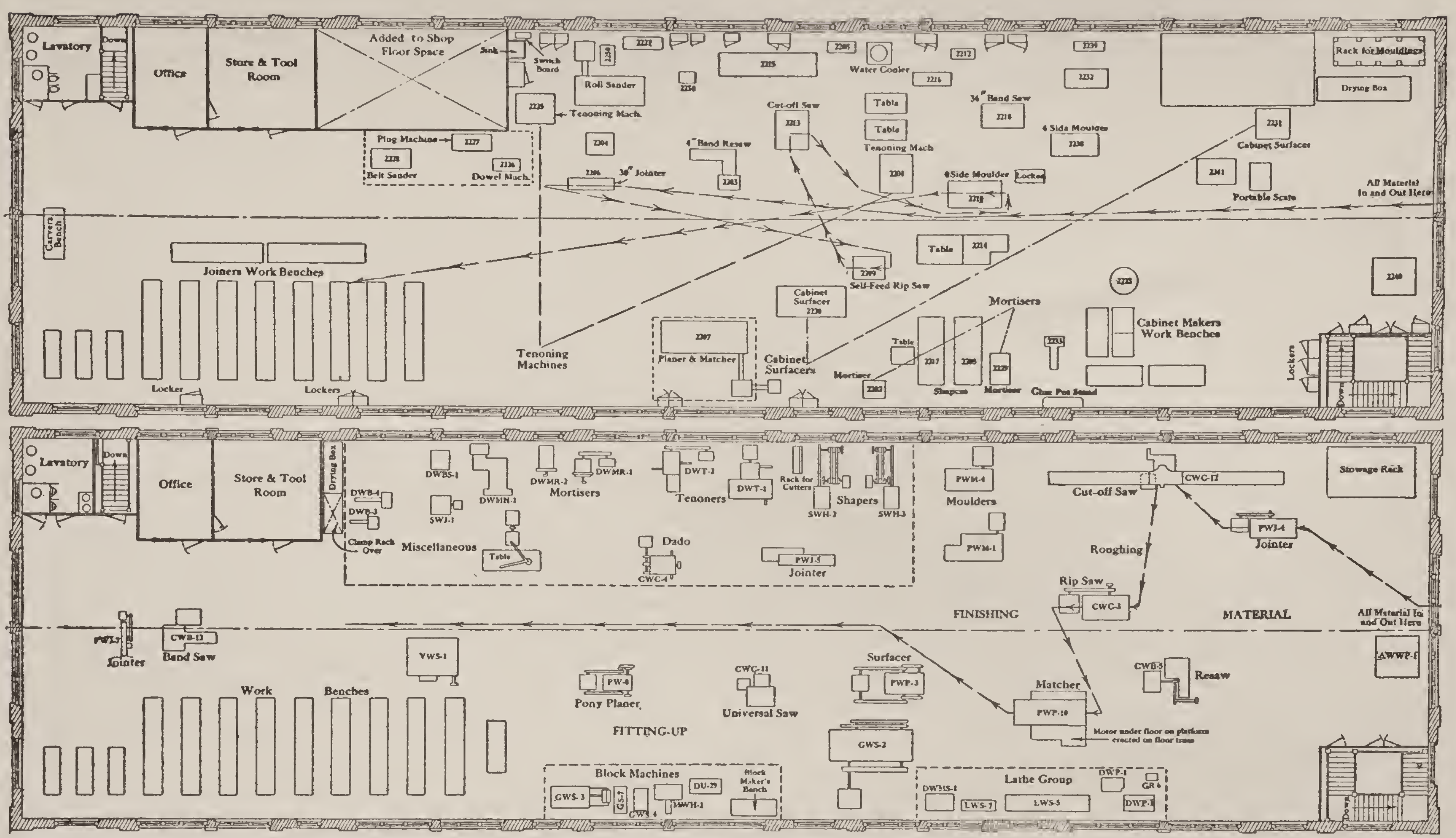


FIGURE XIX: Views of a woodworking shop show what can be done by rearranging the layout. Under the old plan (above), the shop was crowded and operation confused. By regrouping the machines (below), more room was obtained, and straight-line flow of production approximated. The total movement is now 200 as against 425 feet formerly. Machines are arranged: (1) in groups, according to class of work done; (2) individually, with reference to the function each performs more and more become supervisory in their nature. Less and less does one piece of equipment monopolize a man's attention. Take the case of automatic screw machines. It is now common to find one man tending three, four or a half dozen of these. In the textiles one man frequently operates as many as twenty automatic looms. At the Thomas B. Jeffrey Company's plant, three men—a skilled set-up hand with two helpers—operate nine semi-automatic lathes. These constitute practically a department within a department, as they are all in a row and are screened off from adjacent groups. Few, perhaps, are the chances to consolidate machine attention to this extent, but in almost every factory, forethought will yield some economies of this sort. At the Ford plant are many instances of a single operator tending two machines, and in many shoe factories one man directs a pair of gun-stock lathes processing shoe lasts. The ideal facility is afforded whenever the chucking time is an integral portion—one-half or smaller—of the machining time.

In arriving at the best layout of machinery, a good plan is to prepare reduced-scale templates of each machine (and work bench) squared off to include the necessary operating space. Next prepare drawings of the various departments, to the same scale, mount these on convenient boards and proceed to study out the best arrangement. As a place is determined, fix the template with a pin. Considerable adjusting, of course, will be necessary before the proper relative positions are worked out for all the machines. Nor may the best arrangement be reached on paper. Practice sometimes develops unforeseen conditions which compel still further adjustment. Eventually, however, through study and cut and try, the most efficient layout matures.

PROVIDING IN ADVANCE FOR THE LOCATION OF MORE UNITS

AS the various units are located, expansion constantly should be held in view and a certain amount of space set aside for the future addition of new units. Then when seeming need develops for greater capacity, and investigation proves that the need is real, the proper positions will at once be apparent from the layout.

Indeed, future units may well be indicated in advance and clearly distinguished from existing machines by a color scheme. Then as purchases are made, the colored templates can be replaced with white ones, if this is the color used originally. Better still, a different color may be selected for each group of

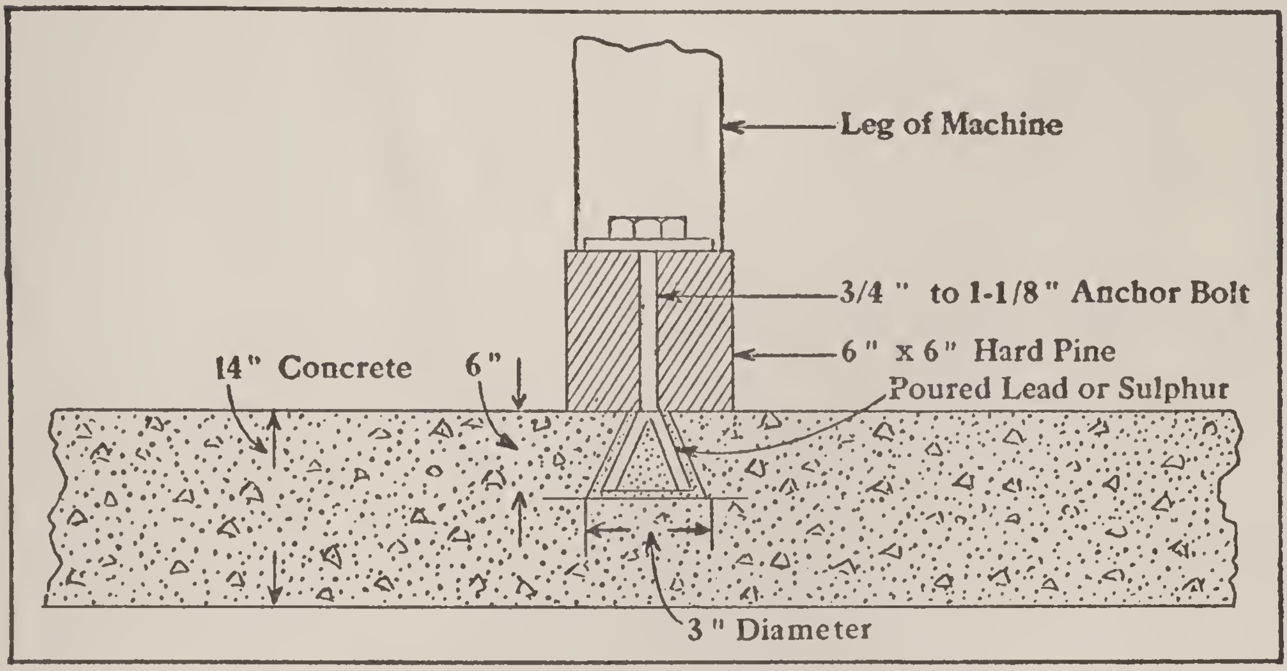


FIGURE XX: In anchoring machines to concrete ground floors, vibration seldom is an important factor. Resting machinery on wood sills usually is enough. If vibration is serious and anchorage also essential, then a good way of localizing the shock is to imbed the anchor bolts, as shown, in plugs of poured lead or sulphur

additions. Suppose white is the color of existing equipment, and blue of projected units. Then red may be chosen for the first group of additions; green the second group; orange the third group. At a glance, the chart will show the growth.

At one factory where this plan is followed the charts of the several departments are kept in a rack in the directors' room, and any one may be pulled out like a drawer for reference on the spot or withdrawn altogether for consultation elsewhere.

To show the relations among the various machines or groups of machines, arrows are traced on the chart indicating the movement of product. Naturally for greatest efficiency these arrows should point in the forward direction, and depart the least from the theoretical straight line of production. Any zigzagging or backtracking is indicative of inefficiency in the arrangement. Long shafts on the arrows, too, indicate faults.

Actual installation, though perhaps not so vital from the cost viewpoint as arrangement, nevertheless is of more importance than is commonly believed. Faulty arrangement is a big handicap, but it is not insurmountable; it does not prevent you from operating each productive unit at very nearly one hundred per cent efficiency. The loss is in the unproductive extras entailed in the wasteful utilization of floor space and the long handling intervals. Faulty set-up, however, means inefficient mechanical operation, frequent disorders, imperfect and spoiled work, shortened life of equipment and vibration with

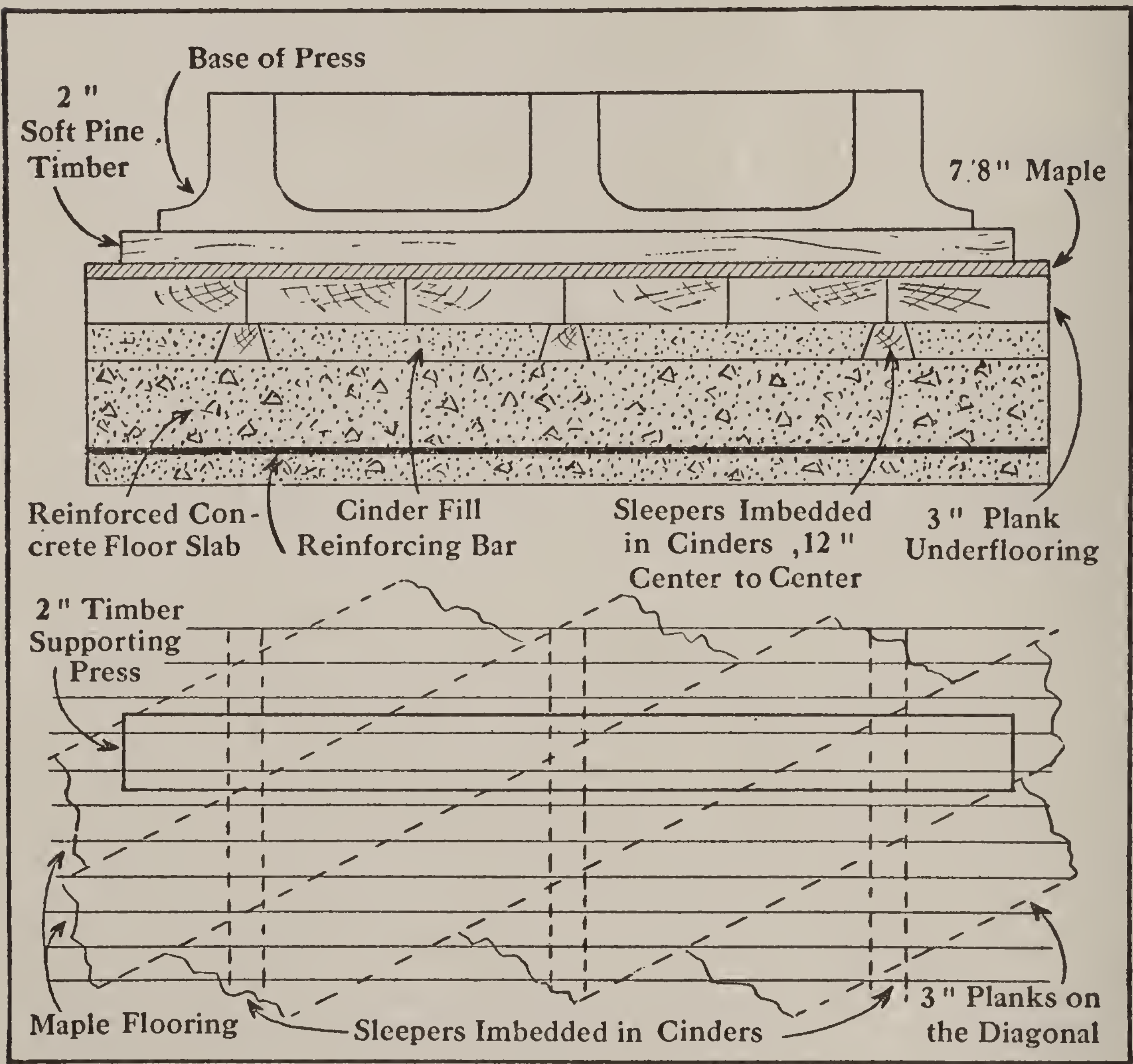


FIGURE XXI: Printing presses are heavy vibration producers. In one large printing plant the shock was localized and the noise largely dissipated by the method of floor construction here shown. Both layers of wood are without joints, to gain discontinuity. The presses themselves rest on timber sills which are not attached to the floor in any way and parallel so far as possible the run of the maple surfacing

its concomitant din, which affects adversely not only mechanism but also work, supporting structure and operatives. To estimate the actual money loss chargeable to improper set-ups is difficult, but the fact of loss is beyond question.

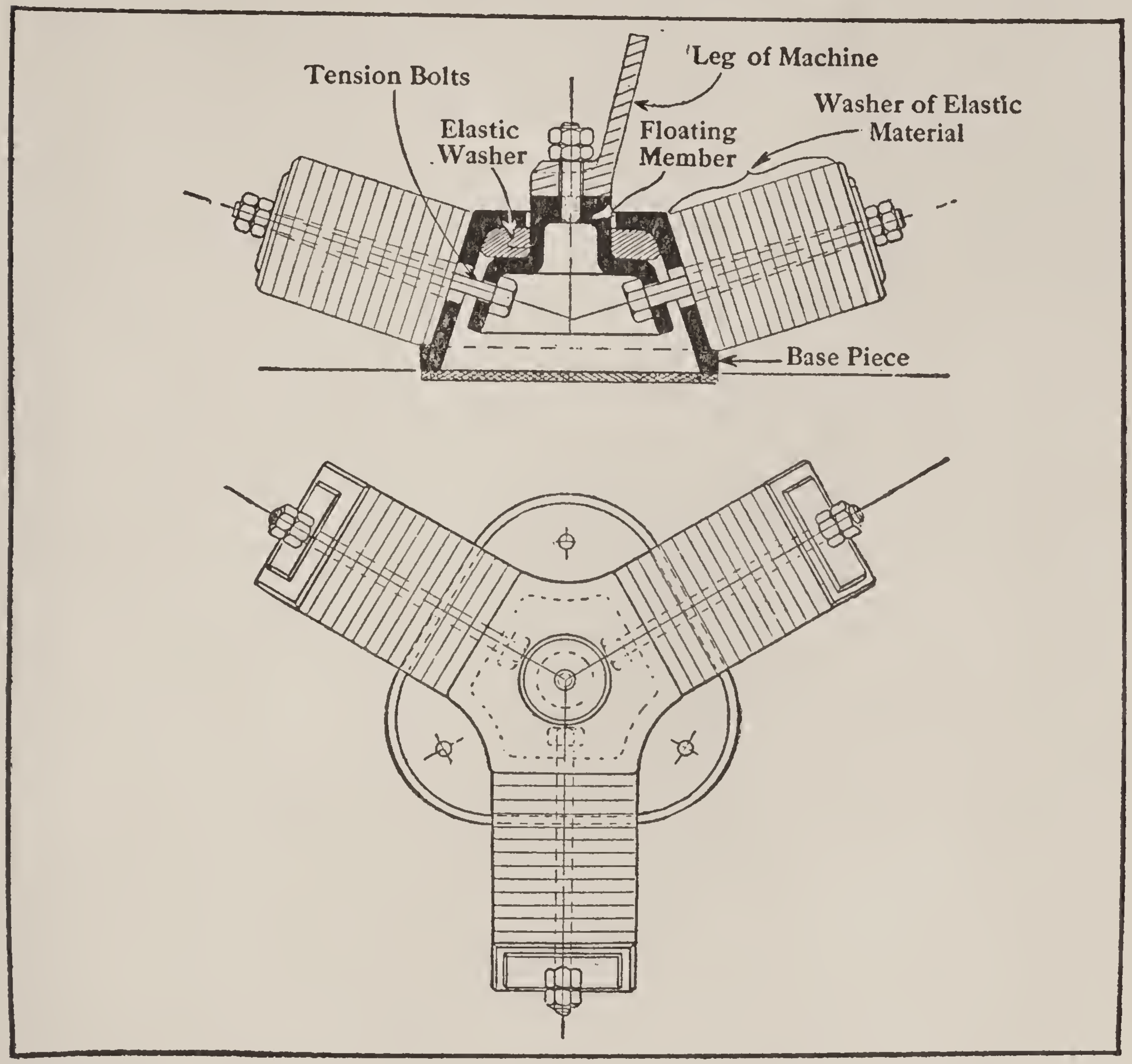


FIGURE XXII: This shows a type of shock-absorbing pedestal developed in England and much used there for attaching vibrating machinery to wood floors. Its success hinges on the lasting qualities of the elastic washer material used. As this compresses with age and loses its resiliency, it has to be replaced, which is the draw-back to any scheme of this kind. Devices based on the use of steel springs are more costly, but they have the advantage of greater permanency

If precision work is desired, and smoothly running machinery is an object, the manufacturer will be as particular on this score as the instrument man of a leveling party or the erector of stationary ordnance, and because a machine is small or not costly, he will not deny it a due proportion of attention.

THREE THINGS TO WATCH CLOSELY IN SETTING UP MACHINES

THESE then are the main points to see to when installing a new machine: first, that the spot selected for it furnishes a suitable and adequate foundation; second, that the machine is accurately leveled; third, that it is fitted up properly, thoroughly lubricated and put in perfect working order; and lastly, that the mechanism is thoroughly understood before operation is begun.

Though these points appear self-evident, their importance is not sufficiently recognized in general, if the experience of machine builders is any criterion. "We find it necessary," says one, "to keep a 'trouble-man' on the road constantly. We furnish full and complete instructions with each machine sold, covering set-up and operation. In spite of this, the majority of purchasers find it necessary to call on us for personal attention. The machine, of course, is blamed and we are told that if we cannot make its operation satisfactory to take it out. Almost invariably, however, we find the fault is in the set-up or in not having followed instructions in starting up. The leveling commonly is poor. This has either been carelessly done or else a cheap, ordinary level has been employed. Light machines frequently are not securely fastened to the floor, whereas the lighter the machine the greater is the necessity for attachment. Anchorage as a rule may be dispensed with only on the heaviest units.

"Failure to lubricate thoroughly is the most common and flagrant omission. It may seem surprising, but because a machine is advertised as self-oiling, some try to run it without filling the oil and grease cups or oil reservoir. I asked one man who complained because his purchase ran stiffly and heated up in the bearings, why he did not oil it. He said, innocently, 'Why, isn't it self-oiling?' As a precaution against this oversight, we now make it a policy to ship our machines with some oil in the reservoir and to make a special point in the instructions of the necessity for oiling."

In leveling a machine, the first essential is a thoroughly reliable level. Second is a proper method of adjustment. A common procedure is to set the machine on steel wedges and drive these up or loosen them until the level is certain in all directions. Then, if the floor is concrete, a convenient way of holding the wedges and furnishing an even bedding is to run cement-mortar underneath. Heavy apparatus sometimes is leveled by means of small screw jacks, which are removed when the cement underfill has hardened sufficiently or left in place permanently, to afford means of releveling quickly if necessary.

Anchorage to the floor is not necessary in all cases, as remarked by the machine tool builder quoted. Heavy units seldom require any attachment. Of light machines, the reverse usually is true. The character of the floor and the type of drive affect the problem. Anchorage to an unyielding ground floor or an upper floor of rigid structural concrete is much less necessary than to a wood floor, and where required at all, can be handled with a smaller number of bolts. Again, when the machines are individually motor-driven, anchorage is not nearly so essential as when shaft-and-belt driven, on account of the displacing force exerted by the belt.

In setting up machines, the prevention of vibration rarely is given the attention it deserves. Vibration is a necessary accompaniment to the operation of all machinery. However, it need not be a nuisance if thought is given to absorbing it in the method of attachment.

A firm, massive and detached foundation is the best preventive. This, of course, is only possible when the floor rests on the ground, and even then some local vibration-absorbent often is necessary or desirable. Attachment of the legs or base to heavy timbers or wood blocks is one means. Imbedding the supports in lead or sulphur is another (Figure XX). Setting the legs on shock-absorbing pedestals or springs is a third way (Figure XXII). A layer of rubber, cork, felt or some elastic material is still another. The disadvantage of this is that the insulating material in time compresses and loses much of its resiliency. If the floor is of concrete, a properly arranged decking of planking often is effective.

At a large middle-western printing plant comparative freedom from cumulative vibration was secured by building the floor as shown in Figure XXI. A quadruple layer of wood, thus intervenes between the base of the press and the slab.

It is by such attention to details as this that machinery is placed for proper team work and that each unit then is brought separately to maximum value in the current of production.

IX

BRINGING MACHINES TO THE PROPER PACE

SMALLER power totals, as the result of improving mechanical conditions, is a natural expectation of the manufacturer. The contrary, however paradoxical it may seem, often is the issue. In a large Ohio metal-fabricating plant, at the end of three years' effort to obtain more efficient operation of machines, three hundred per cent more power was being used. Output during this period had doubled and costs decreased on the average twenty-three per cent. The force numbered twenty-five hundred at the start; at the consummation of the improvement propaganda it had been reduced to two thousand. Power was the only element that showed an increase, and this result was due entirely to more intensive utilization of equipment, but it was a highly profitable increase.

Formerly, the shop had been run without any particular plan. The actual work was left to the foreman to block out; repairs were not systematically anticipated, nor were machines carefully speeded. In consequence, scarcely a machine was operating at highest efficiency; on the contrary, as investigation revealed, so much time was being lost from one cause or another that the actual running time averaged scarcely fifty per cent of the possible. Much work was also found being done manually that could much better be performed mechanically. Substitution of machines for hand work, speeding up of machines and arranging to keep them constantly busy at their best rate accounted for the surprising rise in power consumption.

This manufacturer's experience is typical of what has been effected in scores of plants and of what is possible in every plant whose management has not risen to a keen realization of the value of machine time and reduced its conservation to a system. Every manager is insistent upon getting value received from labor. He should be even more insistent upon getting full value from his machines, whose wages—in many cases far greater than the wages of labor—cannot be separated from the payroll.

"When the men object to any effort to increase machine output," declared the production manager of a Cleveland machine-tool concern, "I tell them it is not that we want them to work harder, but to make the machines work harder—to 'give 'em h——,' in the homely parlance of the shop." Much of the opposition of organized labor to so-called scientific management is due to a misapprehension of the real intent and purpose of the exponents of greater efficiency. Instead of being a speeding-up process, it is, as one industrial engineer recently put it, a *speeding-down* process, so far as the human element is concerned. Less actual effort from labor but more results through the elimination of inefficient movements and the development of

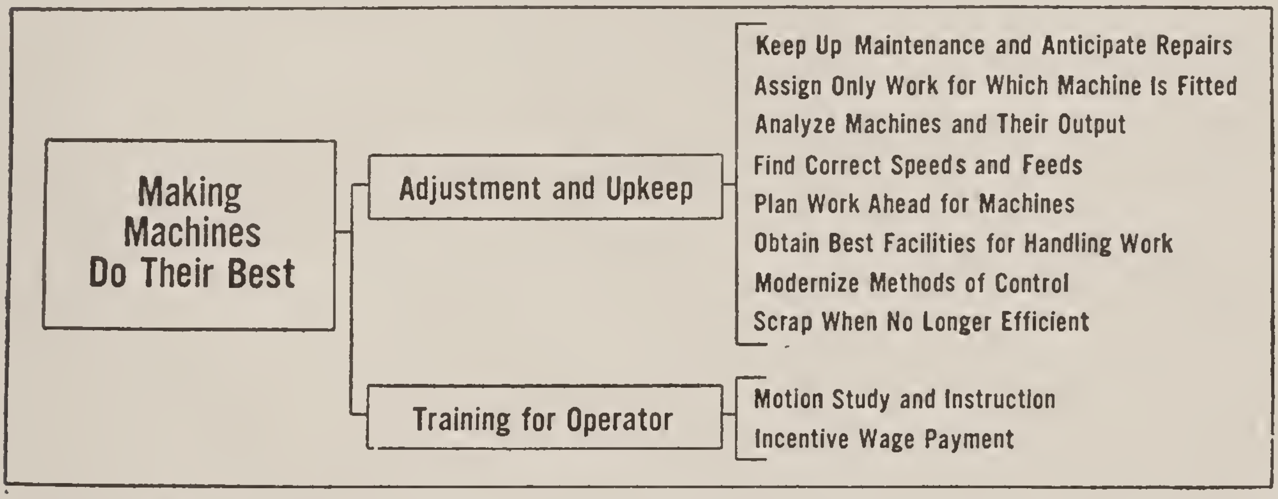


FIGURE XXIII: Few machines, in the average factory, are yielding even approximately the output of which they are capable. "Time-out" for various reasons which proper planning and supervision would remove, improper speeds and feeds and lack of adequate handling facilities are some of the causes. Analyses along such lines as suggested have repeatedly doubled efficiency, and a four-fold increase in production is by no means uncommon

mechanical helps; greater output from machines through more intensive and scientific operation of them.

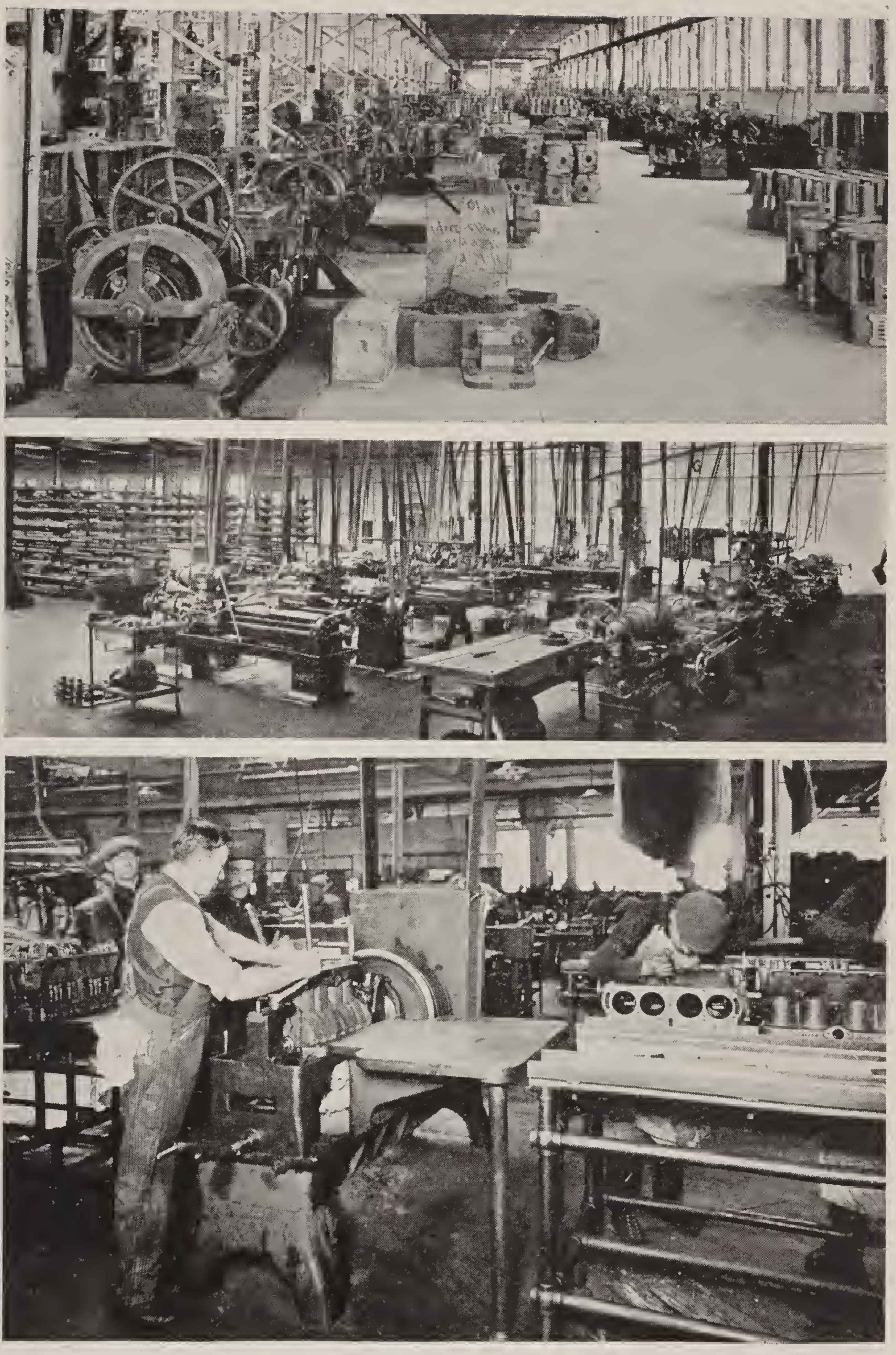
Plans for raising machine efficiency, after the best design has been determined and purchased, thus divide into two general classes: first, improvements which concern the machine wholly, such as finding and establishing the best speed and feed for every class of work, devising better ways of handling material at machines and systematizing both allotment of work and maintenance to the point when idle time on these scores virtually is eliminated. Second are changes which affect directly the operator himself, such as the elimination of awkward and purposeless motions, correction of working conditions—light, heat, ventilation and sanitation—which react upon efficiency, and the securing of the fullest cooperation by incentive methods of compensation, proper working hours and just dealing. What concerns us here are the machine improvements (Figure XXIII).

HOW TO GO ABOUT RAISING THE EFFICIENCY OF YOUR MACHINES

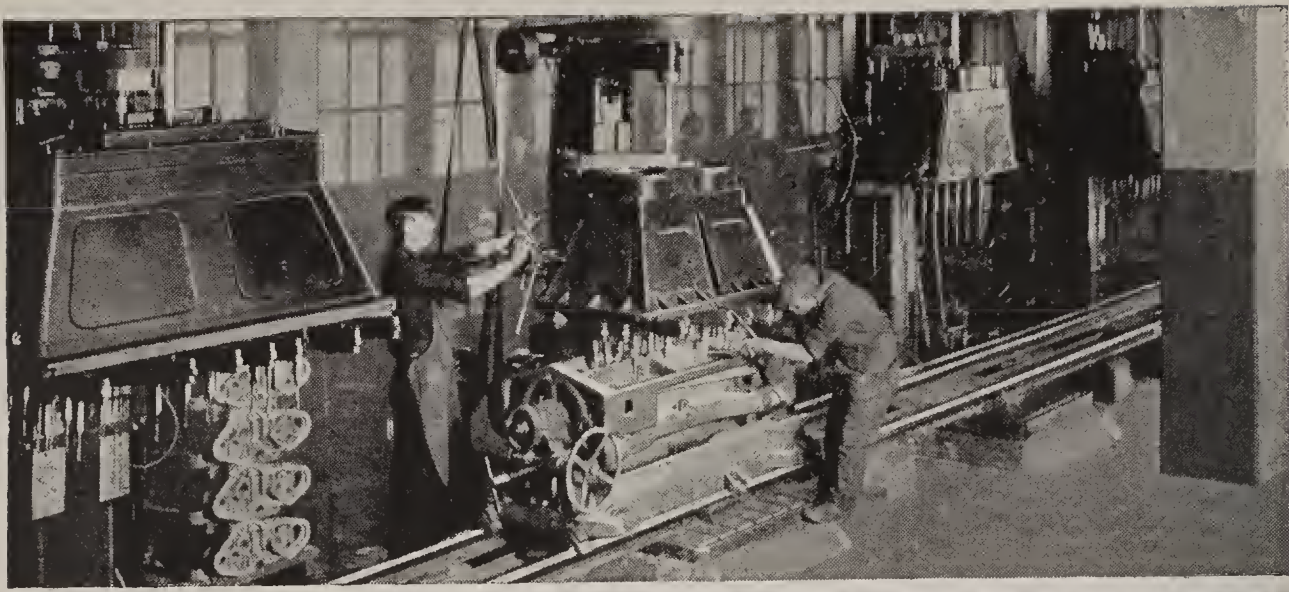
HOW, in a given case, may conditions in this respect be bettered? First is the ascertaining of *what is,* then the determination of *what ought to be,* and finally the adjustment of what is to what ought to be. When the Japanese nation began less than fifty years ago to awaken from medieval conditions, they chose for their slogan: *Adopt; adapt; become adept.* They sent their young men all over the world, to find out the points wherein this and that country excelled. Returning home, these young men became the efficiency engineers of the nation. That Japan today stands where she does eloquently testifies to the clearness of vision of her statesmen and the practicality of their application.

The Japanese motto is a good one for any factory manager to follow. Become conscious of the discrepancy in your factory practice between *what is* and *what ought to be,* as measured by comparison with the best standards of other manufacturers; then adopt, adapt, become adept. Set up as your goal the operation of every piece of equipment at its maximum efficiency, not part but *all* of the running time. Then take those steps as they appear which will eliminate sources of delay or accelerate processing.

It is not enough to know that you have your machines turning out work ninety or ninety-five per cent of the time. You must also know that each machine is operating on all jobs at its best speed, that each unit is being allotted the work for which it is best fitted, that obsolete equipment does not continue to hold a place on the payroll long after it should have been



At the Worthington Hydraulic Works (above), machines are grouped along wall and interior column-line with space left for trucking. The turret-lathe department of the American Woodworking Machinery Company (middle) is group driven, with convenient raw-stock storage The close arrangement of machines performing successive operations (below) saves time and handling labor



At the Packard Motor Company machine time is cut by a trackway for quick transfer of articles under successive multiple drill presses (top). Planing identical parts in groups rather than singly (bottom) is a Ford method. At the Westinghouse plant pneumatic fingers lift and hold the metal. Mechanical counters and air-ejection increase the output of the inclined punch presses at the right relegated to the scrap heap in favor of a more modern and efficient tool, and that no operation is being done by hand which better can be accomplished mechanically. In short, ignorance no longer is excusable on the part of the factory manager. The

DAY PRESS TICKET

MACHINE NO. 2 DATE May 6-1914

PRESSMAN J. Magoon OPERATOR Paul Roe

JOB NO.	DESCRIPTION	NUMBER OF IMPRESSIONS	CLOCK	MAKE READY	RUNNING	CHANGES	IDLE	WHY IDLE
436	8 M 5½ x 3¼		7:10					
	Climax	8 M	30					
			45					
			8:00					
			15					Waiting for power
			30					
			45					
			9:00					
			15					
754	5 M 9 x 5½		30					
	Climax	5 M	45					
			5:00					
			15					
748	10 M 6⅞ x 3⅝ Climax	10 M	30					
	TOTAL	23 M						

REMARKS

S. R. H. FOREMAN'S O. K.

FORM I: How the operators keep track of work on their machines by marking a line in the "reason why" columns, this form used by a tag company makes clear. It tells the operatives' side of machine inefficiency and is checked by an electrical recorder in the manager's office

principles are established. To find out what ought to be no longer is difficult; to find out what is never has been difficult if you took the trouble; to reconcile what is with what ought to be requires only patience and persistence.

Definite knowledge of what ought to be, as established by yourself or fellow manufacturers, is better than theory and is the best possible starting point. Possession of this knowledge equips the manager with a power of attack which the most obdurate shop tradition cannot long resist. He may obtain this by studious application to the literature of factory management, by visiting noteworthy plants in lines similar to his own, and by the employment of expert workers in the field of efficiency who bring to him the force of convictions crystallized by a diversity of experience in scores of industries. Next he may well functionalize the task of mechanical betterment—create a department if need be, which shall have no other responsibility.

Then take one machine or one group of similar machines and put it under close observation. Start the operator reporting reasons for lost time. Charge all time not actually spent in processing to expense accounts, so that the totals may reach and properly impress the man who holds the expense reins. In a word, pare down to the bone the labor actually applied to the product. The overhead ratio will go up—double, perhaps triple; but that does not matter. So far as finances go, costs are costs. What you are after is the elimination of all unnecessary expense and until you frankly and honestly have separated the chaff from the wheat, you cannot begin effectively to cut.

WHAT WAS ACCOMPLISHED IN A PRINTING PLANT BY A DETAILED STUDY OF MACHINE TIME

HERE is a review of the reasons for "time out" at machines in one instance, a printing shop. The manager of this establishment knew in a general way that his machines were idle for longer or shorter periods, but a close analysis, made by means of special work tickets and the use of an electric recording device, proved facts before unrealized.

Each press operative was required to fill out a special work ticket (Form I) every day, giving the reasons for all delays. "No helper," "waiting for next job," "waiting for the pressman," "waiting for stock," "repairs,"—these were some of the excuses given for machine stops.

This was only one side of the story and while valuable information, it was not altogether reliable owing to the propensity of workers to guess at and juggle time reports so as to "come out." By means of the electrical recording device, however, each machine was made to tell its own unvarnished story, instant by instant, on a chart in the superintendent's office. Its evidence was indisputable and showed a time waste of fifty per cent.

With a definite knowledge of *what is*, the superintendent proceeded to achieve *what ought to be.* To eliminate delays on account of "waiting for next job" and "waiting for stock," he installed a planning rack and had each machine's work laid out at least a day ahead. He provided a separate ticket for each job which carried on it full information as to materials required, quantities, when wanted and time allowed for execution and simultaneously he had the stock laid out.

To eliminate delays on account of "repairs" and "waiting for the pressman," he found it necessary to double the force of adjusters. So every source of time out was traced to its source and the rational remedy applied. As a result, practically all of the fifty per cent idle time was reclaimed to useful operation, output per operative increased and costs diminished, and new equipment was found unnecessary.

It is, of course, not necessary to employ a mechanical recording device, although frequently reform can be best and most economically accelerated by this means. Too, not all machine work permits of automatic recording. But by the exercise of a little ingenuity, utilizing the principle of electrical contact, it is surprising the extent to which application is possible. Such records, moreover, have a decided moral value. When workers know that absolute check is being kept on machine activity, they on the one hand are less liable to yield to momentary distractions and on the other hand more prompt in calling attention to any condition which is militating against maximum production. Even so simple a device as a mechanical counter, attached to the throw of a punch press, has a decided moral effect on the workers.

Where mechanical recording is not feasible, about the only way to check up is by stop-watch observation. This necessarily is a slow process, as one observer can watch effectively only one machine at a time. Occasionally a keen analyst can keep tab on a group of machines, but if an absolutely close study is desired individual observation is necessary.

Time-study, however, has a merit which no mechanical device can imitate. The stop-watch man has eyes and a brain, which the electrical detector has not. While checking machine activity moment by moment, to the tenth of a second if need be, the practical observer has a wonderful opportunity to study the efficiency of operation. He will perceive ways of improving feed, speed, handling, control, working conditions and what not. His report, therefore, will indicate not only how to increase productive time, but how to obtain a *better rate of production.*

Harrington Emerson relates an experience which shows the value of putting machines under expert personal observation. One day he went into a large New England textile mill. After a brief tour of inspection, he returned to the office. The president asked him: "Well, what do you think of it?" Emerson replied very frankly that he did not think very much of the machine shop. Whereupon the master mechanic bristled up and said: "Do you realize, sir, that this is a repair shop, that we are here to keep the balance of the plant going, and that we haven't time to bother with a whole lot of time-studies, instruction cards, dispatching schemes and all that sort of thing? Why, the whole mill would be shut down."

Before Emerson could reply the president said: "Let's go out into the shop and you show me what you mean." The first machine approached was a shaper, or little planer. It was operating on a small piece of steel the size of a postal card, making strokes across it. The stroke was about four times as long as it should be. The speed was very slow. It was an old-fashioned shaper made to use carbon tools. The operator was taking a very fine cut almost like a hair, a feed of a sixty-fourth of an inch, with a fine, diamond-pointed tool, whereas he might have taken a cut of an eighth of an inch wide or at least a sixteenth. He was taking four cuts where two would have sufficed—a deep roughing cut and lighter smoothing cut. Emerson figured that the operation was taking fully eighty times as long as necessary. Simply by changing the length of stroke the efficiency could have been tripled, and that in a few moments of time. By substituting high-speed steel, changing the pulleys to make possible a higher rate of speed and perhaps strengthening the machine to stand the increased strain, the efficiency could have been multiplied eighty times.

This is the sort of data an expert time-study man digs up, and obviously no mechanical device could do likewise. Its field evidently is to hunt down delays. To achieve a better rate of operation, a wide-awake, well-informed brain with a keen pair of eyes and a stop-watch offers about the only solution.

Exceedingly intricate is the problem of improving mechanical efficiency. The Taylor school of engineers make an exhaustive study of every machine which involves variables in the control of the operator and finally make a slide rule by means of which in a few seconds of time a workman of average intelligence can determine the proper feed, speed and depth of cut to take in view of the hardness and character of the metal.

Carl Barth, the originator of the slide rule for machine tools, cited an instance at the Tuck School Conference on Scientific Management which shows the value of this device and which also incidentally reveals how wide the discrepancy often is between what is and what ought to be in practice. One day in passing through a shop where he was doing efficiency work, he noticed a lathe producing only a very small chip at a low rate of speed and doing it in such a way as to indicate a very soft grade of steel. This machine already had been respeeded and a slide rule made for it, but the formula had not yet been applied. Barth produced the slide rule, and, making a conservative guess at the hardness of the metal, set it for the material, and for such diameter of work and depth of cut as he found the tool was running. He then read off a spindle speed six times faster and a feed eight times coarser than was being used, making a total of forty-eight times the rate of cutting. When Barth asserted these facts, the operator thought he had gone crazy. But the operator did as he was told; and the machine ran the full length of the cut under a beautiful chip of a kind he had never seen before, or even dreamed possible.

Not all machines are worth this effort. One manager lays down the rule that unless a preliminary analysis indicates that more than twenty per cent saving in the cost of the work will result, it will not pay to go into the matter further. Because of the fact that a new machine may be devised, rendering an old one obsolete, and because of depreciation charges, this executive also believes that unless the saving "proves-in"—that is, equals *in one year* the cost of the necessary investigation and changes which may follow, it will not pay to delve deeply.

Another phase of increasing machine output and decreasing costs is by fundamental mechanical changes in the machine itself. Push-button control, forced lubrication, power-traverse of all heavy parts, automatic feed, multiple spindles, air or magnetic chucks, standardization of repair parts, more convenient height of bed and arrangement of levers, mechanical helpers and many other elements which distinguish the more modern tools, each has its distinctive economy value.

Many of these features, of course, are so radical that for fundamental reasons their embodiment in existing models is impractical if not of prohibitive cost. But a machine here and a machine there will permit of improvement in one respect or another at slight cost. Feed of work, for example, nearly always offers good possibilities. The Westinghouse Electric and Manufacturing Company, to eliminate helpers at their blanking presses, devised a pneumatic arm, by means of which the operator can reach through and lift his own work onto the bed of the machine. In addition, the use of the pneumatic arm greatly increases the safety of operation and has resulted in a very large reduction in punch-press accidents, which is a noteworthy improvement in itself. Another manufacturer doing much heavy plate punching devised some special ball-bearing feed tables, by means of which the press attendant is able with small effort to draw the largest sheets onto the bed of his machine unaided.

So other incidents could be cited showing how managers keenly alert to the value of machine time, have by one device or another eliminated needless delays, cut down total processing time, saved helping labor and improved the mechanical efficiency of their equipment. And by so doing they have increased the output per unit of floor space many times and cut the costs correspondingly.

X

MORE WORK FROM SMALL TOOLS

ONLY a poor mechanic blames his tools, is a saying probably as old as the oldest craft. It has persisted down through the centuries, in all countries and in all tongues. It is current today—except in those establishments where the fact is recognized that behind each complaint or criticism of the workman lies a well-founded cause. "The customer is always right," runs the business slogan of one of America's most successful merchandising houses. "The workman is always right," justly viewed, is equally sound doctrine in the factory. He may not be correct literally, but ninety-nine times out of a hundred, if his kick is taken seriously and the offending condition painstakingly is investigated, a real difficulty or shortcoming will be unearthed, the correction of which will "prove in" handsomely.

So when a workman complains of his tools, don't condemn him hastily—listen and investigate. It may be that the man has never been instructed properly in the use of the particular tool; again, the tool actually may be at fault or the trouble may lie with its upkeep. In any event, it is the part of management to ferret out the cause and apply the necessary remedy.

Wise managers are making this their policy. The importance of having high-grade men to get high-grade work is not minimized; but the attainment of the highest manufacturing efficiency is seen to depend largely on having in the first place perfectly adapted tools of the best quality obtainable, and in the second, on the steady utilization of these tools up to the limit of their effectiveness. A good mechanic unquestionably can produce results with inferior mechanical equipment; but unquestionably also he can do much better work with proper tools and, what is more vital from the cost angle, do it in considerably less time.

Tools thus very largely determine costs and in a factory which aims at quantity as well as quality of output, no effort will be spared to get the most effective use of the small tool equipment as well as of the primary processing machinery.

HOW THE INEFFICIENCY OF SMALL TOOLS CUTS DOWN YOUR PROFITS

SMALL tools, as a matter of fact, are, in the average factory, in greater need of attention than the large stationary units. For, because they are small, low efficiency of use does not come into the spot light as it does with the larger machines. While the investment in a single hand or portable power tool may be insignificant comparatively, in aggregate it is no mean sum and because spread over so many items is much more likely to be utilized inefficiently.

Then, too, the personal equation still dominates largely in the realm of small tools. In many factories, workmen are expected to furnish their own equipment, or at least are allowed considerable latitude in their choice. Also, they are expected to condition their own tools; consequently, in such factories, the greatest lack of uniformity exists usually both in the quality and character of the small tools and in their maintenance. John likes this kind of hammer; Mike prefers another type, although both are doing identically the same work. Joe likes his drill or his chisel edged one way; Dick wants it some other way. If they must furnish their own outfit, Jim, who is parsimonious, will provide himself with a cheap twenty-five cent hammer, which might serve well for housekeeper's general utility work, but is very inadequate for steady use in the shop. Charley, on the other hand, takes to a small sledge when a carpenter's or machinist's light hammer would be proper. As a result, he tires himself out early in the day and dodders through the rest. Seldom is a workman found with just the right equipment for the purpose. A great total waste of time and effort is the result, which integrated runs into large figures. And the management stands the loss.

What is the way out? Standardization of the small tool equipment and its use, as well as the large, is the answer.

First is the determining of the one best tool for every purpose. This is the principal task and may require months of painstaking investigation and experiment. Does it pay? Take this incident for example. Offhand the average factory man would not think that the hammers used by the packers were a matter of much moment. A hammer is a hammer to most people. Yet in the packing room of a large enameled ironware plant, standardization of the hammers proved well worth while. Study of this tool was incidental. Surface indications of inefficiency had led to a detailed study of methods. A cause of restricted output was found to be the hammers. The men were required to furnish these themselves and scarcely two had hammers alike. You might have gone through the collection without finding just the right tool. One result of this lack of uniformity was that whenever a handle broke, much time was lost in fitting a new one. Experiments accordingly were undertaken to establish the proper design and weight of hammer for this particular purpose.

Another source of delay and expense disclosed was personal injury due to flying nails. Scoring the face of the hammer, therefore, was tried and found practically to eliminate this trouble.

Breaking of hammer heads proved to be still another cause of lost time. This was obviated by specifying the exclusive use of steel as against malleable or cast iron hammers, which heretofore had predominated.

Even the best size and shape of head and the length and contour of the handle were investigated, and not until no further improvement seemed possible were prices sought of various hardware manufacturers.

Finally, when arrangements had been made for the proper tool, a quantity was stocked and the workmen were instructed to use this type and no other. Each man is required to sign a receipt upon receiving a hammer and is held personally responsible for its safekeeping. When a handle breaks, he is required to turn in the broken piece before a new one will be issued to him. Considerable speeding up in the output of the packing room was the result and the way was prepared for the introduction of piecework.

As with hammers, so it is with small tools in general. A one best saw, chisel, wrench, drill, knife, file, abrasive stone or paper exists for each particular usage. Until this one best tool is found the highest efficiency is impossible.

HOW TAYLOR STANDARDIZED SHOVELS AT THE BETHLEHEM STEEL WORKS

TAYLOR'S classic experiments with shovels at the Bethlehem Steel Works furnishes perhaps the best example of scientific determination of the one best tool. When Taylor began his work at this plant, he found men using identically the same shovel on all classes of material, from light pea-coal to heavy iron ore. So he experimented first to find the proper load for an average laborer. The way he went at it was this: he selected a pair of men who seemed adapted to this kind of labor and who agreed to work as he directed. He fitted them out with long scoop shovels, keeping a record of the output. Little by little he shortened the scoops until the men were handling a maximum of material in a given period of time. He knew when the limit of effectiveness was reached from the fact that when the scoops were shortened still further, volume fell off. Thereafter when a man or a group went forth to move a pile of material, the proper shovel was issued with the order. If to handle pea-coal it was a long scoop, if iron ore a short scoop, but calculated in either case to hold fully loaded approximately twenty-one pounds, which is the load Taylor found proper for a good, average man to handle.

Having in any case established the proper tool for a particular purpose, in some such manner as at Bethlehem shovels, and at the ironware plant mentioned, packing hammers were standardized, the next step is to determine and impart to the men the best way of manipulating the tool. Usually someone will be found who, like the village smithy of Longfellow, is a real artist in swinging the hammer or shoving the saw. Let the investigator pick him out as a model, and study his method of work until he is satisfied that he has the secret. If no master of the craft is to be had, about the best an investigator can do is to pick out the person who seems to have the most knack and who on actual measurement accomplishes the most work. Then make him the teacher to show the rest. If the investigator has had practical experience with tools, and has more or less instinct for the right way to work, he will be able generally to suggest improvements in the motions of the most expert workmen. Moreover, he can often ascertain the true form by experimenting himself. This type of investigator is rare and valuable, but he can be found.

It is one step to show men the right way. It is quite another and more difficult one to fix in them the habit. Patient but persistent follow-up by the instructor helps. But to secure positive results in a short time, it is practically necessary to link the new method with the payroll. Let the standard times and the wage-increment possible through greater efficiency be based upon study of the proper method. Then it is strictly to the interest of each producer to adopt at once the better way recommended.

SPECIALIZING THE CARE AND UPKEEP OF SMALL TOOLS HELPS TO INCREASE OUTPUT

ANOTHER vital step in raising the efficiency of small tools, which ranks with proper use in importance, is to provide for their systematic conditioning. The traditional practice is to shoulder this burden on the man. This is uneconomical for two reasons. First, it dissipates time and energy which the man would otherwise have for actual production. Second, when men condition their own tools, few make the best job of it, and in addition tools that might and should be employed in common are restricted largely to the one man, because each has his peculiar idea as to how a chisel, for example, should be pointed, and is averse to using a tool someone else has sharpened differently. Or, if the tool is passed around, the last man almost invariably leaves it in such condition that the next man is obliged to spend considerable time fitting it for his own service. Thus, here again the personal equation holds undisputed sway and generally where this is the case conditions can be bettered.

It needs to be made someone's job in each establishment to look after the small tool equipment. Appoint the best mechanic you can find for this work. Lay out a schedule for him and operate a follow-up to see that he holds to it strictly. Provide him with drawings and instruction cards, showing the best way that has been found of conditioning each tool. This information is or should be developed in the course of the investigation to determine the one best tool. Once ascertained, the only practical way of enforcing it is to specialize the care as outlined. One man can be taught to follow a standard of this kind; but to impart the trick to the rank and file would be a mighty task.

Make the man selected feel that the entire establishment depends on him, so that he will take a special pride in the work. Then buttress his self-respect by liberal pay and vigorous support, and you can forget that you have a tool-maintenance problem.

This same man, in the average plant, can also take care of the cutting equipment, the care and conditioning of which submits itself to the same routine.

Closely interlaced with the question of care is the control of tools. This must be centralized for best results and one man made responsible for the safekeeping. In small shops the caretaker can be entrusted with storekeeping duty as well, perhaps with a boy to assist. At some central point establish a well-planned tool storage and have the fixer's bench immediately adjacent, preferably within the same enclosure. Provide a place for each tool and group similar tools together. Identify each with a distinctive symbol indicating its class, character of usage and location in the storage. Have it known by this symbol. Issue only on duly authorized requisitions of a supervisor or in exchange for a receipt of some kind. Brass checks, carrying the workman's number, are commonly used for this purpose, a quantity being issued to the man when he starts, for the full accounting of which he is at all times held strictly responsible. Require the return at the end of the day of tools that are not actually tied up in a machine, for instance, such as drills and carborundum wheels. Inspect each returned tool before putting it away and if in need of attention, shunt it to the fixer. If bad condition is due to abuse or misuse, make note of the fact for the information of the instructor, that the latter may take the man to task in the one case or reinstruct him in the other. Charge breakage to the man if due to his carelessness. Finally, keep trying to anticipate the needs of the busy producers and to deliver the necessary tools well in advance.

This is the routine for tools which, being needed only occasionally by a man here and a man there, are handled economically only on an interchangeable basis. Tools that a worker may need regularly, like gages, wrenches and machine hammers, it is not practicable to control as outlined. The way one progressive factory handles this matter is indicative of the proper procedure. The steady requirement of small tools for each position is carefully ascertained, and the proper assortment is made up and issued to each man starting in. A neat little double-decked tray on rollers, suitably divided into compartments, is the container. An attached metal tag bears the list of contents with the identifying symbols. The recipient signs a receipt, and should he leave, he is required to account for every item. Each day a tool inspector passes around and checks over the trays, verifying the list and making note of any tools requiring attention. New tools are issued in exchange for these, which are subsequently gathered up, taken to the fixer, put in shape and finally stocked for reissuance. The adoption of this arrangement has proved a great time and money-saver.

To get more work out of small tools involves these steps: First, the determination of the one best tool for each purpose; second, the instruction of the men in the best method of handling; third, incorporating the best method in the shop's practice by follow-up and wage-incentive; fourth, specializing the care; and fifth, controlling storage and issuance closely, so that losses from whatever source are minimized. By these methods, the management serves not only the maximum convenience of the men, but its own interests as well.

XI

SHOP FURNITURE THAT INCREASES OUTPUT

EQUIPMENT that actually operates on the product is the first concern of the manufacturer. About material-handling equipment he is, perhaps, equally particular. Partly because their bearing upon manufacturing costs is less obvious and partly because the units are comparatively simple and inexpensive, the manager may, however, give only cursory attention to such auxiliaries as chairs, work benches and tables, stock bins, die and fixture cabinets, tool racks, tote boxes and similar shop furniture (Figure XXIV).

But a chair that contributes to the efficiency of many operatives for long hours, or a bin that is indispensable to proper stock storage, is perhaps as much a tool of production as the factory building itself. Sound principles of economy, therefore, dictate that its cost, quality and service be as fully considered as in buying the primary equipment.

''The right chair for the individual workman is often as important as the right tool with which he does his work,'' recently declared a Michigan furniture manufacturer who has given this matter close study. Many manufacturers are reaching the same conclusion. They are realizing that, far from being a concession to weakness, as old-time managers were wont to believe, seats for workers in many instances positively increase efficiency. Go into any factory where the work permits sitting and you will find, if the management has been lax in this respect, that the workmen have improvised seats out of old nail kegs and packing cases or have made themselves rough benches and stools. These makeshifts are perhaps better than nothing, but if chairs really are an aid to work, it is to the direct interest of the management not only to provide the chairs, but to see that, so far as practicable, they are scientifically suited to the purpose.

About the best example of a seat that is so "suited," is the adjustable-height, spring-back typist's chair, which not only is nicely studied out to avoid fatigue but practically enforces a correct sitting posture. The increased efficiency that has followed the use of this type of seat has done much to demonstrate the value of correct design. But it is in the busy telephone exchanges that the importance of a proper chair has been, perhaps, most conclusively shown. In the early days before control was centralized, sitting was impracticable. When it became possible to make the connection without moving from the spot, the gain was so great from constant standing to being able to sit at all that the exact type of chair or stool at first mattered little. Endeavors to improve the service, however, eventually compelled a close study of the seating problem. The result was the development of the adjustable-height, fitted-back chair we now know, without which the efficient operation of the many exchanges in our big cities, where the pressure is intense, would be wellnigh impossible.

WHAT HAS BEEN DONE IN FACTORY PRACTICE TO SEAT WORKERS PROPERLY

IN the factory field the necessity for absolutely correct seating is perhaps not so pronounced, but as the causes of inefficiency are traced down this problem is bound to take on increasing importance. Already in some plants it has been given considerable attention. At the H. Black Company, for instance, where the majority of the operatives are girls and the work such as to be done best when seated, the chair question has been uppermost for several years. Of the various types of chairs developed, the most satisfactory, according to Mr. F. R. Mott, equipment engineer, is a simple home-made affair—the frame metal and the seat wood—which has an adjustable-height, spring back. This chair, besides being extremely restful, is quite inexpensive to make—a qualification especially desirable in a factory furnishing.

To gain the advantage of sitting when the work requires moving about, the Waltham Watch Company has fitted with wheels the chairs of those who tend groups of automatic watch lathes. These machines are small and are mounted in a row on benches.

Points to Consider in Selecting Shop Furnishings

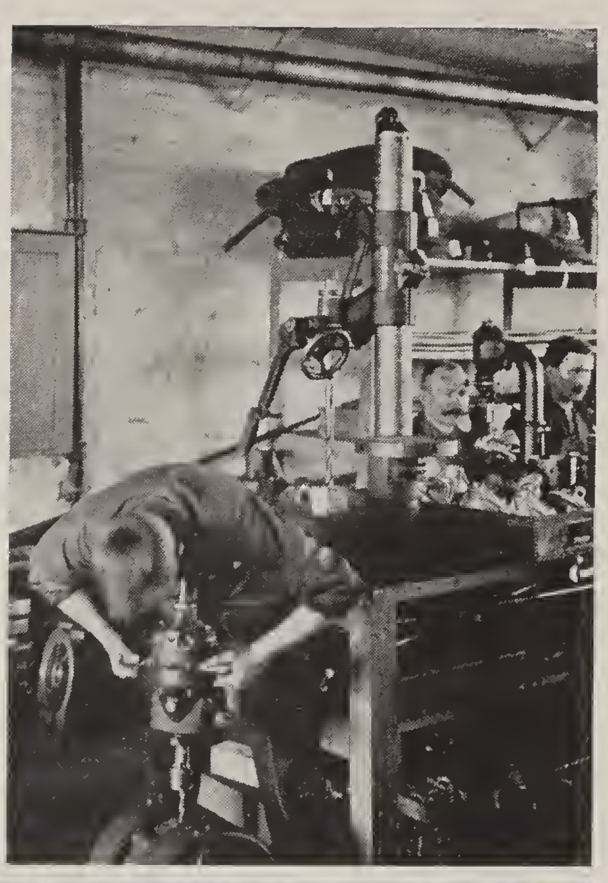
- **General**
  - Number. Present and Future?
  - Size and Shape. Conform to Present Equipment?
  - Location. How Much Space and Where?
  - Durability. Material and Workmanship?
  - Arrangement. Easily Portable?
  - Safety. Accident Hazard? Fire-resisting?
- **Particular**
  - Chairs and Stools. Comfortable? Adjustable?
  - Work Benches and Tables. Adjustable? Work Surface Sectioned?
  - Bins and Lockers. In Sectional Units? Compact?
  - Tool Racks and Cabinets. Convenient? Sufficient Protection?

FIGURE XXIV: Because auxiliary equipment, as chairs, benches, bins, and tool racks, are "non-productive," is no reason for their being selected without careful consideration of all the time and use factors, of which the most important are here suggested. Such equipment is vitally related to the resultant economy. Like buildings, they should be looked upon as "tools of production"

Close to and paralleling the benches a rail has been laid. This guides grooved wheels on the front legs of the chairs. The rear wheels roll on the floor. But small effort is required of an operative to pull herself along from machine to machine.

At the steel works of William Jessop and Company in England, by eliminating the legs and hanging the chair from overhead by a chain, tilt-hammer operators can remain seated while shaping long rods. The height of the seat is adjusted to the limb-length of the user by adding or removing a link or two of chain. By this device the efficiency of these operators was increased more than a third. Several other shaping mills, in America as well as abroad, employ similar means.

Where continuous seating cannot be provided by some such arrangement as described, it is still possible to gain some benefit by allowing the workers to sit down for a few moments now and then. When the sitting intervals are fixed by study, a net increase in individual output usually is the result. In one instance the operation of cleaning boilers was done in a quarter less time when chairs were provided and the men required to stop and rest at regular intervals. When the matter is left to



Portable power drills (right) enable one man to do the work of several with hand drills (left). The capacity of many hand tools has been so multiplied. In the well ordered tool room (below) at the Nonotuck Silk Mills, small tools used in common have each a definite place, which is marked by a silhouette of the tool itself. Before reissuance, edged tools are conditioned on the two machines shown

Chairs on rollers (top left) enable bench-lathe hands to tend several machines. A seat swung from overhead (top right) permits worker to be seated. Just below are packing benches with "manger-feed" excelsior container. A bench with a suction exhaust duct (bottom left) makes a dustless operation of rubbing castings. Compartments (bottom right) make working space individual the will or whim of the workers, the fullest benefit seldom is obtained. Taylor, it will be recalled, in his experiments with the pig-iron handlers at the Bethlehem Steel Works, found it necessary to stipulate when the men should pause to rest and for how long. The same principle holds here.

A still better way where applicable is to have operatives "spell" one another. This arrangement has proved effective at the Postum Cereal Company. Here the girls, who tend the moving belts which convey the product at certain stages in the manufacture, are relieved every two hours and take their places at a bench operation nearby. On returning to their station, after an hour seated at the bench, they are quite rested and in the meantime have not been unproductive. As a result they remain fresh and attentive throughout the day.

From these few examples the importance of properly seating work-people is evident—where continuous sitting is possible, the provision of scientifically suited seats; where standing is necessary, arrangements for sitting at intervals in restful chairs or for changing to other work intermittently which permits sitting.

WORK BENCHES SHOULD BE REGARDED AS MACHINES IN IMPROVING PRODUCTION METHODS

A PRODUCTION study of work benches and tables is equally profitable. A bench is a bench to the casual observer. To the keen manufacturing executive, however, it is a tool and the material of which made, the height, width, construction and location all are factors which for best results need to be carefully determined. Wood, formerly the only material used, is in growing disfavor not only because it is flame-fodder, but because, in food-product factories especially, it is unsanitary. Steel, moreover, makes a much more compact and neater appearing bench or table, as well as being more durable. Where, as in pattern shops, wood is desirable for the top, the frame can still be metal. In machine shops, benches wholly of steel are now common, and in many instances where wood is retained, the working surface at least is covered with some material as steel, slate, marble, glass or composition which is spark-proof and non-absorbent.

Height depends on the nature of the work largely. The closer to the floor or truck level, generally speaking, the better, to keep the lifting distance small. On the other hand, workers seated in ordinary chairs should not be required to bend too much, and when the material handled is quite light it may pay to let the machine-bed level determine the height. Transfer trucks or tables on wheels of the same height can then be employed and the bench hands provided with high chairs. This arrangement is found in the finishing department of the Hammermill Paper Company and has expedited certain operations between machines and benches considerably.

Again, production may be facilitated by having an adjustable-height bench. In the cleaning room of an ironware plant, the output of the grinders are increased many per cent by providing them with stands which can be raised or lowered at will. The lowest level permits the castings to be tipped on and off easily, while the higher levels bring the pieces up to a point best suited to the height of the individual grinder.

Width, too, should be considered from the workman's side. Wide benches are often used to permit operators to work on both sides. This is economical of floor space, but of questionable efficiency otherwise. Workers as a rule interfere less with one another, and oversight is simpler when the people all face one direction. Where this arrangement is not possible, a partition down the center is some help.

PROVIDING EACH WORKER WITH A SEPARATE BENCH OR DIVIDED SPACE PROMOTES EFFICIENCY

COMPLETELY to individualize the working space, however, requires that each person have a separate bench. In the ironware plant previously mentioned, the filers, chippers and rubbers formerly occupied long benches against the wall. When these were cut up into short sections, one for each man, and all faced one way, it became possible for the first time to order their work properly and to make studies preliminary to setting equitable piece prices.

When, of course, a bench supports a number of small machines driven from a common shaft, economy of drive practically necessitates not only long, but often double benches. In such cases the best the manager can do is to divide the space as has been suggested.

A good example of bench division is seen at the Champion Spark Plug Company, in the assembling department (Page 110). Here the partitions are arranged to form receptacles and holders for work, and incidentally give the operative a certain isolation. From a compartment at her right the assembler takes a part, and joining it to another part from a compartment at her left, combines these with a third part from a compartment in front, and places the finished assembly on an inclined rack also in front. This rack, in addition to being conveniently placed, also serves to cut off the view from the one opposite. When filled it is removed for tightening and inspection and an empty rack replaced.

At the Kohler plant, in the packing department the benches on which such articles as individual lavatories and sinks are crated or boxed, are arranged with the same consideration for the convenience of the worker. Separate benches are provided for every man. Their level is such that the packer nails at waist height yet the lift is short. At the back on a standard are shelves and compartments for packing materials, nails, labels, and so on. These it is the business of a store-room clerk to keep filled. Open crates are delivered on one side, product on the other. One trucker keeps supplying the stock, while a second removes the packed goods. This scheme was such an improvement over the old practice that a fifty per cent greater output of the packers immediately resulted. An even better arrangement is found at the Western Electric Company where conveyors, operating in connection with similar benches, supplant truckers entirely and the packers have no lifting at all to do.

Another bench in which use has been carefully considered in the design is in use at the Norton Company plant (Page 110). In rubbing the castings much annoyance was caused by the dust, the removal of which by the ordinary method was impracticable. By placing an exhaust duct underneath the rubbing bench and fitting a grating in the top, the difficulty was neatly solved. The dust is now sucked away quickly without either hindering the work or obstructing the light. In still another instance openings through a bench at intervals, and a moving belt underneath to remove finished product, brought about a large increase in output.

At the Ford plant a bench without a top is employed in assembling the magneto flywheels. The top members of the frame form a track along which the work moves as assembly progresses from operator to operator. A shelf underneath furnishes a stock storage which is both convenient and space-saving. Revolving benches or tables are also found in a number of places, which enable one attendant not only to supply with a minimum of effort a group of operators seated around the table, but virtually to control their pace.

Such benches as these are machines in a very definite sense. To the manufacturer who isn't getting as much utility as he might out of his benches, they may suggest improvements that will increase the balance on the right side of the ledger.

So it is with other shop furniture—stock shelves and bins, die and fixture cabinets, tool racks and tote boxes. Many of these, like chairs, are conspicuous by their absence in the older shops or else represented by makeshifts of the workmen's own contriving. In the more backward shops in this country, and even more commonly abroad, the custom still is to pile work on the floor. When the necessity for some system in the storage of materials and tools is seen, the home-made wood furnishing usually first makes its appearance. Eventually, however, the greater convenience, durability and safety of the factory-made steel article makes its appeal and in time is substituted. Consider, for instance, the advantages over wood of the standard metal tote boxes now procurable: not only are these more durable, sanitary and free from fire risk, but, built with slightly tapered sides, the empties nest as neatly as baking tins, economizing both floor space and handling labor. The standard metal bins, racks and cabinets have also the many advantages that go with the sectional bookcase principle on which they are constructed.

Of course, in some factories the requirements are so special that no standard article will answer the purpose. Then the resources of the construction department must be called into play or the help of a nearby jobbing shop enlisted. When this is the situation, managers are prone to build of wood because "it is cheaper" and "less trouble." At a small expense for angle irons and sheet metal, however, and a little ingenuity, home-made furnishings of metal may be built almost as cheaply and easily as of wood. Sometimes odds and ends of metal scrap can be utilized, with a reduction in cost. At the Seymour Manufacturing Company an extremely serviceable rack for the storage of sheet and bar brass and German silver was constructed out of old steel rails with heavy square timbers for uprights. Old angle irons and wrought-iron pipe, too, often work up to advantage. At the Rathbone, Sard and Company's plant, in Aurora, sheet-steel scrap is constantly accumulating from the manufacture of sheet-metal stoves and out of it, mostly, the ingenious blacksmith has fashioned a variety of shop furnishings—desks, stands, racks—even trucks, to suit their peculiar needs.

XII

KEEPING MACHINERY IN CONDITION

"MY only rule for selecting a security," a shrewd investor in railroad securities once said, "is to limit myself to those roads which show high maintenance charges." High maintenance costs on the mechanical equipment of a factory similarly are a good index of the value of the investment represented. Perhaps nowhere else is the ounce of prevention so well worth the pound of cure as in the upkeep of machinery.

The saw-mill manager recognizes this fact when he pays his saw filer higher wages than any other employee in the plant—in some instances more than the superintendent. But with such a man on the job, the saws are always cutting.

The wire shop superintendent recognizes this fact when he keeps his belts tensioned so that they will pull effectively, but still not be so tight as to bring destructive pressures on the bearings. He does not wait until a belt breaks or a bearing burns out, throwing a machine and probably several men out of work for hours. Neither does he put off belt adjustments until the machine stalls on even the lightest cuts. He anticipates such emergencies by taking systematic care of his belts.

But the must lucrative preventive repair of all is efficient lubrication. An automobile manufacturer some years ago made the remark, "If it were not for the little rocks on the road and the forgetfulness of the man behind the oil can, my cars would never wear out. And of these two, I would choose the rough road." That same manufacturer shortly thereafter out-distanced his competitors by being the first to introduce automatic lubrication in his cars. He had eliminated the man with the oil can.

In the metal-working line forced lubrication has made rapid strides, and today most up-to-date machine-tool builders advance this as their salient claim to favorable consideration.

Lately, too, woodworking machine builders have extended the use of oil cups on the bearings considerably. Sooner or later some enterprising designer will solve the problem completely by providing automatic central lubrication for the whole machine. The only task which will then be left to the oiler will be to keep an adequate supply of oil in the reservoir.

Manufacturers who have machines without the self-oiling feature may obtain considerable advantage, however, by fitting oil and grease cups on the bearings. Even when the job of oiling has been functionalized and a good man, trained in the fine points, has been made responsible for this part of upkeep, trouble ensues. Some machines contain as many as two hundred points requiring the systematic attention of the oil can. It is too much to hope that even a very good man will not occasionally overlook some of these.

Again, it is by no means assured that when oil is squirted into a duct it will strike home. The duct may be filled with a case-hardened plug of dirt. This is particularly liable to be the case in a woodworking shop, which is always more or less dusty even though it be equipped with an efficient exhaust system. Every woodworking man has had experience with burned-out bearings due to this cause. One manager, after having this experience with the same bearing twice within a few weeks, ordered an oil-cup fitted. The cost was ninety cents for material and labor. Re-babbitting the bearing cost nine dollars more. Considerable time has elapsed, but the bearing still is running without heating in the slightest. Oil and grease cups in this shop were subsequently fitted to all bearings.

Care of the cutting edges, too, is an important item which, strange to say, is neglected in woodworking shops, perhaps, more than in almost any other branch of industry. Practically every manufacturer uses some woodworking machinery. It may be only in the pattern shop, or the principal activity of the factory may be the fabrication of wood. It might be supposed that the incidental user is less attentive to these details than the man who has practically no other kind of machinery. On the contrary, the most flagrant inattention is found in plants equipped with a miscellaneous and great variety of woodworking machines. Until the millman finds a planer knife actually turning out rough stock, or a saw refusing to follow a line, nothing is done. By that time a quantity of material either has been ruined and finds its way to the firewood pile, or it must be set aside to be worked over into smaller stock. And often the quality of the lumber is blamed instead of the tools.

This is because, following the traditional rut, the average manager allows his interest in a machine to subside after it has passed satisfactory acceptance tests and the order for payment has been approved. But the upkeep of a costly woodworking tool is fully as important as the design. The progressive manager sees to it that, when a new machine is installed, provision is made at the same time for its proper care.

In order to get the maximum return on the investment and to use the labor in the shop to its full capacity, it is necessary that saws and knives should cut at close to one hundred per cent efficiency from the time the whistle blows in the morning until quitting time at night. Unfortunately, in many plants, the millman is left not only to judge when, for example, the saw at which he is working needs attention, but also to see that the required repairs are made. Beyond that, he is often expected to apply the remedy himself. Even if the mill man is competent to do this, it is obvious that he is not necessarily the man most interested in seeing that he gets the maximum output from the machine and so will not always do it.

To get the best results, the care of the cutting equipment should be made a separate function of the management and the shop. It should be some one person's business to see that the saws are right, and that the knives are sharp. Some managers fully appreciate this and have organized and equipped their plants accordingly. Realizing, moreover, that the location of the repair department is frequently as important, from the service viewpoint, as its outfitting and manning, they are particular to pick the most convenient point feasible. An instance of this strategy is seen in a number of mills using large, heavy band saws. Here the saw-filing rooms are found on the floor directly over the largest of the saws and trap doors allow the saws to be hoisted directly from the machines.

Belts formerly were an occasion of great concern to the factory man, and ten years ago an analysis of reasons for shop troubles would have been replete with belting experiences.

Shop No. 363 Description 4 Pl.M.M. Builder Price 1323 00 Date 12-31-13

Year	INVESTMENT			INTEREST			DEPRECIATION (on machine alone)			TOTAL INTEREST AND DEPRECIATION	
	Inventory	Auxiliary Equipment	Total	Rate	Amount Year	Amount Week	Rate	Amount Year	Amount Week	Year	Week
1914	$925.00	$2775.00	$3700.00	6%	$222.00	$4.27	10%	$92.50	$1.78	$314.50	$6.05

(1) Month	(2) Interest and Depreciation Expense	REPAIRS (3) Labor	REPAIRS (4) Material	REPAIRS (5) Total	(6) Grand Total	Hours Run (7) Standard	Hours Run (8) Actual	Cost Per Hour (9) Standard	Cost Per Hour (10) Actual	(11) Cost Efficiency %
Jan.	$30.185				$30.185	265	238	0.114	0.126	91
Feb.	24.22				24.220	185	113	0.131	0.214	61
Mar.	24.22				24.220	220	92	0.110	0.264	42
Apr.	24.22	$7.16	.02	7.18	31.400	205	126	0.153	0.249	63
May	30.185	.16		.16	30.345	265	181	0.114	0.167	67
June	24.22				24.220	220	184	0.110	0.182	84
July	24.22				24.220	210	171	0.116	0.141	83
Aug.	30.185				30.185	270	237	0.112	0.127	88
Sept.	24.22	.34		.34	24.560	210	194	0.117	0.127	92
Oct.	30.185				30.185	275	247	0.110	0.122	90
Nov.	24.22	15.11	.05	15.16	39.380	210	225	0.187	0.177	103
Dec.	24.22				24.220	210	200	0.116	0.121	96
Total	314.500	22.77	.07	22.84	337.340	2745	2208	0.124*	0.162*	80*
	✓			✓	(2)+(5)			(6)÷(7)	(6)÷(8)	(9)÷(10)
					✓					
								*= average figure		

FORM II: Every machine in use at the plant of the Bullard Machine Tool Company has its performance recorded on one of these cards. The machine whose repair charges are high is thus made prominent by this inefficient cost figure

A machine indifferently lubricated still will operate; dulled cutting edges still will produce work, though of inferior quality and with excessive spoilage. But a faulty belt makes sustained operation impossible. Every time the machine runs into a hard load it comes to a dead stop; the belt slips, breaks or comes off. Then ensues an annoying delay while hurried repairs are made. And even the smallest defect in the application means a measurable leak in power. Most industrial establishments, in spite of the wide adaptation of chain, gear and individual drive, remain large users of belting. Systematic attention to the belting is in most plants, therefore, of prime importance. This is particularly true of woodworking shops, where numerous belts still are necessary on individually motor-driven machines.

Just as in upkeep of cutting equipment, so with belting, the matter should not be left to the machine operator. Nor does it avail to trust it to a millwright who has no means for determining how tight a belt is or should be, and who tightens and repairs belts only when actual trouble has developed.

To Frederick W. Taylor, chiefly, belongs the credit for reducing belt maintenance to a science, and every manufacturer will do well to study his method.

Taylor's method is to ascertain the following information about each belt in the shop: (1) location; (2) purpose; (3) exact length over pulleys, measured with a steel tape; (4) width; (5) thickness in inches; (6) maximum and minimum tensions under which the belt should run. The limits of tension he ascertains from the determinable physical facts listed, simply and quickly by means of a belting slide-rule devised by Carl Barth. Quality, nature and length of service also are allowed for in this rule.

The next step is to prepare a year's schedule for overhauling each belt. On new belts Taylor sets these overhauling dates: after twenty-four hours of service; at the end of the second, fourth, eighth and sixteenth days respectively; again at the end of the first and second months; after that at the end of from two to six months.

After a belt has settled down to regular service, it may not need retightening oftener than once in three to six months. How often will depend largely on its quality and the kind of work it has to do. The proper interval is established by the length of time it takes for the tension to drop to the minimum.

To provide a means for accurately retightening belts Taylor devised a bench equipped with a pair of tension scales, and so graduated that the exact length of belts as determined by measurement over the pulleys can be laid off. The scales are set at the proper point, the belt fitted on the drums and the tension read off. The belt is then shortened until the proper tension is indicated.

In order to insure attention at the proper intervals a tickler is provided which has a pocket for each day in the year. Each day the necessary orders are issued to the belt fixer and when he returns his ticket with the accomplished repairs noted, the information is recorded on the data card or sheet and a new order is made out, ready for the next date on the schedule.

Any intelligent workman can be trained to take care of belts, once the necessary data have been compiled. By the tickler system, upkeep becomes automatic and repairs are made when they should be—before something goes wrong. Needless to say, the work should be done at such times as will interfere the least with machine operation. Managers who have reduced belt upkeep to a routine as described usually arrange to have the repairs made out of working hours.

A CARD INDEX FOR ANTICIPATING MACHINE REPAIRS

PRECISELY the same plan has been applied in numerous plants to the upkeep of equipment in general. Information relating to various features of machine operation is collected and upon it as a basis provisions are made for anticipating every conceivable repair. One manager employs throughout a tickler system similar to that described for belts. Each item of equipment has its card, upon which are noted all the salient facts—first cost, inventory value, maker, floor space taken, accessories needed, power required, depreciation rates. Columns also are provided for the entry of the cost of repair, including both labor and material. Every time a repair is made, a report is rendered on the general condition of the unit and the probable future need for repairs. On the basis of this a ticket is made out and filed in the tickler. Each morning the manager's assistant places on his desk the tickets filed for that date. As he reviews these the manager refers to the machine-record card, and to the reports on previous repairs, if need be, to refresh his memory. If he thinks immediate action essential, he puts the ticket into the order channel. The maintenance department with this ticket in hand makes a special inspection of the particular machine at the earliest opportunity, attends to any small repairs found necessary and reports back any need for further attention. Any extensive repairs deemed advisable are then made the subject of a special maintenance order which is planned, scheduled and estimated as to time and cost just as is any special order. By this plan close control is extended over the activities of the master-mechanic's crew, which in the average factory is left pretty much to its own devices, with the inevitable result of excessively high upkeep and repair expense (Form II).

In this particular plant, moreover, the workers are paid either by the piece or on a bonus plan, and they can be depended upon to follow up the management closely and hard on any laxity or inefficiency in equipment upkeep. That is the management's part of the bargain and naturally the workers whose ability to earn good wages is predicated upon the mechanical equipment being always in first-class condition, are intolerant of even the smallest lapse from standard. They are, moreover, exceedingly careful in their own use of tools not to bring on prematurely the need for repairs through rough handling.

To facilitate prompt repairs should breakdowns occur, what is in effect a "first-aid-to-crippled-machinery" stockroom of repair parts is operated. Here is kept one or more duplicates of every part subject to such wear as periodically to require renewal or that experience has shown is most likely to give out suddenly. How many of a single part are kept on hand depends, of course, on the number of machines using that part and on the relative failure hazard—the greater the number of identical machines, the smaller the relative number of the part necessary. This fact, too, is always kept in mind when purchasing or building new equipment. Further to facilitate prompt repairs in case of emergency, "first-aid" kits of tools are kept in readiness on special trucks, and these often have proved their value.

To keep ahead of conditions that cut the output of the machines, to centralize repair work, to minimize wear and tear, and to make repair parts completely interchangeable on similar units, is an aim in this and every well maintained shop.

Part III

INDUSTRIAL TRANSPORTATION

AUTHORITIES AND SOURCES

FOR PART III

Chapter XIII. Developed from studies in the Barrett Manufacturing Company, Universal Portland Cement Company, Hendee Manufacturing Company, a bottling works, and others.

Chapter XIV. Based on studies made at the plants of the Seymour Manufacturing Company, Continental Motor Company, Atlantic Stamping Company, Pierce-Arrow Motor Car Company, Home Furniture Company, Sterling Piano Company, Detroit Axle Company, Chalmers Motor Company, Plimpton Press, Brown & Sharpe Company, and a metal goods company.

Chapter XV. Based on studies made of the Philadelphia Navy Yard, and the plants of Prime Steel Company, Cutler-Hammer Company, M. A. Newmark Company, Cincinnati Milling Machine Company, Ford Motor Company, Duff Manufacturing Company, Wolverine Brass Company, Tremont Manufacturing Company, Willys-Overland Company, Lodge & Shipley Company, Hart-Parr Company, the Industrial Works at Bay City, Michigan, a wire mill, and an eastern tube mill.

Chapter XVI. Based on studies made of the following plants: Hart-Parr Company, Pierce-Arrow Motor Car Company, Willys-Overland Company, Louisville Car Wheel and Railway Supply Company, National Cash Register Company, Bush Terminal, Ford Motor Company, Trussed Concrete Steel Company, W. M. Shoch Company, Hendee Manufacturing Company, Hydraulic Pressed Steel Company, Baldwin Locomotive Works, National Acme Company, Utica Drop Forge Company, Westinghouse Electric & Manufacturing Company, Clark Brothers, Boston Manufacturing Company, Seymour Manufacturing Company, Philadelphia Navy Yard, York Manufacturing Company, and an eastern machine shop.

Chapter XVII. Based on studies of methods in the plants of the Sherwin-Williams Company, Van Camp Packing Company, Postum Cereal Company, National Cash Register Company, Western Electric Company, National Acme Company, Lukenheimer Bearing Company, Brennenan Bakery Company, Kohler Company, Ontario Biscuit Company, Home Furniture Company, Pierce-Arrow Motor Car Company, a drug and chemical company, and others.

XIII

FEWER MOTIONS IN MOVING MATERIALS

MATERIAL handling is rated in an accounting sense as a non-productive operation. For that reason it is sometimes given little thought. But as numerous instances have shown, it is well worthy of analysis; indeed the elimination of superfluous motions in moving work has yielded savings equal to, if not exceeding those gained by close study of processing times.

These savings have been made—

First—By straightening out the kinks in the flow of production and eliminating backhauls.

Second—By shortening the time and space intervals between successive operations.

Third—By eliminating the picking up and putting down of work and so far as is practicable keeping it on the same level throughout the sequence of operations.

Fourth—By reducing the number of times work has to be handled and rehandled.

Fifth—By shouldering the burden of moving materials and product as largely as feasible on mechanical devices.

Sixth—By making gravity supply the energy of propulsion wherever possible.

These six principles are fundamental and should be held steadfastly in view in working out all problems in factory transportation. Maximum efficiency and economy are then certain to result.

No cut-and-dried solution exists for any particular case. Usually the maximum saving and the greatest convenience are afforded by a combination of several means, some and not the least of which may be home-made. The best solution, at any rate, only results from a careful adjustment of the means to the conditions in each instance, following constantly the simple principles stated above.

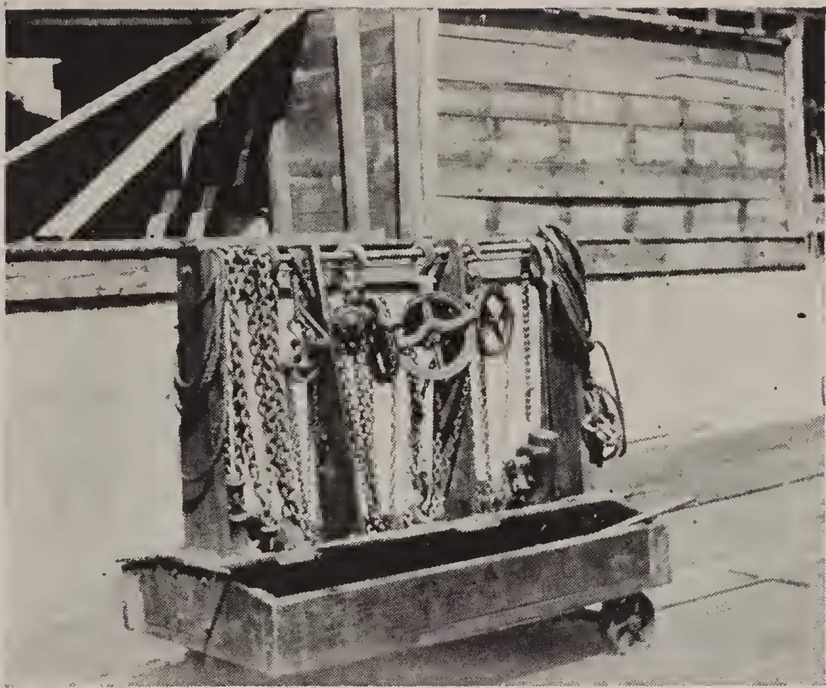
Hand carriage was, of course, the primitive method of moving materials. And the husky navvy with his sinewy arms still holds forth in some establishments. Taylor in his experiences with the pig-iron handlers at the Bethlehem Steel Works demonstrated how greatly the efficiency of such labor can be increased. But a simple crane fitted with a magnetic lifting device is the equal of a score of the stoutest and most carefully trained man-handlers. So whenever labor is still employed extensively to move materials, the possibilities of mechanical substitution are indicated, with attractive resultant savings.

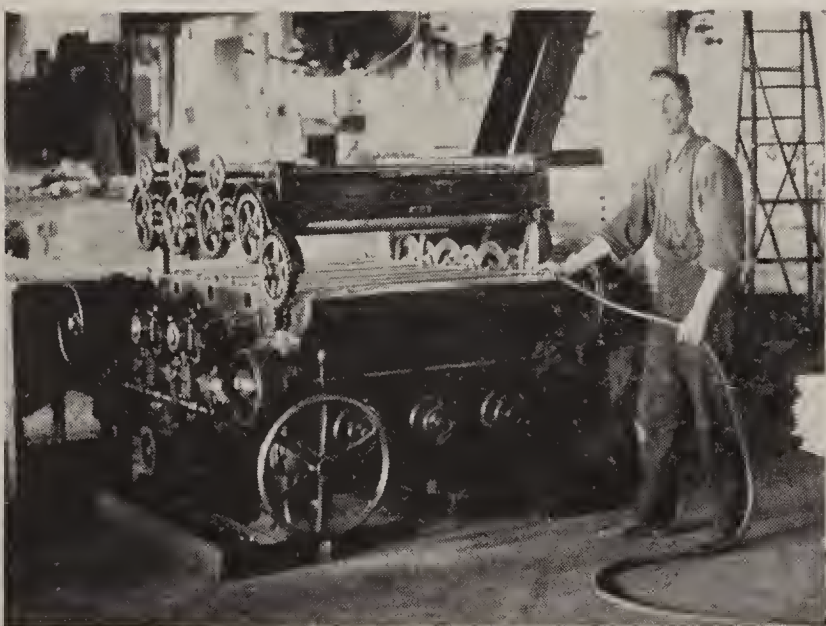
HIGHLY DEVELOPED TRANSPORTING EQUIPMENT MAY NOT ALWAYS BE ECONOMICAL

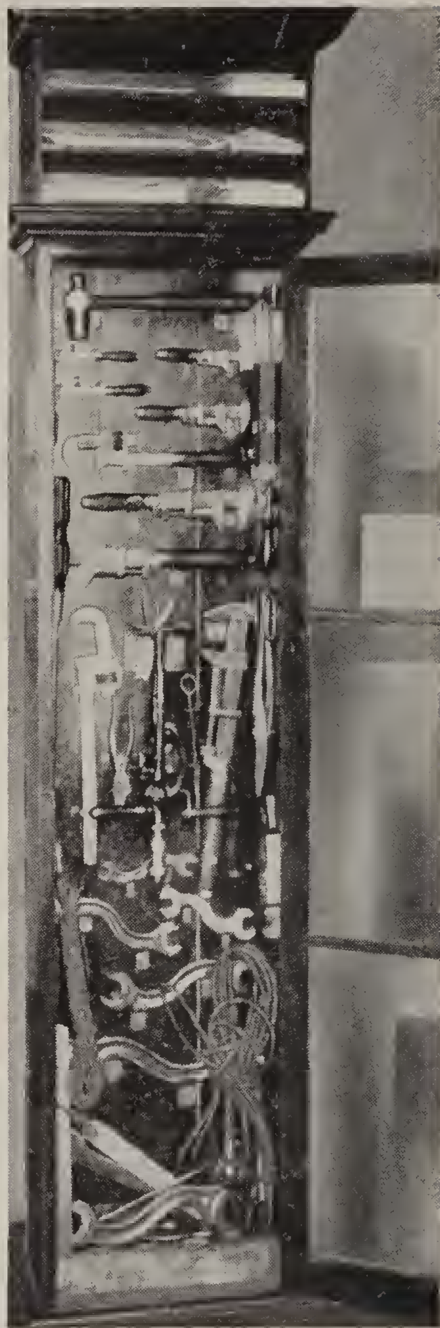
IT is possible, on the other hand, to go too far in the opposite direction—to over-mechanicalize, so to speak. Often a more primitive device, or handling at some stage in the traditional way, works out to be cheaper than some elaborate, exquisitely wrought-out, specially designed contrivance, entailing a large investment in heavily depreciating equipment and a high power expense for operating. Such devices may greatly facilitate production in terms of square feet of floor area, and make for other economies; but when the interest and depreciation on the expensive equipment, plus the power and repair charges, are weighed in the balance the actual economy may lie in the old way, or at least part-way between.

Thus, in case of the foundry cited in Chapter VI, an installation of costly conveyor equipment for handling the molding sand did not "prove in." This conveyor, a belt-type, transports molding sand from the conditioning room to the molding floors and automatically distributes it to hoppers from which the molders draw as needed. On the return, passing underneath the foundry floor, the belt receives the sand which drops through

Permanently wired tables and a portable test-instrument desk (lower left) permit small motors to be tested together. Another company (lower right) uses dynamos in a similar group test, and pumps the current into the power mains. Direct reading scales and beam scales in the open (left above), stock bins on wheels and galvanized iron lockers for stock (right) cut costs







This emergency truck (upper left) carries chain-falls, pump and screw-jacks. The emergency tool cabinet (right) at the New York Edison Company also facilitates quick repairs. Frequent use of compressed air (left) particularly in woodworking plants keeps the machinery free of dust. Below is the well appointed repair shop of the Douglas Shoe Company gratings and returns it to the conditioning apparatus. By the help of this device the productivity of each square foot of molding floor was increased several-fold and the direct labor cost of molding cut in two. The manager naturally was elated. Shortly afterwards, however, a new cost system was installed, and when the true cost of molding pieces under the new arrangement was disclosed, to the manager's surprise and chagrin it

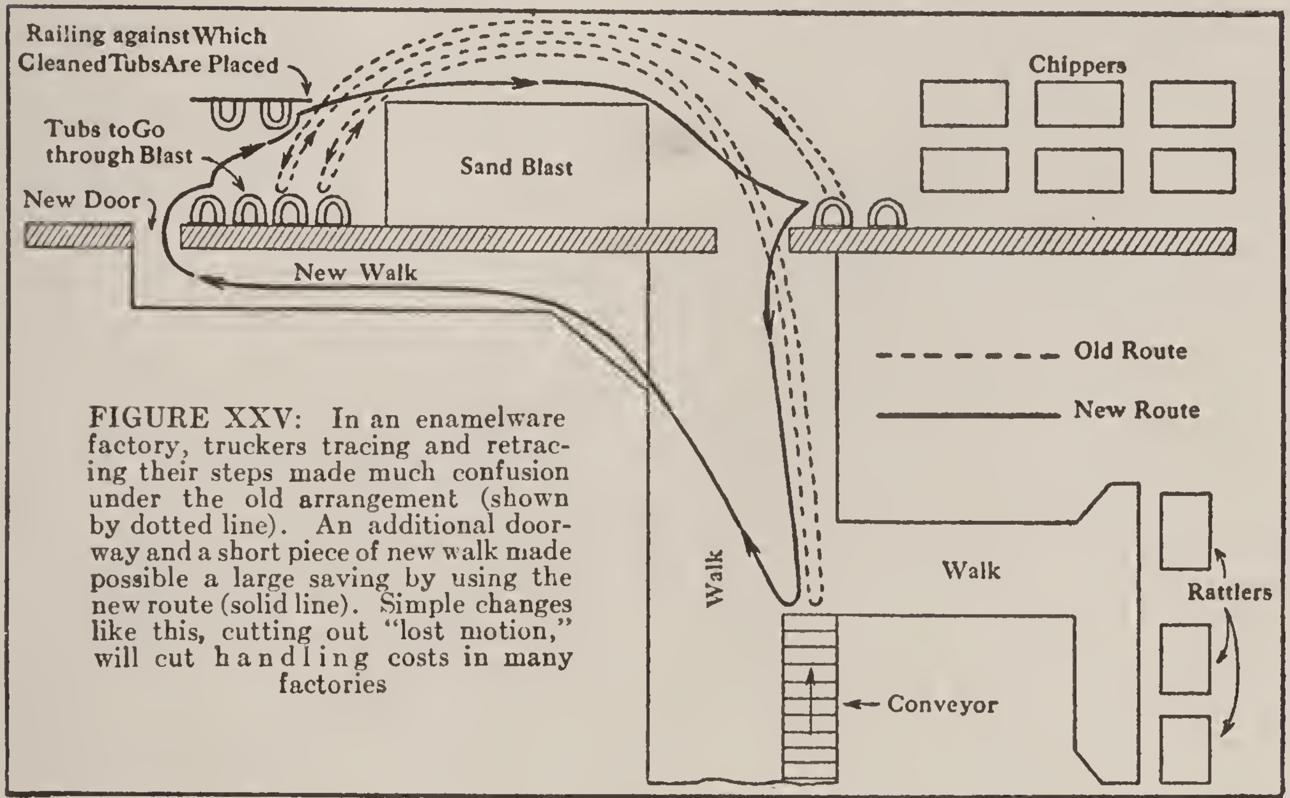


FIGURE XXV: In an enamelware factory, truckers tracing and retracing their steps made much confusion under the old arrangement (shown by dotted line). An additional doorway and a short piece of new walk made possible a large saving by using the new route (solid line). Simple changes like this, cutting out "lost motion," will cut handling costs in many factories

was higher than under the old. It was shown that the cost under the new arrangement would only be less when the department should be put on a two or three shift basis.

Had this manager based his improvement upon carefully prepared cost figures, instead of upon his more or less blind bent to resort to mechanical means wherever and whenever he could, he would not have made the change—at least he would have deferred it until the necessities of the business justified continuous operation.

And so it works out in many instances. It is a case of "looking before you leap," always. No manager is warranted in making a change in his transportation methods, unless it be so simple and inexpensive a change that the economy is off-hand evident, without a careful comparison of the actual cost under present conditions with the actual total cost, as closely as it can be estimated, under not only one, but every available alternative. Often, as in the instance cited, the choice made will be found to give worthwhile economies only when the transporting equipment is used continuously. Time may be saved, labor lessened, production increased thereby; but unless with these savings and this increase in output capacity, a considerable reduction in *total* cost also results, it will probably pay better to expand along old lines—or at least by making changes which require little or no additional investment.

That a primitive method of moving materials may, on occasion, be more economical than any modern contrivance is illustrated in the case of another foundry, whose output is mostly small and medium-sized castings which one or two men can load. A horse and cart, the manager of this establishment has found, offer the greatest economies in the transportation of his castings from the foundry floor to the cleaning and machining room. By using several carts, the horse is kept busy hauling while empties are always waiting to be loaded.

On the other hand, if the castings were so large and heavy as to require mechanical power to lift them, an overhead crane, a moving sidewalk conveyor, an industrial railway, an overhead monorail system, motor trucks, or hand trucks might offer the greatest convenience and maximum economy, depending on the length of haul and quantity of castings to be handled in a given length of time.

Thus it is that in particular instances local conditions, the nature of the business, the policy of management, the hours of operation, the value of the ground, or what not may be the determining factor among the many points that must be taken into consideration and carefully weighed in the balance if a correct mechanical solution is to be reached.

SIMPLE CHANGES IN EXISTING ARRANGEMENTS OFTEN CUT HANDLING COSTS

IN many instances the best solution does lie along the line of improving existing conditions or equipment, and usually in all cases the first steps may well be in this direction, even though at the time the ultimate solution is in mind. For example, in

Building a Factory Around Its Transportation System

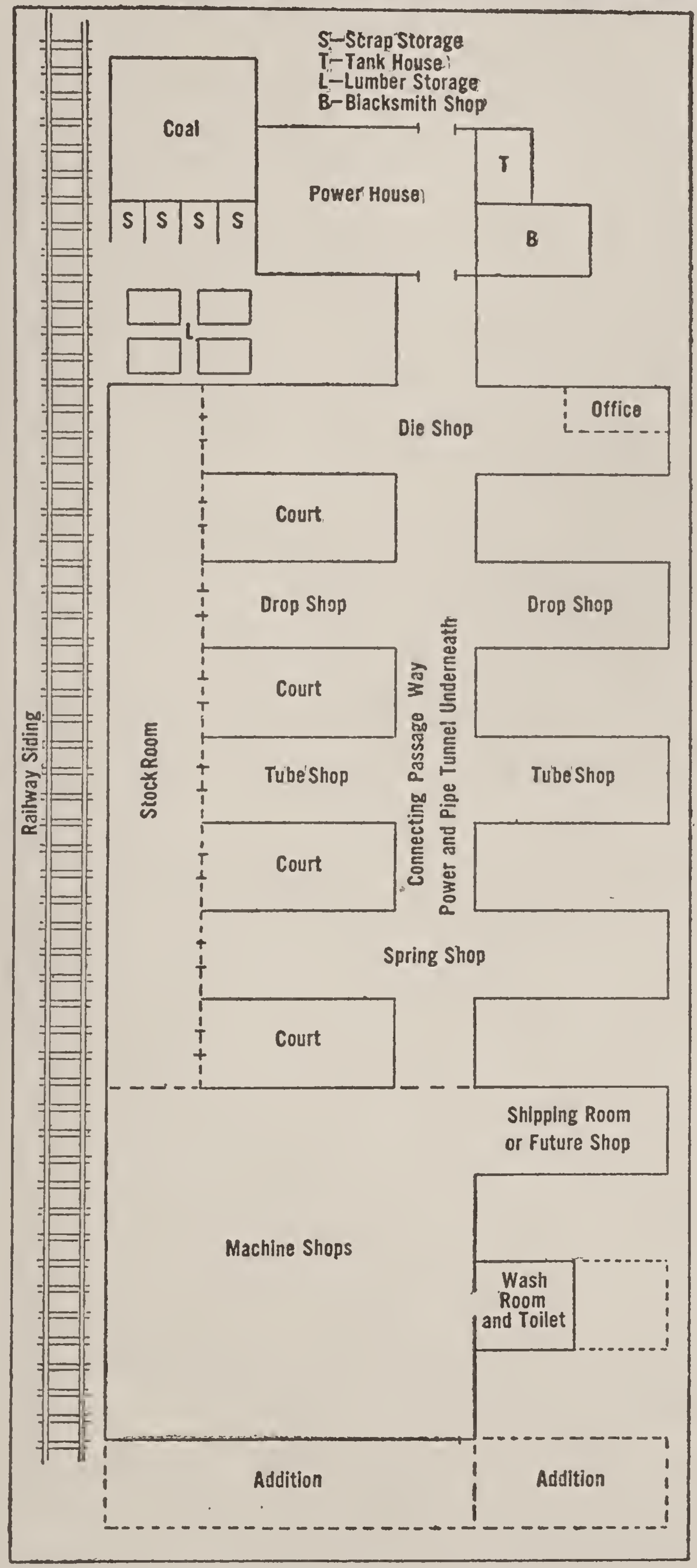


FIGURE XXVI: Transportation was recognized in its true importance in the new plant of the Hendee Manufacturing Company. First the system—a motor truck with trailers—was decided on; then the thoroughfares were laid out; around these as a backbone the machinery was located; finally, the housing structure was determined in accordance. Plenty of land permitted single-story construction, giving grade-level transportation throughout. Enough trailers are provided so that they may be used as serving platforms at machines. A single motor truck, driving and steering on all fours, in combination with these, handles the entire movement of material.

On the railroad side, thrown like a header across the several departments and parallel to the connecting passageway, is the stockroom, with doors leading to each department. Portable loading platforms permit freight cars to be emptied so rapidly that the railroad finds it cheaper to allow its engine to remain rather than return later. Openings through the wall separating the stockroom from the workshops, permit stock to be taken directly from the racks and fed into cut-off lathes. Doorways and thoroughfares are so liberal in size as to permit full-sized motor trucks to enter freely one ironware plant, the transportation of bath tubs from the molding floors to the sandblast room is accomplished by means of a moving sidewalk conveyor. This ends forty or fifty feet from the sandblast room and automatically dumps over a bumper, from which the tubs are immediately removed on two-wheel trucks. Ultimately it is the intention to pick up the tubs at this point and carry them through the sandblasts on an overhead monorail system. The manager, however, was not ready to take this final step, because experimental work was under way which might have important bearing upon how the pieces are to be handled in the sandblasts. But he felt there must be some way of improving existing conditions other than by installing the overhead system.

Investigation disclosed that a great deal of time and labor was being expended at this point. For one thing, the truckers were going and returning through the same doorway (Figure XXV), and this made considerable confusion and delay. Accordingly the manager had a truck-way built around through another doorway, to the other side of the blast room, and instructed his truckers to enter through this doorway, returning through the first.

It then became possible for the truckers to pick up a cleaned tub every time they deposited a dirty one and deliver it to the chippers, who occupied space close to the first door. Formerly, separate truckers had been required for this transfer operation. Thus, not only was a vast amount of confusion eliminated, enabling four truckers to do the work that had previously required six, but two other truckers were displaced who had been tied up most of the time trucking cleaned tubs to the chippers. Here was a straight saving of service of four truckers which, at $1.50 each, had a money value of $6 a day, or $1800 a year (on the basis of 300 working days), without a penny additional investment other than the few dollars expended on the new bit of truck-way and for a pipe-railing near the blast room against which cleaned tubs temporarily could be stacked.

But this was not all. The investigator, noting further that considerable time was lost in loading and unloading the tubs, owing to the inaptness of the trucks for handling conveniently this particular shape of article, next proceeded to devise improvements in the truck itself which would do away with this awkwardness. For the ordinary square toe he substituted a pronged one. A bath tub could then be loaded without turning it around from the position which it occupied when delivered from the sidewalk conveyor. It could also be stacked against the wall and nested with other tubs directly from the truck without reversing as formerly. Waist-high legs were also fitted to save stooping. The changes were completed with the addition of a super-frame of angle irons and rollers, as shown on page 145. The front part or ''leg'' of this frame is almost vertical so that when a tub is picked up it has only to be tipped back a few inches to take a bedding. The other part of the frame is horizontal when the truck is at rest and serves another purpose as will be seen later.

These simple changes, the cost of which was trifling, not only saved time in loading and unloading, but also took the burden of carriage almost entirely off the man, so that the main task left him was to furnish propulsion. Two men were now able to handle all the lugging at this point. Thus was effected an additional saving of $3 a day, or $900 a year, making a total daily saving of $9 and a yearly saving of $2700.

Ultimately the entire movement of tubs in the cleaning and machining department was handled with identical trucks, resulting in further savings. In case of some of the machines, the truck also was found to serve admirably the purposes of a loading platform, supplanting hand or pneumatic hoists. This was accomplished by revolving the tubs about the angle of the super-frame until they rested on the horizontal part of it. As the turning point comes approximately opposite the center of gravity of the load, the tilting takes little energy. Likewise small effort is required to slide the lading from the truck to the machine bed, because of the rollers. The operators can now load and unload their machines without the aid of either lifting tackle or helpers and a substantial increase in their output has resulted.

Thus all told fewer men were required for trucking; fewer mechanical devices and less power were required for handling pieces on and off machines; and the machine operators had more time and energy for productive work. And these benefits followed the application of a little common sense in improving a very ordinary piece of equipment, better adapting it to its work, shouldering on a mechanism the burden of carriage, and on gravity the burden of motion.

In a woodworking shop another common piece of equipment —a work table—was made to do duty as a transporter merely by fitting large casters on the four legs. In this way picking up and putting down, and handling and rehandling of material, was largely eliminated. Not only was the expense of moving work cut in half, but operation as a whole expedited.

HOW TRANSPORTATION MAY BE MADE TO DOVETAIL WITH PRODUCTION

IN other factories, where the product is light and carriage by hand is not burdensome, the cost of transferring goods in process from one operation to the next has been reduced to the minimum by careful arrangement of machines, so that the work progresses without covering much ground at any stage. In fact, it is by no means impossible, in many cases, so to lay out departments that operatives on one operation feed from the finished pile of the preceding. The transportation problem in such cases then resolves itself into getting goods from one department to another most quickly and economically.

In many plants, too, the moving and the processing operations have been so interlocked as to have the former exert a marked influence on the economy of the latter. In fact, a scientific transportation system re-orders the entire shop and to a greater or less extent sets the pace. So conversely, a slovenly and antiquated system may so clog the flow of production as to vitiate to some degree the benefits of modernized methods in other particulars. If the production links have progressed to the "steam" age, so to speak, while the transportation links are still in the "horse" or "manual" age, harmonious co-ordination of effort is practically out of the question. The net result can only be a slowing down of the entire establishment to the "horse" or "manual" pace.

Again, the transportation links often become the determining and dominating factor. For example, in an operation in a bottling factory, an endless horizontal belt conveyor, employed to transport cases of bottles from one stage to the next, sets the pace for both stages, keeping the two sets of operatives working in unison. For if the bottles come around more rapidly than the second set can take care of them, they continue on around again. Thus the operatives at the initial point are advised either that they are feeding too fast or that the second set are not holding their own. Conversely, if they do not come around fast enough, the second set are not slow in making known the fact; for, being on piecework, their interest lies in seeing that the bottles come around as fast as they can handle them.

Transportation is seen at its highest development, perhaps, in a cement or food-products mill, where the material is granular from start to finish, requires at no point handling by hand, and can be moved from each succeeding operation to the next by some type of automatic conveyor, either belt, bucket, screw or pipe. The conveying system in such plants is at all points nicely adjusted or proportioned to the speed or capacity of the processing machinery so that the whole plant operates, processing and transporting equipment together, as one carefully coordinated machine.

Control of labor is greatly simplified where such an ideal relation of processing to transporting equipment obtains. In fact, as one manager whose plant operates under this fortunate condition stated to the salesman of a firm of production engineers, who was soliciting the opportunity of improving his labor situation: "We have no labor problem. Our machinery is almost entirely automatic; it sets the pace; the workmen simply conform."

In these instances transportation has been considered in advance and the design of buildings, type and layout of machinery, sometimes even the selection of site have been determined with the requirements of economical material handling always uppermost. Where, too, the nature of the industry dictates crane handling, transportation usually receives thorough consideration in advance. (Frontispiece and Figure XXIX, page 167.) In the lighter industries, however, the fact that the materials can be lifted by hand and any light truck will do for moving them leads altogether too frequently to overlooking or undervaluing the importance of transportation. This is a mistake. Regardless of the nature of the industry, the problem of material handling is always a fundamental one, and leaving it to afterthought invariably results in faults such as have been mentioned earlier in this chapter, the subsequent correction of which is usually both difficult and costly, to say nothing of the steady loss from the time operation is begun until the shortcomings are discovered and remedied.

The transportation system is really the backbone of any factory. It should be seen as such and the entire layout of the factory shaped to conform with its requirements. An excellent example of the correct procedure is seen at the plant of the Hendee Manufacturing Company (Figure XXVI, page 131). Here the backbone simile is not figurative but actual. If the transportation system were to be sketched in on the drawing in thin bands of color, the system would present an appearance not unlike a spinal column with its vertebrae.

What applies to the transportation inside the factory applies with equal force outside the factory, in handling incoming and outgoing freight. For, looked at broadly, the transportation links at either end of the productive processes are merely continuations of those between, and for best results should be worked out along similar lines and to the same degree. If left undeveloped, while the links within the factory are highly developed, the retarding effect will be felt all along the line. Parallel development realizes best results.

XIV

MAKING THE MOST OF HAND TRUCKS

HAND trucks of one description or another are at once the commonest and oldest kind of transportation equipment in the factory, and a large variety of types have been evolved to meet different conditions. How one manager took an ordinary two-wheeled truck, and by a few simple and inexpensive changes transformed it into a type ideally adapted for his special purpose has been told. In other instances this type of truck has been made to give vastly better service, at a large economy of time and labor, by utilizing it in connection with a mechanical haulage device, to adapt the truck for full loadings on a steep ascent or descent, or to haul it over long horizontal stretches without human aid, save at the start and at the finish.

In the ordinary factory the two-wheeled truck, however, has a limited application. Even for loading finished and cased product, it is giving way to conveyors of the continuous and automatic type, by means of which even fairly large articles are made to flow in practically unbroken streams from warehouse into freight car or wagon-truck. Two men in such case—a loader and an unloader—are usually all that are necessary to keep the equipment busy, doing work that a dozen truckers with the old equipment would not be able to do as quickly. Similarly, in unloading, a conveyor system may often be advantageously adapted, saving trucking labor and greatly accelerating the speed of the operation.

The two-wheeled truck, moreover, while ideally adapted for quick and easy loading and unloading, is not a scientifically designed device for wheeling, any more than the two-wheeled horse cart, for the reason that too much of the load is borne by the trucker. As a general proposition, mechanical devices which presuppose the expenditure of a great deal of muscular energy are to that extent faulty and uneconomical. Man power is best expended in the work of forward travel, to overcome tractive resistance, but not to oppose gravity directly. The ordinary wheel-barrow, of limited application in the factory anyway, is open even more to the same objection.

As a result trucks with level beds on four wheels—in effect, platforms on rollers, have in many instances very largely replaced the more primitive two-wheeled type. Such trucks have been developed in great variety, to suit different needs. There are trucks adapted for heavy loads and trucks adapted for light loads; trucks with wooden platforms and trucks with metal platforms; trucks with stationary beds and trucks with roller beds; trucks with handles by which to pull them and trucks without handles which must be pushed; trucks with low platforms—as low as it is possible to have them and yet get wheels under them—and trucks knee-high and higher; trucks with large wheels and trucks with small wheels; some iron-shod, others tired with wood or fibre: each in turn peculiarly adapted to some situation (Figure XXVII).

HAND TRUCKS SHOULD BE SO LIMITED IN SIZE THAT ONE MAN CAN HANDLE THEM

GENERALLY speaking, trucks of this description should be so proportioned that one man can without special difficulty push them when loaded to the maximum. When so large, either in size or capacity, as to require two or more men to propel them they almost invariably are unsatisfactory in operation. The men are forever waiting on one another and while a few exert their full force, the majority merely make a pretense and a simultaneous full effort is a happy chance. And yet in some factories the aim seems to have been to get the largest sized trucks possible, in order to carry a maximum of material each trip, regardless of the fact that on occasion as many as a dozen or more men might be required to move them.

In an eastern brass mill the favorite truck was about the size in ordinary baggage service. Empty it weighed nearly a ton; with load, three to four tons. Four and five laborers were regularly required to man a single one of these, and in transferring metal from one department to another, where there were slight inclines to be traversed, ten or a dozen men were often needed. A heavy overhead for handling labor, which a new cost system made evident, finally proved to the management that something was wrong with the transportation system.

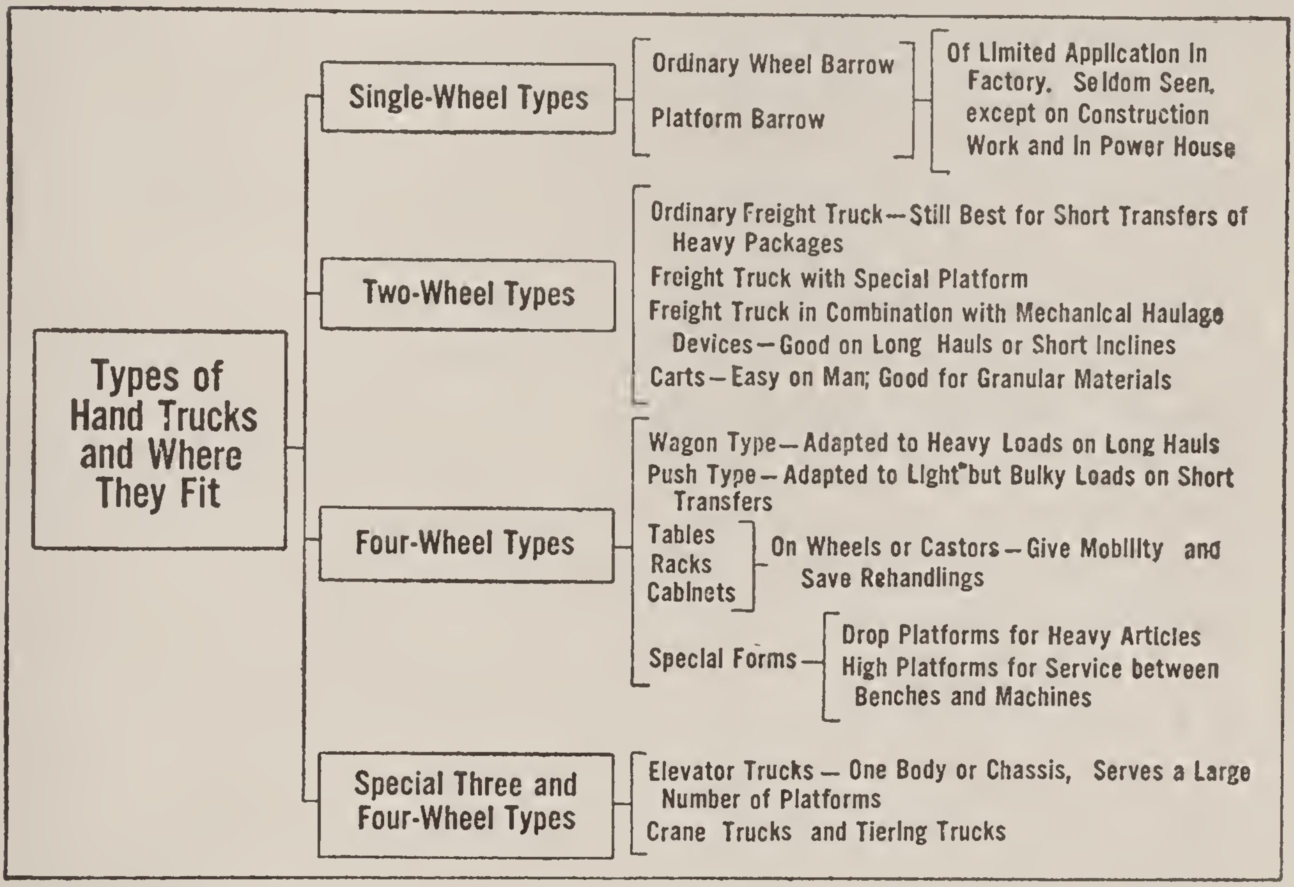


FIGURE XXVII: Hand trucks, the oldest device for transportation in the factory, while they are giving way to conveyors, industrial railways, motor trucks or overhead carriers in some instances, still continue to hold their own for many purposes. Even the old-fashioned two-wheeled truck, for short transfers of moderately heavy articles, is still king. The recent development of the elevating type of truck greatly broadens the application of this class of equipment

After some study and investigation a much smaller and lighter type of truck was adopted, with a platform of the same width and height but only half as long, and fitted with spoked wheels running on ball bearings—a light, substantial affair, capable of carrying about two tons of metal. This truck one man could pull on the level, and when the inclines were eliminated extra help at no point was required. A saving of nearly fifty per cent in the trucking labor resulted.

Nor was this the only saving. So greatly did the old trucks encroach on the floor space that the passageways almost constantly were congested, as were the aisles around the machines, seriously impeding the flow of production. Adding to the confusion and delay was the constant scramble of machine operators for empties to receive their output. The shorter trucks took up so much less space, and could be handled with so much greater facility around the machines, that the worst of this congestion was eliminated. More of the smaller trucks were had, also, so that the operators seldom had to hunt or wait long for empties.

A few long trucks were still required to handle long bars, but the bulk of the product, it was found, could be taken care of on the shorter trucks, and all of it could be so handled up to certain stages.

The fact that long trucks were required to handle some of the product at certain stages, it seems, had been the reason originally for adopting this style. The management was averse to having several different types, so they had standardized on the long one; which shows that standardization, while in the abstract excellent, may on occasion be overdone.

FACTORS THAT DETERMINE THE BEST HEIGHT OF TRUCKS FOR LOADING AND UNLOADING

ANOTHER important point to consider is the height of platform. The lower it is the greater the ease of loading and unloading heavy materials; and in case of light materials, as for instance wood parts in a furniture factory, a low platform allows high piling. If trucks are to serve as feeding and receiving platforms at machines, on the other hand, a low level is disadvantageous.

Truck platforms for economical handling should be about the height of the machine bed or work bench which they serve, so that material can be slid from one to the other. If used only for transporting, and loading and unloading is by hand, a height of twenty-four to thirty inches is most convenient, since this is the height at which a man carries things at arm's length. A lower level compels him to stoop, and this is hard on the back.

A higher level is equally inconvenient, putting an undue strain upon the forearms and lower abdominal muscles. In a given case usually a compromise is necessary between these various conditions.

A disadvantage of the low platform is the restriction placed upon the size of wheels. This is immaterial if only short distances are to be traversed. But if there are long trucking stages, trucks with fairly large wheels are necessary for economical operation. Tractive effort decreases with the size of wheel. A small wheel must revolve several times to cover the distance a large one negotiates in one revolution. Yet hardly more energy is required to turn the large wheel once than the small wheel. Then, too, large wheels traverse easily floors so rough and rutty as seriously to impede the progress of small wheels.

Over smooth floors, and with ball or roller bearings, small wheels are nearly as efficient as large wheels over indifferent surfaces and without ball or roller bearings. Such bearings, however, are desirable in any event, since they not only decrease greatly the effort required for propulsion, but make operation comparatively noiseless; and this in a factory where the sources of inefficiency are being hunted down relentlessly, is an important consideration.

How the wheels are tired also affects the noiselessness and economy of operation. Metal tires make the most noise and are also hardest upon the floors. Yet they are most generally in use. Of late, however, soft tired wheels have come somewhat into vogue. These leave nothing to be desired from the standpoint of noiselessness; moreover they are easy on floors; but the trouble and expense of keeping soft tires in condition deters their general use. Then, too, soft tires offer somewhat greater resistance to motion. A happy compromise, therefore, would seem to be afforded by wheels tired with fibre or wood. Wheels so tired are very satisfactory for heavy loads and are particularly good under wet conditions. They operate as easily as metal tired wheels, are comparatively noiseless in operation and are much easier on floors.

Trucks, like all other equipment representing investment, require to be kept busy as continuously as possible if they are to pay for themselves. One way to make the trucking equipment "earn its living" is to limit the number of units sharply. This used to be very largely the practice with factory managers in their laudable aim to retrench on all non-productive items, and it is still true with some executives. But they are more and more realizing the false economy of this. Study of the time and labor consumed in merely picking up and putting down work, in handling it off and onto trucks, piling and re-piling it on floors, has helped them to this conclusion.

So we now find managers going to the opposite extreme—in an endeavor to eliminate the great loss in time and labor involved in rehandling material, providing practically an unlimited number of trucks. In some factories, indeed, trucks are used to such an extent for other purposes besides transportation—for feeding and receiving platforms at machines, for stock repositories in stock and shipping rooms, and so on—that virtually the entire floor seems on wheels (Page 146).

In woodworking establishments, for example, study has shown that it costs fifty cents a thousand feet to pick up lumber and put it down again. Hence every time an operation of picking up and putting down is eliminated by introducing an extra truck, fifty cents (less the depreciation and interest charge on the truck) are saved on every thousand feet of lumber processed. And if it is easier to use a truck than not to, as it usually is in the average shop, the manager will find that apparently an unlimited number of trucks are absorbed before a surplus of empties is visible.

The labor saving is only a portion of the total economy effected by increasing the trucking equipment to the point where material needs never to be rehandled except when processed. A large element of delay also is eliminated, greatly smoothing out the routing system and shortening the total time of processing—in cases as much as fifty per cent. The efficiency of the truckers or "move" men, too, in some instances has been more than doubled; or what is the same thing, the number of them required approximately halved.

When these several savings are integrated it is evident that a large investment in trucking equipment is justified in order to bring about the happy condition of having all material constantly on the move, or ready to move on the instant.

METHODS THAT KEEP MATERIAL MOVING WITHOUT EXCESSIVE ROLLING EQUIPMENT

TO be able to do with fewer trucks, and yet at no point be compelled to rehandle material piece by piece, has led managers to various ingenious devices. In one woodworking factory, the superintendent provided for the use of his cut-off man loading boards about the size of truck platforms, and upon these, instead of on the floor, lumber cut off was piled. Then it was possible for two men to load one of these boards, with its pile of material, onto a truck platform bodily. It was a heavy lift, but considerable time and labor were saved. Besides, separate trucks for each pile would have been impracticable on account of lack of space. As it was, the loading boards, when full, had to be stacked two and three high for economy of space.

In a novelty metal-goods factory, large heavy wire baskets were provided to receive the goods, and these were lifted onto truck platforms by the aid of overhead tackle. In another factory, the work tables or serving platforms at machines were made mobile by the expedient of adding large casters to the legs. In still another, the serving platforms were rested on wood horses, built with special adjustable top pieces, set on wedges. The adjustment was such that, when the wedges were driven up, a regular truck could be run under. On releasing the wedges the platform would sink just enough to come to a rest on the truck.

In all these attempts to limit the trucking equipment without losing the advantage of a mobile floor under material, it is apparent that the end sought is to keep the rolling part of trucking equipment constantly on the move, and the platform part of trucks constantly in service holding material, whether in motion or standing still at machines, or in the stockroom. And this is undoubtedly the ideal condition for economy.

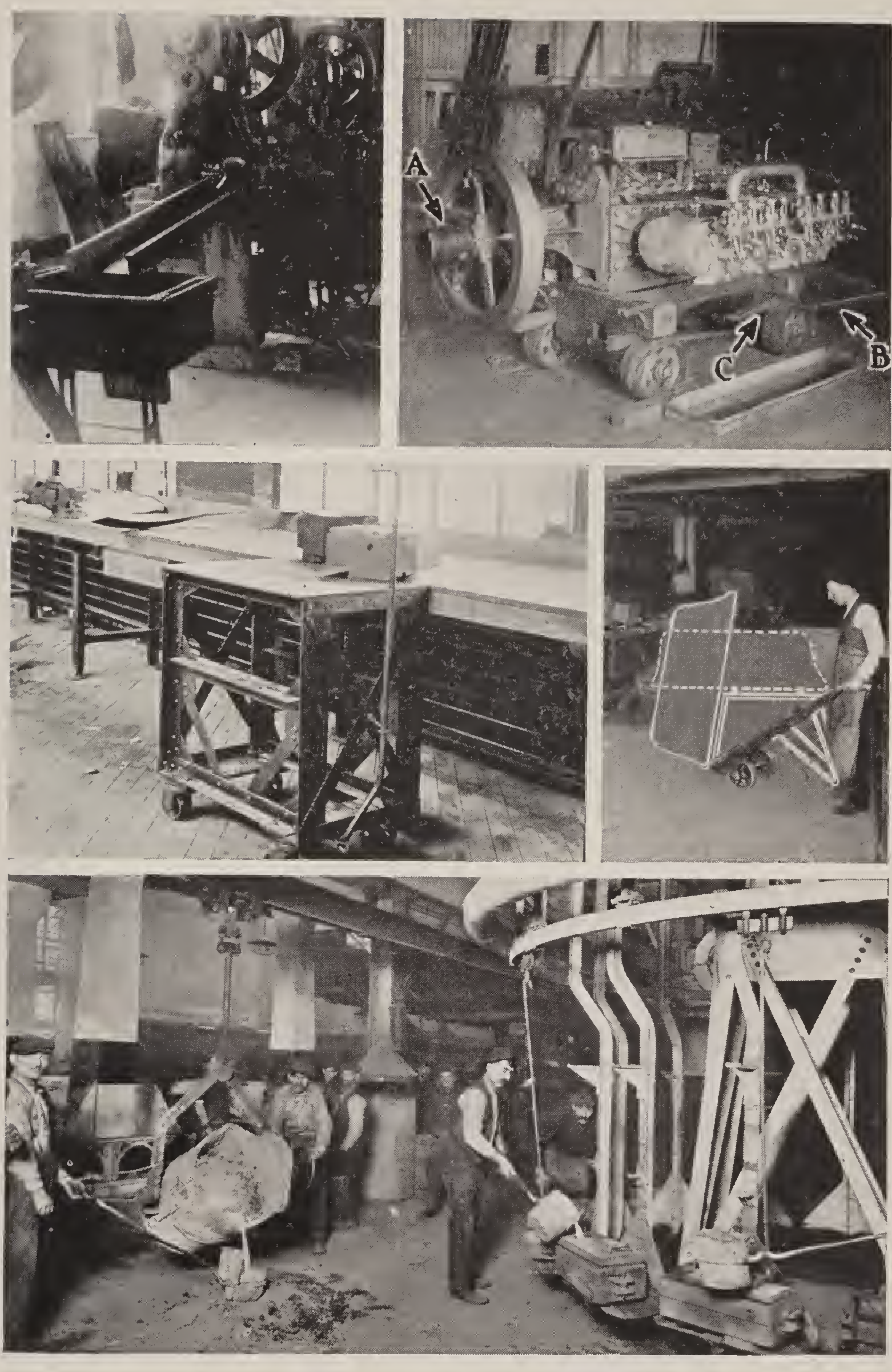
It must have been a manager or engineer with this end and ideal in view who contrived the type of trucking equipment which embodies an under frame, or "chassis," separate and distinct from the platform, yet arranged to work in connection with it. The frames are low and substantial in construction, in some types wholly of steel, in others of steel and wood combined. The platforms usually are of wood and rest on skids, or runners. The clear height underneath the platform is either just more or just less than the height of the bed of the truck frame, depending on whether the bed is at lower or upper adjustment. The adjusting mechanism is actuated either by the truck handle or by a special lever. When the frame is to be backed up under a platform the handle or lever is placed in such a position that the bed occupies its lowest level. As soon as it is directly under the platform, by changing the position of the handle or lever the bed is raised, engaging the platform and lifting it clear of the floor. The trucker, or "move" man may then proceed with his load. Disengagement is accomplished as quickly and easily.

The economy of this type of truck arises from the fact that work need never be removed from the platforms except to be processed, while one frame serves seventy-five to one hundred platforms. The wheels are always wheeling, the platforms are always holding.

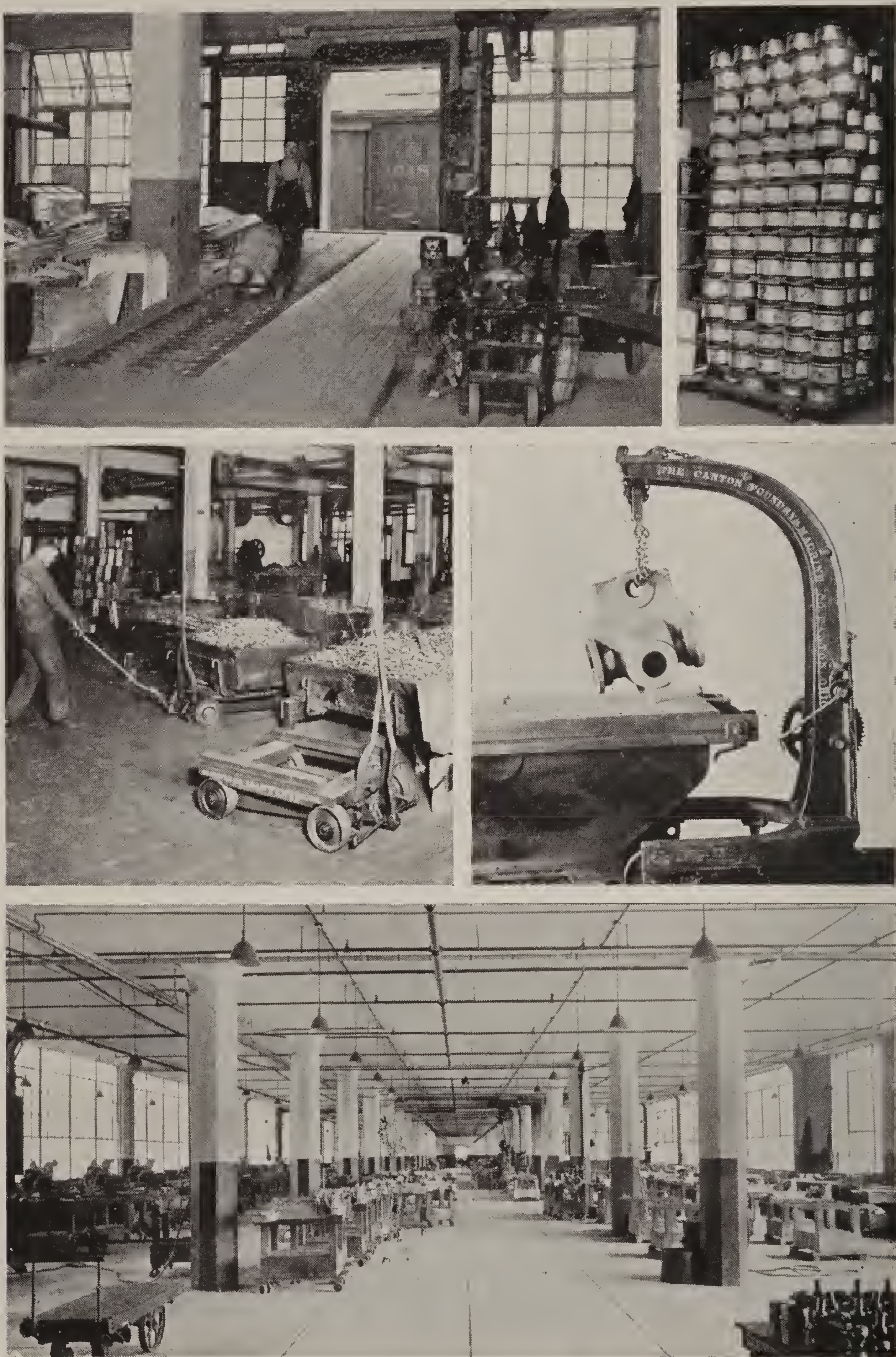
Practically no limit exists to the variations that may be made in styles of platforms. They may be built to any height; the surface made in any form—flat, cupped or razor backed; made single, double or triple decked to suit the particular case. They are usually made perfectly flat and low, and in this form serve most purposes. Since the users generally make their own platforms they are able to construct them in any form to suit themselves; the chassis alone is standard.

Instances of unique application of this device are many. In a factory specializing in gears, the platforms are fitted with poles, or uprights and the product—what of it is annular—is ringed over these uprights. In this way the carrying capacity is considerably increased, the parts are kept separate and distinct, and breakage largely avoided.

In the body department of a large automobile factory some one hundred and fifty platforms have been built to serve the high-priced carpenters in their work. On these is kept



Rehandling is saved (upper left) by chuting material from machine to machine; by testing gasoline engines on a truck (upper right), (A) safety covering over shaft projection, (B) tongue, (C) wedge; and by bench-high trucks (middle left) Special trucks give "fewer motions" in handling bath tubs (middle right). In the Ford foundry a "merry-go-round" conveyor brings the molds to the men



Two-wheel trucks are made efficient for hauls on inclines by an inset moving platform (upper left), while low trucks are made to carry high stacks of stamped ware by trays between layers (upper right). By the elevator truck shown (middle left) one set of wheels serves 75 to 100 platforms. The crane truck (middle right) lifts and carries. Continental Motor Company's trucking facilities (below) within arm's reach of the men at all times all the material they will need for a day. One boy, at a dollar a day, with one chassis does all the trucking. Finished parts for one car body, to be taken to the assembly department, are piled on three platforms. These must then be sufficient to complete the car body, or a good reason given for shortages. Thus the platform combination is an instrument of control as well.

In another factory making small machines, the platforms are double-decked and the parts to make one complete machine are piled on one platform; those for the upper portion of the machine are on the upper deck; those for the lower portion on the lower. Two assemblers work together from one platform; one can only take parts from the upper deck; the other only from the lower deck. If there is a shortage of parts the stockroom must be requisitioned; and the reason, if not apparent, is forthwith investigated. In this instance also an important element of control is furnished.

In a metal-stamping works it was the custom to throw the plate into large cases, and whenever it was necessary to move one of these cases the services of two to four men were required to lift it onto an old-style truck. Now "runners" have been fastened to the bottoms of the cases, which permits an adjustable-bed truck to be pushed underneath so the case can be lifted and moved easily. Thus a boy is enabled to do the work which formerly required two or more men.

In a foundry and machine shop where formerly all of the handling was done by overhead cranes, this same equipment has been installed to handle the smaller loads for which crane service is not economical. Each class of equipment is now employed on the class of work for which it is best fitted and a considerable gain in efficiency has been the result.

CARE AND CONTROL OF TRUCKING EQUIPMENT SAFEGUARDS HIGH-GRADE SERVICE

AN important point about all trucking equipment is its care and control. Where one man can be kept continuously busy with one piece of equipment, the responsibility for upkeep can and may often be put up to him. Where conditions do not permit of this arrangement, the head of each department should be held responsible for the trucks under his charge. Where this, too, is impracticable, someone can and should be appointed to look after the trucking equipment of the whole establishment, and be required from time to time to report on the whereabouts, use and serviceability of every unit.

To facilitate control, every truck should be numbered or lettered, and if attached to a certain department, labeled with the name or symbol of that department. If not so labeled, difficulty will be experienced in keeping trucks where they belong. In addition to the name of the department, instructions should be lettered on each truck, in plain type, ordering prompt return to the department to which it belongs, and department heads found keeping trucks which belong elsewhere should be reprimanded or penalized for so doing.

It is also a good plan to have the weight of each truck plainly indicated. This will be found to save time and inconvenience on occasion when the net weight of a truck load is wanted in a hurry.

Identifying trucks by numbering or lettering is not only of considerable assistance in keeping tab on them, but also in record keeping. And some kind of a running record should be kept of every piece of equipment, in such detail as its value may warrant. For inventory purposes identification is absolutely essential.

In the stockroom should be kept a supply of extra wheels, axles, handles, tongues, bolts and nuts to facilitate quick repairs. It doesn't pay to have a truck put out of commission every time a wheel or an axle goes bad, while waiting for a new part to come from the makers. It costs but little to keep extra parts on hand, and delays due to tardy repairs may be just as expensive as "time out" at a costly machine tool.

XV

CRANES AND OVERHEAD CARRIERS

OF all devices for moving materials, that which is most closely patterned after man himself is the crane. In it man has imitated his own unique aptitude as a carrier, only magnified ten, a hundred, in cases a thousand-fold. As for picking up and transporting small and light objects short distances, nothing is so convenient and flexible as human hands, so for moving large and weighty materials no handling contrivance is superior to the crane. The larger and heavier objects become, the greater the efficiency of this class of equipment.

It is the immense superiority of the crane for handling bulky articles that makes it unrivaled in the iron and steel industry; here it is found in its greatest variety and highest development. So important is crane equipment, particularly in shops that build heavy machinery like boilers, locomotives, dynamos and motors, engines, machine tools, agricultural implements and structural steel fabrications, that it is found taking precedence over all else in the design of the buildings. To provide adequate crane service is the fundamental and primary consideration, and the housing structure itself must take the form and proportions that best suit the crane layout (See Frontispiece).

By a crane is meant any type of material-moving mechanism which operates by picking up and carrying; and in this respect it is unique, for practically every other handling device is capable only of the latter motion. To this fact—that a crane is both a lifter and a transporter—is very largely due its high efficiency. Also for this reason cranes divide themselves into two general classifications—cranes that are essentially hoists, and as such primarily auxiliaries to other moving apparatus or adjuncts to processing equipment; and cranes which are essentially transporters.

Secondary reasons for the high efficiency of the crane are, first, that it operates high above the working level and so makes minimum interference with use of the floor space; second, that it is omnipresent in the sense that, within its compass it gives equal service to all parts of the shop; third, that it is equally handy on all levels up to its own height; fourth, that as a traveler it can make speeds which are impracticable on the floor level; fifth, that in size and capacity it can be varied to meet all requirements; and sixth, that, although within its range the most flexible of all handling contrivances, it is the most easily controlled. There is no hunting around for a crane. It is either in a definite locality constantly, or can be located at a glance and summoned by a wave or a push button.

EFFICIENCY OF CRANES MAKES THEM ECONOMICAL DESPITE INTERMITTENT USE

UNLIKE other transporters, too, continuity of use, although highly desirable, is not necessarily indispensable for economy. Particularly is this the case if the loads to be moved are heavy. In the Philadelphia Navy Yard, for instance, in one of the shops where at intervals there are ponderous castings to be handled, an overhead traveling crane for this especial purpose has been found to pay for itself handsomely, even though used only two or three times a day. Figuring interest at six per cent, the daily savings approximate twice the capital charges on the cost of crane, runway and installation. This considers labor-saving only and takes no account of the probably greater savings due to increased speed of production.

On the other hand, if the objects are small, crane-handling may prove the most expensive way. Even a small power crane will cost not less than fifty cents an hour to operate, not including the wages of the operator. Hence, to bring a crane into position to pick up a small article may cost more than to handle it by some other means.

The mere size and weight of objects to be handled, however, by no means defines the sphere of usefulness of the crane. By grouping articles, parcels of a size and weight it pays to handle

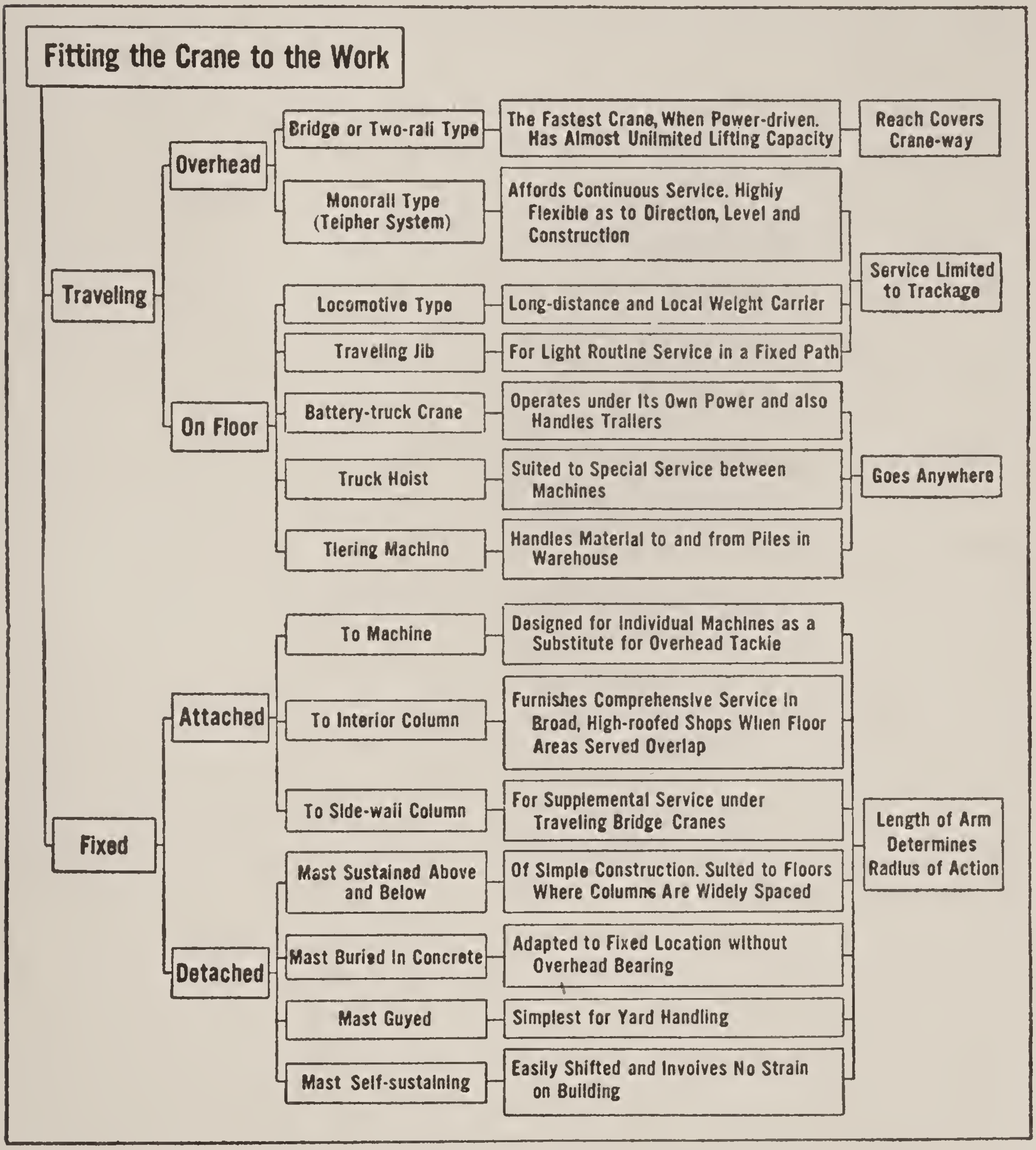


FIGURE XXVIII: Cranes are both hoists and carriers in one. Overhead traveling types are adapted for general service. Both hoist and propulsion may be powered, both hand-actuated, or either one power and the other hand, depending on the load and the distance. Jib-cranes are usually swung by hand, but the hoist may be controlled by electricity, air or hand, depending on the weight to be lifted. Locomotive cranes and trolley truck cranes are also classed under "Track and Trackless Systems of Transfer" and truck cranes and tiering machines under "Making the Most of Hand Trucks"

with a crane often can be formed, and this equipment made applicable to industries, as, for instance, woodworking, in which offhand it would seem to have no place. Here the interplay of the transportation with the production system is seen. If it is feasible to arrange that small articles can be held until large parcels are formed—and in many cases this is merely a matter of arrangement—crane-handling may offer the greatest economy. So it will pay the factory manager, no matter what his line of manufacture, carefully to consider the possibilities of this class of equipment, freely consulting the best engineering talent available, before coming to a decision, lest he overlook a big opportunity for savings. Particularly in connection with his storing and shipping, will he find it to his advantage thoroughly to investigate what can be done with cranes.

OPERATING MONORAIL CRANES IN COMBINATION WITH SPECIAL HAND TRUCKS AND AUTOMOBILES

A GOOD example of the use of cranes in warehousing is seen at the establishment of M. A. Newmark and Company, wholesale grocers. While theirs is essentially a storage and delivery proposition, the same kind of a transporting system would solve the stock and shipping problem for many a manufacturer. More than that, it is full of suggestion for processing departments. This company receives and delivers, on the average, two hundred tons of freight a day. Incoming freight is received mostly by railroad; outgoing freight leaves very largely on motor trucks. The warehouse recently built is of heavy beam-and-girderless reinforced concrete construction, and transportation was very carefully considered in the design—as indeed it always should be. The system consists of a very complete traveling-crane outfit of the monorail, or telpherage type, two spiral chutes and four fast electric elevators. Special trucks are also provided which may be pushed around or picked up bodily and conveyed by the telpher. Those which are used to collect articles to be sent out are designed, in addition, to set on the bed of a motor truck and lock in place, two of them forming a load.

In distributing incoming freight, one of the unloading types of trucks, which differs from the delivery kind mainly in being narrower so as to pass through a car door, is pushed to the car door, or inside if there is room, and loaded; after which it is pushed back onto the platform, where a telpher picks it up and rapidly conveys it to its destination. If this is on one of the upper floors, the telpher (Page 163) boards an elevator which carries a continuation of the monorail and is arranged so as to permit its operation by the telpher-man without leaving his seat.

Reaching its destination, the truck is lowered and unloaded at convenience, permitting the telpher to return immediately for another load. As it is able to make up to five hundred feet a minute, exceedingly rapid distribution of incoming freight is possible. In fact, less than two-thirds the former time is required and fewer men by two.

Outgoing freight is collected almost wholly on the lower floor, the spiral chutes bringing down goods from any of the upper floors in a minimum of time and with maximum economy. At the bottom these are sorted and assembled in the special delivery trucks, picked up by a telpher, taken out and lowered on a waiting motor truck. Five minutes is all that is required to remove two empty body trucks and replace them with two loaded ones; three minutes and ten seconds is the record time, and the manager confidently expects to get it down to an average of four minutes. Formerly, loading with ordinary trucks required over an hour, and when a truck came in loaded it took an hour and a half to unload and reload. The saving in automobile time alone is enormous, and not only goes far towards making the motor-trucking profitable, but in addition amply justifies the telpherage installation.

If there is enough outgoing merchandise on any one floor to fill one of the special delivery trucks, the chutes are not used but the load is assembled on the spot and conveyed directly by the trolley and elevators to the shipping platform. Frequently it is even possible to make up a load from an incoming car and transfer it without rehandling to a waiting motor truck.

A telpherage installation is also the backbone of the handling system at the Ford Motor Car plant, and to the unique facility it affords is due much of the success of the wonderful Ford production scheme. It is the express delivery system of the plant.

Where the overhead monorail system has the advantage over traveling cranes of the two-rail type is in the facility it affords for serving comparatively low stories, turning curves and moving in any direction, and serving more than one floor without transfer of load. It can also go through the side of a building, and thus load or unload cars or trucks most convenient to bring in there, when an ordinary crane would only be able to reach a siding at the end of the building. On the other hand, material must be moved within reach of a telpher, unless a great many cross rails are provided; whereas the beam crane, with its two-way horizontal travel, can be brought *directly* over the article it is to pick up. Too, the telpher is somewhat sharply limited in capacity. It is hardly practicable for loads above three tons, on account of the strain it puts on the supporting structure, whereas there is almost no limit to a beam crane. Thus while the two often enter into competition, on the whole each occupies a distinct field and in it is supreme.

An unusually interesting example of a telpherage installation, where offhand beam-cranes might be thought specially adapted, is in the new plant of the Duff Manufacturing Company. The main shop is a single-story structure with a central, high-studded monitor-roof bay, thirty-five feet across, flanked on the one side with a thirty-foot wing and on the other with a sixty-foot, divided into two thirty-foot bays. The central area is served by a traveling crane, but it is of the bridge type, and operates in conjunction with the telpherage system in the side bays. Under each intermediate roof truss, or twenty-two feet on centers, is suspended an I-beam upon the lower flange of which the trolleys of the telpher-hoist travel. The I-beams project slightly into the central area, or just sufficient to meet the I-beam carried by the bridge-crane. The main travel, of course, is up and down the central area, and the bridge-crane is able to reach every part of it; but when material is to be moved to and from any part of the side bays, the bridge-crane takes position opposite the nearest cross connecting I-beam rail, and the telpher leaves the bridge. On leaving it breaks a contact, so that the bridge-crane cannot shift or be shifted from its alignment until the telpher returns. Thus accidents are practically impossible.

With this system, stores are delivered, goods unloaded and loaded, machines and heat-treating furnaces are served, scrap removed—in fact, every material-moving requirement is met, eliminating hand trucking almost altogether, with a great saving of time and labor. The same system would solve the transportation problem in many establishments.

In another case, in addition to the bridge-crane, the central area might be provided advantageously with a regular traveling crane, on a superimposed runway, giving an independent service for handling articles too heavy for the telpherage system, as well as affording a special quick transfer for this bay.

QUICKER WAYS FOR TRANSFERRING MATERIAL FROM ONE CRANE TO ANOTHER

CERTAIN limitations of the beam crane have been referred to, one of which is that ordinarily when a load is to be transferred to a second crane serving an adjacent bay, a rehandling operation is necessary. But there are instances where this transfer has been accomplished with remarkable neatness and dispatch.

Perhaps the most notable instance of this kind that has come to attention is in the warehouse of an eastern tube mill. The building is about one hundred feet wide and is served by two cranes on parallel runways. Great bundles of tubes, weighing five to ten thousand pounds, are swung from one crane to the other without ever touching the floor. The method of procedure is this: The two carriages are run as close together as possible, extra slings are passed around the bundle and hooked onto the tackle of the unloaded crane, whose operator at once begins to take up all slack; then while he continues to hoist, the operator of the first crane eases off and the load swings over. A handling "stunt" bordering more on the acrobatic could hardly be imagined.

In another instance a similar transfer from one crane to another is accomplished by means of a small motor-driven turntable set in the floor. As soon as the one crane deposits its load an attendant throws the operating switch, and in a fraction of a minute the object or parcel is on the other side in convenient position for the second crane to pick it up.

Another limitation of the crane is the time consumed and helping-labor required. However, by a little ingenuity it is in many cases possible to pre-position slings around material to be moved so that the crane-men can "hook" it almost on the run. And truly wonderful adeptness they acquire in doing this. At the Hart-Parr plant, so clever has the operator of the crane in the erection shop become, that he can pick up without assistance a twenty-ton traction engine. At the Newmark establishment, the telpher-men have no difficulty, with the special rigging provided, in either picking up or dropping the body truck.

But where it is applicable, that which makes the crane almost perfectly self-helping is the magnetic lift. This may be fitted to any kind of crane or hoist, dispensing with slings and grappling tackle altogether. It is of course usable only on iron and steel and scarcely practicable for loads above two tons. For this reason, and because of the possibility of current failure, the application is chiefly to cranes used as loaders and unloaders or as auxiliaries to machines. For handling pig iron or small castings of more or less uniform size, for example, it is unrivaled in efficiency.

It is also uncommonly efficient for handling iron and steel scraps, in a few seconds of time picking and transferring from bin to car huge tangled and matted masses which a gang of laborers with forks and shovels would wrestle with for as many hours.

Instances of economies effected by adapting this device are legion. The recital of one will suffice to show what can be done. On page 164 is pictured the use of a forty-three-inch diameter magnet for loading identical steel castings, ten at a time, at the Deutcher Works of the Prime Steel Company. Formerly two men were required to handle a single casting. Thus the lift does the work of twenty men.

At the Cutler-Hammer Works, in the structural steel shops, electro-magnets are also used to convey I-beams and built-up girders, weighing as much as two tons. The magnetic grip afforded by contact of a forty-three-inch magnet-lift with the upper flange, at or near the middle, is sufficient to hold the two together firmly. Long steel plates are handled similarly, except that the crane is fitted with two lifting-magnets, so that grip can be taken at the third points. To guard against sudden release of the load, through failure of the current, safety grapples are also provided. By using these to sustain the load over long carriages, too, current is economized.

WHEN TO USE ELECTRIC POWER FOR CRANES AND WHEN AIR POWER

ELECTRICITY is commonly thought of as the sole motive power of cranes; and indeed were this power not available, the crane would not be seen in its present wonderful variety of forms and high development, and the magnetic lift would have no existence. Nevertheless for many types of cranes, and particularly those like jib-cranes which class primarily as hoists, air-power is fully as efficient and not infrequently more so. Where air is especially suited is in handling moderate and uniform loads on short, uniform lifts for which it affords an unsurpassed, high-speed, low-cost service. For instance, in ice making, for hoisting the cakes out of the tanks just this kind of service is required, and the standard equipment is a light beam-crane with an air-operated hoist. In foundries and machine shops, too, cranes so powered find a wide application, particularly as auxiliary equipment to facilitate the handling of work being processed which is too heavy for one or two men to lift. Air-hoists also offer many advantages for loading and unloading cars and other vehicles. When used for this purpose the air-cylinder usually is fixed to some part of the equipment, either vertically to the mast or horizontally on a projection of the jib, and hoisting is at the end of the jib only, although loads may be swung in or out over a wide range of area. But when used to serve machines the cylinder is trunnioned in a vertical position and travels back and forth on the jib thus giving equal service to every part of the space circumscribed by the tip at the jib.

Then there are cranes, both of the jib and beam type, for light work, which are equipped with differential pulley hoists, and practically all jib-cranes, and many light beam-cranes with power hoists, rely on man-power for propulsion. Man-operated monorail cranes, too, are common, particularly in foundries, for conveying molten metal from the cupola to various points on the floor.

Jib-cranes are met with in a variety of forms. Sometimes they are attached to the side of the building; again to the interior columns, being of such dimensions as to cover practically the entire floor; occasionally to the headstocks of machines, to give exclusive handling service; and where it is inconvenient to hang them on a part of the structure, or there is nothing to attach to, made self-supporting.

A common type of self-supporting jib-crane has for the vertical mast a heavy steel pipe, the lower end of which for several feet is buried in a massive block of concrete. The upper pintle is of the ball-and-socket type while the lower operates on ball-bearings, making a rigid freely-moving piece of equipment.

FOR LOCAL HANDLING OF MATERIAL JIB-CRANES GIVE FAST AND LOW-COST SERVICE

ANOTHER type of self-supporting jib-crane is seen at the plant of the Cincinnati Milling Machine Company, and so far as known is original with this company. The mast is a light structural steel tower (Page 164), tapering from the bottom up, and the base is simply attached to the concrete floor with expansion bolts. Thus the cranes may easily be shifted, to conform with any rearrangements of machinery. They are for secondary service and cover one entire bay of the machine shop. Some are equipped with power hoists and others only with differential pulleys, depending on the requirements of the machines they serve, and all are on ball-bearings so that the touch of the finger is sufficient to slide the hoist or swing the jib. For carrying work from one end to the other, or to deliver finished pieces to storage, as well as to bring in rough castings, an overhead traveling crane is provided, and this is kept busy on a regular schedule. An eight-foot aisle is kept open down the center, and the arrangement is such that when a piece is finished it is placed out there and the overhead crane on its next trip takes it away.

Jib-cranes of the portable type are also common and for many purposes give unique service. A rare type is that used by the Trimont Manufacturing Company. It is electrically operated, with overhead trolley, and travels up and down the shop on a single rail. Balance is maintained by a pair of horizontal wheels, at the top of the mast, which engage between them an iron-bound timber attached to the roof trusses. The low story height and the character of the construction led to the adoption of this piece of equipment. Were the roof higher and the side wall construction of the proper design, a jib bracketed to the side would probably have been adopted, as affording the same service without encumbering the floor space. Such cranes, indeed, are much used for secondary transportation in erection shops, one or two of them doing the work of half a dozen stationary jibs and also giving a through service in the side bays. Of course, as very strong specially designed wall columns are required, the use of such cranes must be anticipated when building, whereas the type used by the Trimont Company could be introduced in almost any existing structure.

Then there are portable jibs of the locomotive type for heavy yard service; battery-truck cranes which are capable of a variety of service; and small jibs on a wheel base (Page 146) pulled around by hand as a truck. Lastly there is the tiering type of portable crane or elevator for piling stock. With this equipment two men can do the work of six or more, in less time, with less chance of breakage, and can carry the stacks to the ceiling if the floor strength permits.

XVI

TRACK AND TRACKLESS SYSTEMS OF TRANSFER

AN industrial railway may well be regarded as a trucking system with a standardized roadbed, and this characterization points its greatest advantages as well as indicates its limitations. Where the moving of work through a factory can be restricted to well-defined lines of travel, an industrial railway affords many facilities; but where the vehicles must reach every part of the floor, and serve as repositories for work at machines, it is not as a rule satisfactory.

This is not the case, however, in factories where the work is of such a nature as to require crane-handling at machines. An industrial railway then frequently gives an ideal supplementary service. Indeed, it is in combination with cranes that this method of transfer is most commonly found.

An excellent example of such a combination is seen in an eastern machine shop (Figure XXIX). The building is a four-story affair, with an open traveling-crane way at one side extending from top to bottom. A standard-gage siding occupies the ground level. Rough castings are brought in on regular freight cars, picked up by the magnet crane and transferred to any one of the floors desired. Successively recessed galleries make this possible. On each floor are industrial tracks extending across the further end of the building and down the middle of the central bay. The two side bays are served with small traveling cranes. Thus it is possible to transfer a load to or from any portion of the floor, from or to any other part of the building or the siding below, without the use of trucks or elevators and with two rehandlings at the most.

A noteworthy point about this particular installation is the fact that the problem of material handling was grasped in its true import at the outset and the entire structural arrangement subordinated to it. Too often it is left to care for itself as it may, and like most afterthoughts, never reaches a satisfactory solution. Particularly is this the case when the nature of the material does not require that it be handled by crane. But it is almost as necessary to provide for an industrial railway in advance as for a crane, since for best results the trackage should be integral with the floor. True, an industrial track can be laid on any floor that is level and strong enough to carry it, but it is never so satisfactory in operation as a track neatly inlaid, across which hand trucks can go freely and even work can be dragged.

Nevertheless, an industrial railway may often be installed subsequently to decided advantage. At the Philadelphia Navy Yard, for instance, in the yard of the forge shop a collection of old davits and discarded steel and iron fittings had for years been gathering. There was plenty of good stock in this, but the expense of getting it into the shop was so much that it was cheaper to use new steel at two cents a pound. By installing an industrial railway and erecting a stiff-legged derrick at a central point in the yard the situation was reversed. The savings thus realized in a few months paid for the new equipment, to say nothing of the benefits realized through easier handling of the stock in the shop.

HOW AN INDUSTRIAL RAILWAY CUT DOWN EXPENSES

AN eastern brass mill furnishes another instance where an industrial railway paid for itself in a short time. The plant had grown without any particular plan. When the development of the business made it necessary to provide a central boiler plant, to supply the several engines stationed at different points throughout the mill, the only available location was at a considerable distance from the siding. And to find space for coal-storage pockets, it was necessary to go down the road about a third of a mile from the power-house site.

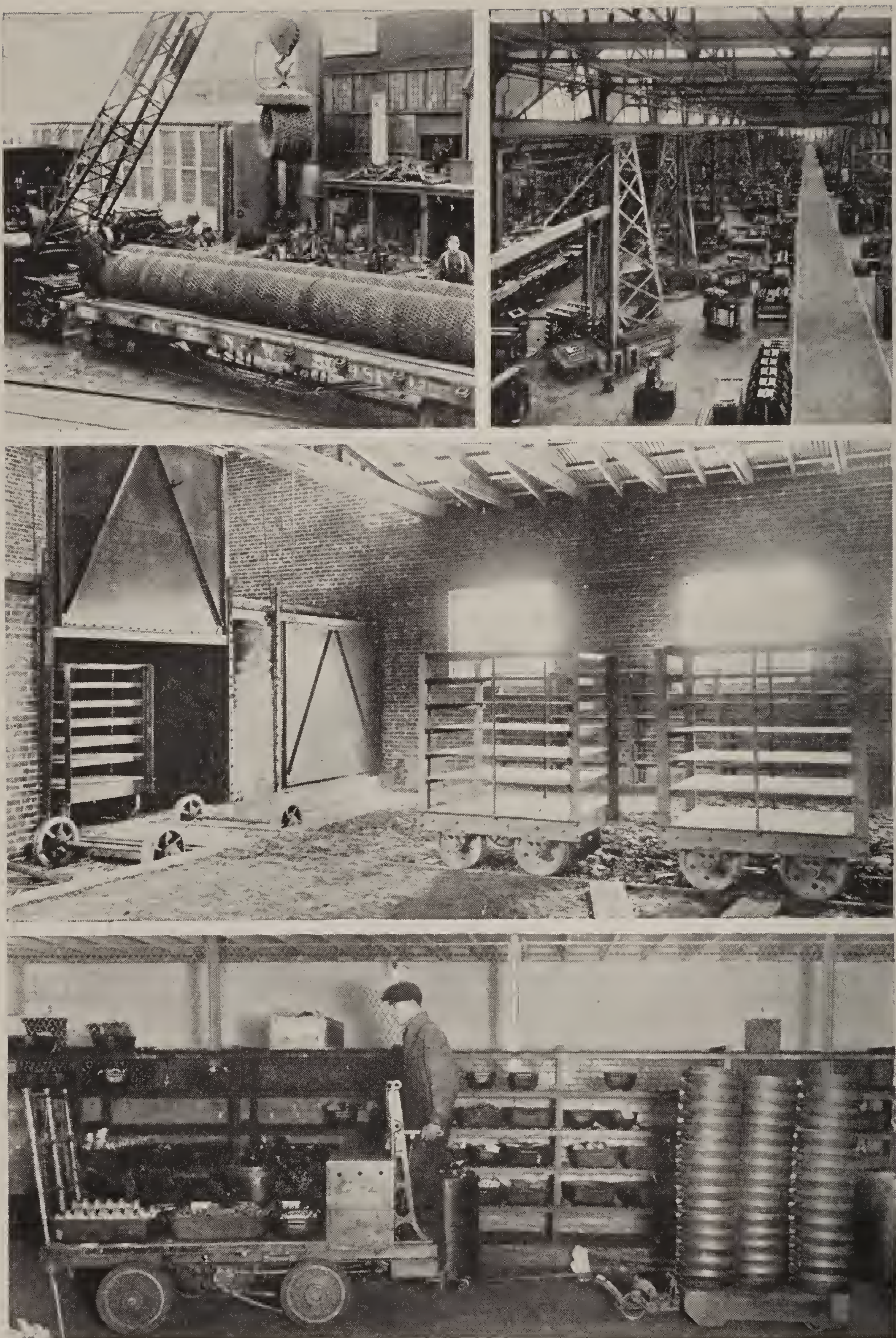
At first, what coal was needed each day was hauled down by means of horse carts and dumped on the floor of the boiler house. This proved a decided nuisance, besides being expensive. Finally an industrial railway was installed, with special coal-carrying cars the sides of which can be let down to permit shoveling the coal directly into the furnaces. Each car has a capacity of one ton and enough cars have been provided so that dumping on the floor is no longer necessary. One attendant is able easily to handle the cars back and forth and he is kept busy only a part of each day.

Industrial cars may be had in a variety of forms to suit the particular usage—even in as great variety as hand trucks. The simplest form is the platform or flat car, the standard height of which is about twenty inches; but they may be had in any height, up to the level of benches and machine beds and down to within a few inches of the floor, to permit easy loading of heavy articles like castings, pianos and slabs of stone without the aid of hoisting devices. For foundry use special car bodies fitted to carry ladles of molten metal may be had, and for core and other oven work there are cars with rack uppers. Then there are cars with variously shaped hopper bodies arranged to discharge either by tilting or by opening the bottom, or dropping one or both sides. In short, there is almost no limit to the possible variations in form or arrangement of industrial cars—which fact gives to this class of equipment a breadth of application far greater than offhand might appear.

WIDTH OF GAGE AND ITS RELATION TO THE METHOD OF HAULAGE

A GREAT variety of gages also are found from as narrow as eighteen inches up to 4′ 8½″, the standard railroad gage, and wider still for special conditions like lumber lorries, kiln cars and transfer platforms. The two gages most commonly found are twenty-four and thirty-six inches. Generally speaking the narrower the gage the greater the flexibility of the system, owing to the narrow spaces that can be served and the sharp curves that can be turned; also the easier it is for one man to push a car. But the nature of the material to be handled usually

Cranes are not limited to handling large, bulky articles. Small articles grouped also may be so handled to advantage (top). Special slings enable a crane operator unaided (middle) to pick up twenty-ton tractors. At the M. A. Newmark Company (bottom), a monorail carrier picks up and transports loaded trucks, which also serve as auto-truck bodies



Magnet-lift attachments on cranes greatly increase their efficiency. The one shown (upper left) does the work of twenty men. Swivel cranes, easily shifted, serve groups of machines (upper right) Core-oven operation in a car-wheel plant is facilitated by rack cars and a transfer platform (middle). Industrial motor trucks have largely supplanted hand trucking at the Pierce-Arrow Motor Car plant.

must be taken into consideration and the gage determined in accordance. The wider the gage, as a rule, the less economical man-pushing becomes; and when as a regular procedure, more than one man is required, power-haulage usually becomes more economical. This is also true when large quantities of material must be moved at fairly regular intervals over long stretches of distance.

For power-haulage, the manufacturer has choice of either self-contained battery cars or of battery tractors operated in conjunction with trailers. For service within manufacturing establishments, the battery truck is perhaps best adapted, while the tractor finds its highest usefulness in plants spread out over a wide extent and composed of numerous structures. In this case man-power is relied on for most short distance transfers within buildings, and tractor-haulage for negotiating the longer stretches through and between the various shops.

As such a tractor can pull loads from five to ten tons at a speed of five to seven miles an hour, and on one charge of the batteries is good for twenty-five miles, its utility and economy are apparent. An electric tractor, which takes its power from a trolley, is more efficient and reliable, but from its very nature is more or less limited to yard work and even for that is less desirable than a battery tractor because of its well-known hazards to life. This would not, of course, be true if power were supplied through a slot in the floor, but such an installation is seldom feasible and is besides rather too costly.

Still another way of supplying power for propelling industrial cars is by moving cable. This is a means commonly employed in mining and engineering construction, but rarely adapted to manufacturing establishments. Animal power is also available, but scarcely feasible under most conditions—at least for inside haulage. For steady service, at any rate, power tractors are more economical and eminently more satisfactory in general.

As has been pointed out, the sphere of usefulness of an industrial railway is rather sharply limited by the fact that flexibility is sacrificed for ease and smoothness of haulage. But this difficulty has in cases been overcome to some extent by providing the cars with an extra pair of (flangeless) wheels hung on cams.

These ordinarily are snugly gathered up under the platform, but when it is desired to leave the track the cam is thrown down and the wheels take a position slightly below the flanges of the regular wheels, coming into action and bearing the load. By this means the radius of action is considerably widened and the industrial railway often made applicable where otherwise it would not satisfy.

WHY IT PAYS TO USE STANDARD RAILWAY GAGE FOR INDUSTRIAL SYSTEMS

ANOTHER limitation of the industrial railway is that rehandling is required whenever material in transit must be transferred to or from the standard gage system with which practically every plant of size, that spreads out over the ground and has a large yard department, necessarily is provided.

A duplicate narrow gage system is one way of saving some of this rehandling, but the cross-over complications make this impracticable in the majority of cases. For this reason the standard railroad gage is often used exclusively, within as well as outside the buildings, and thus the tracks made indiscriminately available for either industrials or regular freight cars. Where the use of wide-gaged industrials within the shops imposes no particular difficulty, such a system offers many advantages. At the Hart-Parr farm-tractor plant, which consists of a half dozen or more detached, single-story structures occupying several acres of ground, standard gaged tracks extend into, across one end of or through nearly every building, and are continuous with the yard system which flanks the plant on either side and at its outer end connects with the serving railroads. Raw materials for the foundries are brought in on regular cars; castings therefrom are conveyed on industrials to the storehouse or to the machine shop directly; miscellaneous supplies are delivered to the storehouse and product shipped on freight cars; rough castings are transported from storage to the machine shop, and finished castings to the erection shop, either on industrials or hand trucks, depending on their size. Within, man-power is chiefly relied on, but outside and through some of the buildings whose construction permits a ''pony'' engine is operated, and of course

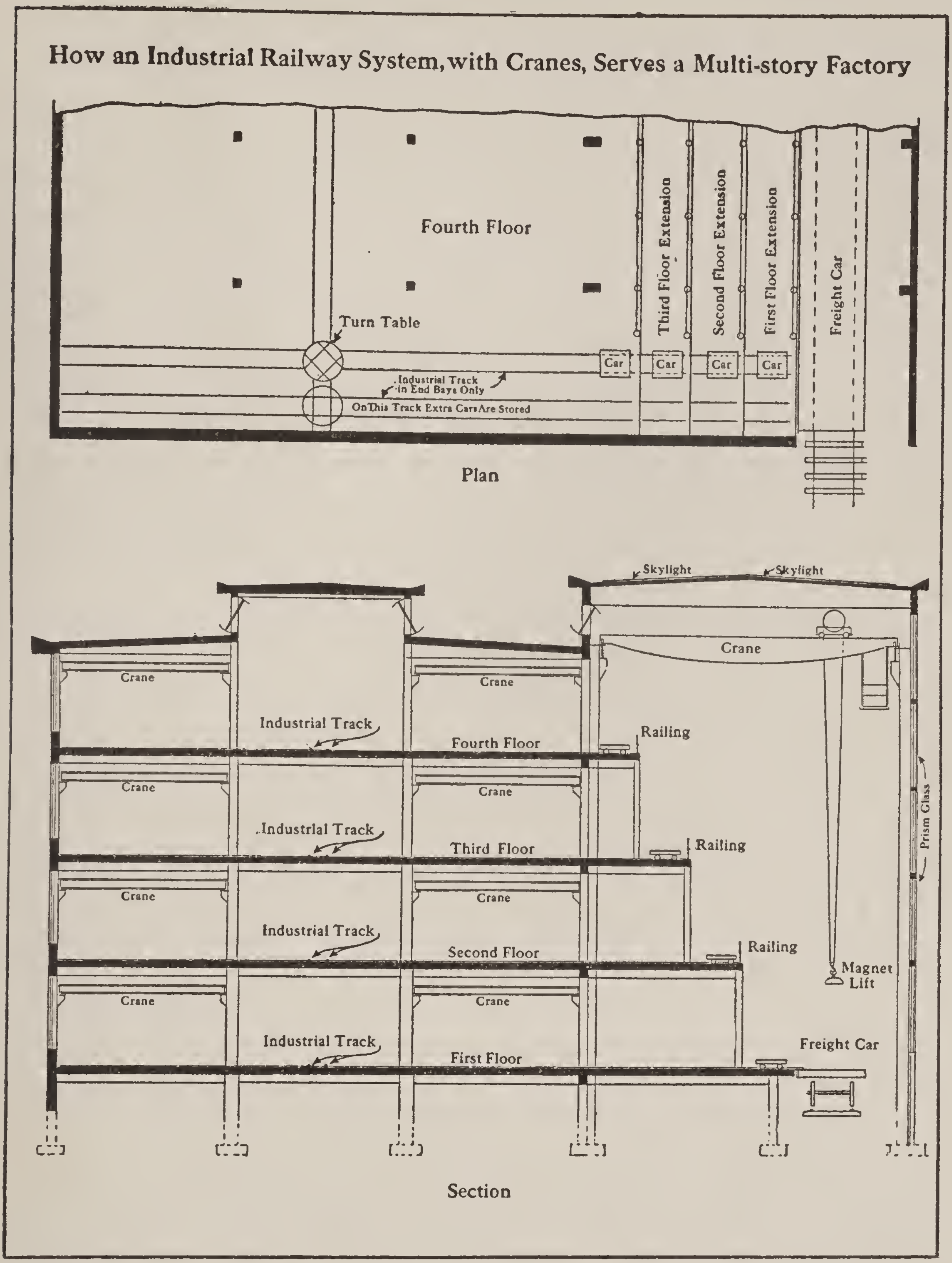


FIGURE XXIX: In this eastern multi-story machine shop, the transportation problem was recognized in its true proportions at the outset and the fundamental design of the building made to conform with the principles of economical handling of materials. Cranes and industrial railways often are seen together in single-story plants, seldom in the combination here illustrated. Successively recessed galleries permit the one large crane to transfer materials from the freight car below to any floor. The industrial railway system, in conjunction with the smaller cranes in the side bays, enables this material to be put directly into the machines. Finished product reaches outgoing freight cars by the same direct route

this is always employed to move the full-sized railroad cars.

A steam locomotive is, however, objectionable around many plants, not only on account of fire hazard, but because it is a dirt maker. Accordingly it is rapidly being supplanted by other types which are devoid of these undesirable features. In some instances it is possible to use the electric locomotives to advantage; compressed air locomotives are not uncommon and have their good points; and at the National Cash Register plant a steam-battery engine is employed, giving the advantage of steam without the spark danger and smoke nuisance. Recharging is necessary about every four hours, which is a drawback. None of these types, however, are equal in point of all-around satisfaction to the storage-battery tractor. This type is able to move about freely within the plant as well as outdoors, without danger to life or property, and if spare sets of batteries are kept on hand and facilities provided for quickly exchanging them, affords practically continuous service.

WHERE MOTOR TRUCKS HAVE THE ADVANTAGE OVER INDUSTRIAL RAILWAYS

LIMITATIONS of industrial railways have been cited, which operate to narrow their field of application. The development of the storage-battery industrial truck still further encroaches upon this field. What is lost by not having a special travel-way is more than offset by the gain in latitude of action —a motor truck can go anywhere the aisle space permits. In addition, the cost and upkeep of tracking is saved, and the floors are not cut up with tracks. These are important considerations. Also a motor truck system can often be subsequently installed where an industrial railway, without extensive reconstruction and rearrangement, would be impracticable.

For the successful operation of a motor truck system, however, a good, even floor, kept in thorough repair, well defined and scrupulously maintained aisle spaces, and systematic routing are as essential as tracks and scheduled operation to an industrial railway.

How the floors should be arranged for best results is indicated by the layout in a Youngstown plant. Here the yard between buildings and around each building is paved with concrete as are the floors. The aisle spaces within are plainly defined by white lines and the rules relating to keeping these free for traffic are rigorously enforced. All changes in levels, of which there are several made necessary by the topography of the site, are compassed by easy slopes. A motor truck can move about in this plant with the greatest of freedom.

This is a one-story plant. But as a motor truck loaded can take with ease grades up to ten per cent and if double motored fifteen to twenty-five per cent or steeper, depending on the load, in a multi-story building, by a suitable arrangement of ramps, almost equal freedom of action and continuity of service is possible. Incidentally the ramps are available for the use of the operatives, replacing the conventional stairways to which they are vastly superior. An excellent example of the use of ramps is at the Shoch building in Philadelphia, shown as the frontispiece of the volume on Buildings and Upkeep.

If there is not room for ramps, inclined elevators may be used; and if not for these, platform elevators always remain. In any event the fact that a plant consists of buildings of more than one story in no wise militates against the use of motor trucks.

Motor trucks are found in a variety of forms, sizes and capacities, but the standard type is a simple platform affair with four equal-sized, solid rubber-tired wheels, weighing with batteries and motor about two thousand pounds, with a rated speed of seven to eight miles an hour and a radius of action of twenty-five miles, and having a carrying capacity of two thousand pounds.

The practical speed depends on the load and on the character of the floor, but a truck loaded in excess of its rated capacity, on a fairly smooth and regular floor, can easily make four or five miles an hour. It is thus three to four times as fast as a hand truck, and as its capacity is five to six times that of the average one-man truck, it is fair to say that it is capable of doing fifteen times as much work.

The operator stands on a projection of the platform, either in the front or in the rear, and has complete and instant control over his machine. The curves he can take depend altogether on the arrangement of the driving and steering mechanism and this is an important point to consider in buying. Sharper turns can in any event be made than with industrial cars, and if steerage is by all four wheels, a truck can turn on a radius about equal to its wheel-base. If the drive also is on all four wheels, it can take still a sharper curve by half, or virtually spin around a fixed point. The flexibility thus conferred is apparent, particularly for service in an old shop where the layout by no means is the best.

The cost of operating a battery truck, including power, operator, maintenance and investment charges, will average between three and four dollars per day, depending on the cost of power for charging and the operator's rate. But if kept reasonably busy and intelligently directed, it can be depended upon to save several times its operating cost every day. In one special instance, it saved an owner forty-eight dollars a day over his best previous methods and one-fourth of this amount would be a fair estimate of the savings realized in the average case.

As an example of the special uses to which battery trucks can be put, at the Boston Manufacturing Company a standard chassis has been fitted with a coal-carrying body, which has a capacity of sixteen hundred pounds and dumps "clean." The same truck is also utilized to carry ashes, and when so used is fitted with sideboards to increase its capacity for the lighter material. By a judicious arrangement of plankways about the yard, where a hard, level surface is not available, a wide, almost unlimited radius of action is had.

In a Canadian plant a standard truck, equipped with a hand-winch, is employed for warping on coils of wire and cable. In another instance a special body has been arranged to carry fire extinguishers and other fire-fighting paraphernalia. In a third, emergency repairs are provided for in a like manner. In still other cases, trucks with elevating frames have been adopted, operating in conjunction with loading platforms, just as do the small elevating hand trucks described in Chapter XIII.

At the Hydraulic Pressed Steel works the same effect is secured by the use of trailers in connection with a battery tractor. The trailers travel on a pair of large wheels centrally placed, which gives great freedom in turning, while balance is preserved by a pair of smaller wheels, of the caster type, at either end. The trailers serve as repositories for work at machines and the tractor can haul as many of them in train as its tractive power allows. This is rated at five tons, but during tests on a good floor it has hauled ten tons. Its speed empty is seven to eight miles an hour and loaded five to six miles.

The trailers vary in superstructure, to suit different purposes, but the chassis is standard so that a tractor can couple to any trailer. At the present time two of the tractors serve four hundred and fifty trucks, but it is expected that they will be able to care for double this number. To facilitate operation, the plant has been divided into streets and avenues enclosing squares of twenty feet. These are numbered, and the trucks are routed in accordance, one man at a central point controlling the entire movement. He keeps on a card index a record of all trailers and the materials that are loaded on them, and through a system of telephones reaching every part of the plant he and the tractor men are kept in constant touch. By the installation of this system the services of at least forty material handlers have been saved and production has been speeded up vastly.

TO GET BEST RESULTS FROM MOTOR TRUCKS SCHEDULED OPERATION IS ESSENTIAL

IN the foregoing case the arrangement for controlling and routing the battery tractors is full of suggestion, and unless there is some such plan worked out in every instance, satisfaction—at least the fullest satisfaction—may not be realized. At the Willys-Overland motor car plant a fleet of battery trucks is kept busy on regular schedules delivering materials and supplies from the storeroom to the various departments, also on the way back picking up finished parts for delivery to storage. The foremen know just about when to expect a truck and plan accordingly.

At the Pierce-Arrow motor car plant a battery truck is similarly operated, and as it has to pick up goods at various points through the factory, a great deal of time is thereby saved. In this instance, within two weeks of its installation the truck had released the services of five men at an average wage of five hundred dollars per year. Thus, allowing five hundred dollars a year for fixed and operating charges, the one truck will save directly two thousand dollars in labor alone.

At the Bush Terminal a battery truck equipped with a crane is employed. This truck is a special one with motor-car sized wheels, has a radius of action of sixty miles, develops a draw-bar pull equal to that of a five-ton locomotive, and can lift and carry two thousand pounds on the hook. It is used for a great variety of purposes: to load and unload cars and drays; to carry material into a building or on shipboard and stack it up; to spot loaded freight cars and canal boats; to help heavily-loaded drays; to replace derailed industrials and to haul trailers. It is, in fact, the handiest piece of conveying and hoisting equipment about the place, which is one of the best equipped establishments in the country for handling materials economically.

Again, full sized motor trucks are used to advantage in the Baldwin Locomotive Works and other plants to transport "pony" locomotives and similar equipment. They are also employed here, as in a great many instances, to handle incoming and outgoing freight from and to the local freight terminals and wharves. Wherever such trucks can be kept continuously busy, and quick-action loading and unloading facilities are provided, they show large savings, whether for transportation inside the plant or on the outside.

XVII

AUTOMATIC MATERIAL HANDLING

"NOBODY builds a paint factory a single story high," declared a superintendent in this industry recently. "Why? Because we take in our oils at the top and pipe the ingredients from floor to floor till the shipping room is reached. Gravity does the trucking of materials from process to process through pipes."

But liquids are not the only materials that may be made to "flow." It has long been recognized by transportation experts, for instance, that pedestrian traffic portrays fluid characteristics. It is as if the crowds were composed of minute molecules of matter moving independently yet with a co-ordinated direction. So it is with factory products. And proportionately as they are uniform in size and produced continuously, regardless of size or character, do they come under similar laws and submit themselves to conveyor-haulage—either belt, bucket, screw, pipe, or chute.

Thus not only liquids of varying degrees of viscosity, and granular substances in the bulk—such as sand, cement, grain and flour—but isolated articles of metal, wood, leather, rubber, cloth and packaged goods of every description, even truck-loads of material, are resolvable into flow lines and so may be handled most economically and conveniently at one stage of production or another by some type of conveyor.

Where evidently conveyors as a class are most advantageously applicable, and where, therefore, they are found in greatest variety is in industries that are highly specialized and working continuously on a standard product. Of course, the more the product partakes of a fluid or flowable nature, the greater the opportunity for thus handling.

Industries that manufacture largely to order, or have a greatly-diversified product, lend themselves less readily to the use of this equipment. But even in these, the conveyor often finds application in the handling of auxiliary material, such as for instance the molding sand in a foundry.

Conveyors are replacing not only truckers but elevators. "We no longer use elevators," states a manufacturer of office equipment, "except to bring material up. They are too slow for downward transportation. Our processes are arranged so as to finish on each floor opposite the entrance to a spiral gravity chute which drops the goods to the stock and shipping room on the first floor in a few seconds of time. This method is not only quicker and less expensive, but it saves trucking equipment."

In making letter files, also, this manufacturer makes use of a conveyor, of the endless, horizontal-belt type, which serves not only to deliver the various sheets of covering paper to the assembling benches, but to gum them as well. Thus, in addition to carrying, it performs a productive operation; more, it enables one man—the feeder—to determine the pace of all the others.

MAKING CONVEYORS PROCESS AS WELL AS TRANSPORT MATERIALS

SO in many establishments conveyors are found serving not only the purposes of transportation, but important production functions as well. A particularly good example of this is seen in an Indiana canned-goods factory. Peas are the principal output and as the canning must all take place within the space of a few weeks after the crops mature, reliance has to be placed on mechanical equipment as largely as possible. The peas are received vines and all, and are delivered directly from the farmers' wagons to the hopper of a separating machine which combs away the vines and removes the pods.

From this machine the peas are chuted to a shaker which removes the crushed ones and any bits of pods remaining, and delivers the good product to an inclined bucket-conveyor. This elevates the peas to another machine on the second floor, where they are immersed in a strong brine solution, the chief purpose of which is to bring about a gravity separation of the peas into two grades. The heavier (harder, older and, therefore, less valuable) grade sinks to the bottom, the lighter (softer, younger and preferred) grade rises to the top of the solution. Each

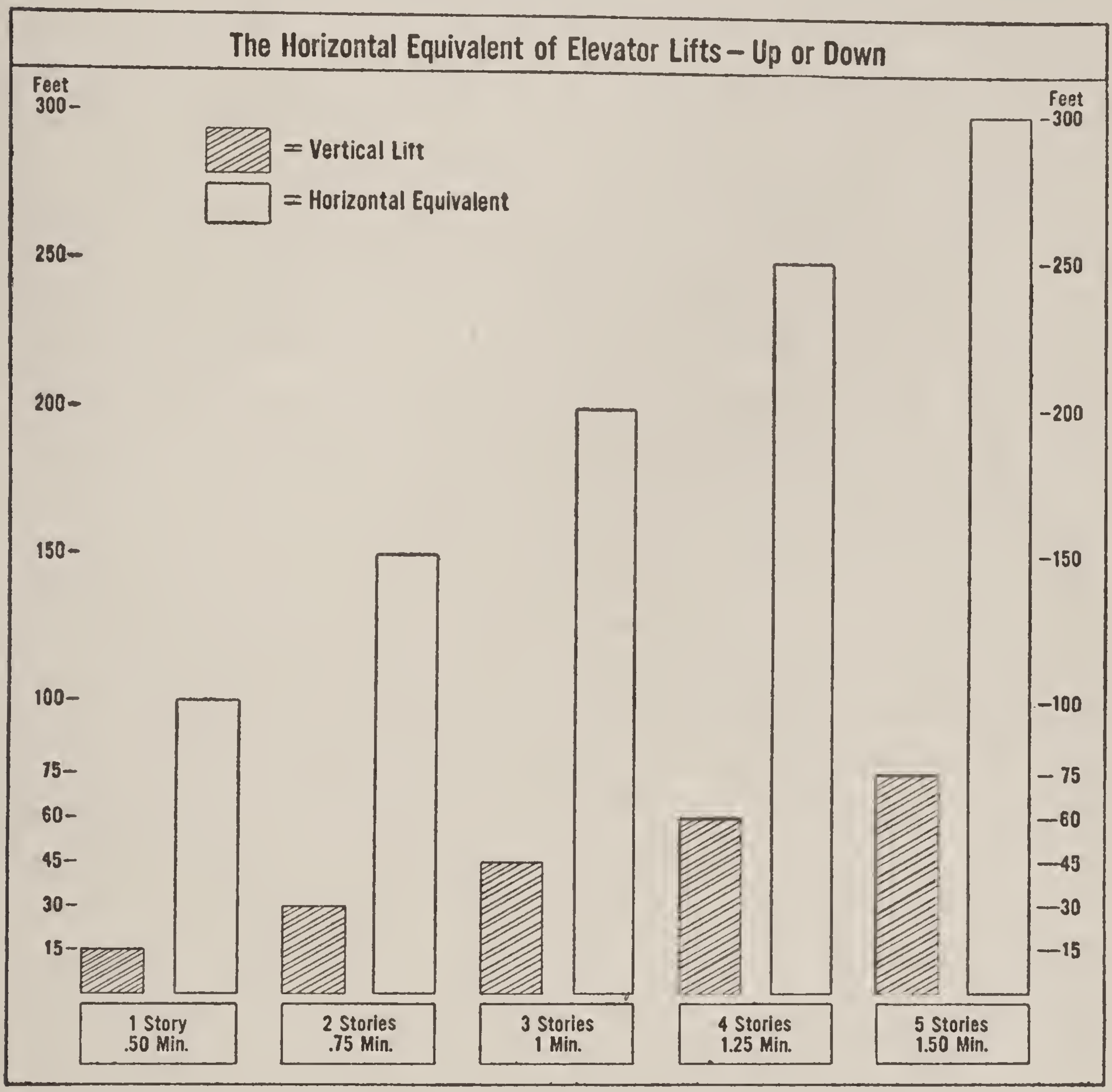


FIGURE XXX: These figures, the result of time study by H. M. Wilcox of Miller, Franklin & Company, in a game-table plant located in the heart of a large eastern city, reveal the inefficiency of elevator transfer. The shaded areas indicate the distance travelled by an elevator and the white areas, the distance covered by a truck in the same length of time. Thus while an elevator is ascending or descending five stories, or 75 feet, a trucker can travel 300 feet on the horizontal. The time would be a minute and a half.

grade is then separately drawn off and passes through an inclined revolving screen, and as the product advances in this it is continuously subjected to the action of a fresh-water spray, to wash away the brine.

At this point the product is collected in pails, so as to permit handling the two grades independently thereafter. Nearby is a chute feeding a fourth machine on the floor below. This separates the peas into several sizes, and the smallest of the tender grade become the "petit pois" of commerce and command the fanciest figure. Again, the peas, as they are delivered from the several outlets of this machine, are collected in pails, from which they are dumped on wide horizontal belts. Attendants line up on either side to pick out any imperfect peas or waste particles, and after another washing, the product is ready for cooking.

When this essential operation is done, the peas are dumped from the cooking kettles directly into the hopper of a filling machine. Of these there are three, grouped closely, and served by a system of gravity and belt conveyors which deliver empty cans, fed in on the floor above, to each in turn as fast as they can come under the spout of the machine and be filled. At the point where the conveyor divides, there is an ingenious little diverting device which automatically routes the cans down the three branches in turn. Just before they reach the divide, the cans are each subjected to the action of a sterilizing steam-jet.

In passing through the filling machine, the cans are not only filled but sealed—all automatically and without waste of either time or material. From it they are ejected into a large metal basket, suspended from an overhead trolley, and as soon as this is filled it is removed and immersed in a tank of cold water, to arrest cooking. After draining and drying, the cans are rolled down an incline through a mechanism which automatically wraps them in labeled paper and are then ready to be packed and stocked.

A conveyor is also employed in getting over the packing boxes which are made in a building across an intervening alley. This first elevates the boxes high above the roof of the box factory and car-top level, and then chutes them down a gravity section to the packing room. Formerly it was necessary to truck the boxes across the track and take them up to the packing floor on a platform elevator. The immense saving realized by substituting a conveyor is apparent. Too, by nicely timing the delivery of boxes, to accord with the delivery of cans, congestion is avoided in the packing room and the pace practically set.

It would be difficult to find an establishment where the unique versatility of this class of material-moving equipment is better and more fully illustrated, and where, too, its possibility as an aid to processing machinery if not an integral part of it, and its function as a pacemaker of production are more clearly revealed.

In a Cincinnati brass-goods factory conveyors perform a productive function also. The reciprocating type of horizontal conveyor is here employed. This consists of a steel trough mounted on inclined legs of ash, which are attached rigidly both to the machine and the floor. These snap back the trough after it has been pulled forward by a source of power. Thus a peculiar reciprocating motion is imparted which causes the lading to travel forward in practically a continuous stream. The economy of this device lies in the fact that the material alone is transported. Of course, it is suitable only for granular substances like sand, gravel, broken stone, grain, ore-dust, coal, and ashes, and obviously is somewhat limited in its application for handling these. In this case, however, it ideally suited the purpose, as will be seen.

The casting floor is at the top of a five-story reinforced concrete building. When the castings are shaken out, the sand falls through gratings to the floor below. It falls between parallel lines of reciprocating conveyors. Each day's accumulation of sand is allowed to stand over night to cool and absorb moisture which an attendant supplies. The next day it is shoveled into the trough of the conveyor, and by the time it reaches the lower end and drops through a riddle into the buckets of an elevating conveyor, to be delivered to the molding floor again, the shaking which it receives enroute has put it in proper condition to be used again.

HOW CONVEYORS SOMETIMES SERVE BY DELAYING MATERIAL IN PROCESS

A CONVEYOR ordinarily is thought of as a means of expediting the movement of material. In the plant of an Ohio baker specializing in wrapped bread, however, equipment of this type serves the opposite purpose—to lengthen not to shorten a transportation link. A certain time-interval must elapse while the dough is passing from the weighing to the kneading machine in order that it may rise properly. The conveyor, therefore, is made purposely long, but an operation of handling is saved and storage space economized. It consists of a series of horizontal belts, one above the other (Page 181) reaching nearly to the ceiling and extending across the front end of the oven room. Its initial section is inclined, reaching from the feeding table to the uppermost horizontal line. Chunks of dough of the proper weight are cut off from a larger mass and dropped on this in quick succession. Reaching the top, they travel back and forth slowly, down a level each time, until a half hour or so later they reach the kneading and loafing machine. From this the loaves emerge in one or the other of two standard shapes and are immediately placed in tins for baking.

A purposely retarded delivery is also furnished by a conveyor of the moving sidewalk type in an ironware plant. This forms the axis of that part of the foundry which is given over to the molding of bath tubs. As the castings are dumped they are rolled over from either side onto the conveyor. Too hot to truck, they are nevertheless promptly taken away and by the time they reach the terminal of the slow-moving conveyor, at the entrance to the cleaning department, and are dumped over a bumper, they are cool enough to be taken in hand immediately by truckers and hurried through the cleaning operations.

At some point in many industries, physical or chemical changes in the product fix a definite time interval between successive operations. In such cases, the delayed conveyor-link supplies carriage and automatic regulation of the time interval as well.

INGENIOUS APPLICATIONS OF CONVEYORS IN FOOD PRODUCT INDUSTRIES

NO industry makes fuller use of conveying equipment or dovetails it more completely with productive operations than does the manufacture of packaged cereal foods, particularly in the filling and packing stages. At the Postum Cereal plant, the empty cartons are fed in continuously at one end of a moving belt conveyor, presently pass under the spout of a grinding mill which is located on the floor above, automatically receive the precise quantity by weight necessary to fill them and continue on their way with scarcely a moment's pause. A few feet further along, the loaded cartons pass in quick succession under a gumming device, and a set of mechanical fingers directly afterwards automatically fold over the freshly gummed flaps and hold them down until the quick-setting glue can get in its work —a matter of second-fractions.

Next the cartons are tumbled over and wrapped in waxed paper—also mechanically. Hot electric plates between which the boxes now pass, soften the wax enough to stick the flaps securely. Then for the first time human hands intervene, removing the sealed packages and placing them in a waiting cardboard packing case. As soon as each case has its complement of cartons, it is shoved onto a second belt conveyor which at the end delivers to the shipping room, but in between subjects the cases to the action of a gumming and sealing mechanism, as were the cartons.

Perhaps the most universal opportunity for advantageous use of conveyors in a factory is at the receiving and shipping ends. Where this type of transportation finds no other application, it is often employed with unique facility in either or both of these places. It may be only a moving chain operating in a groove in an inclined platform, carrying lugs which engage the axles of trucks and thus take the burden of carriage, loading or unloading. Or it may be a pipe or chute to transfer granular material as grain and sand and coal from cars to bin. Again, it may be of the belt-and-bucket type, to carry and elevate materials to floors or bins above. Or a roller conveyor actuated by gravity may be used, which transports articles from the packing benches to the shipping platform and even into the cars.

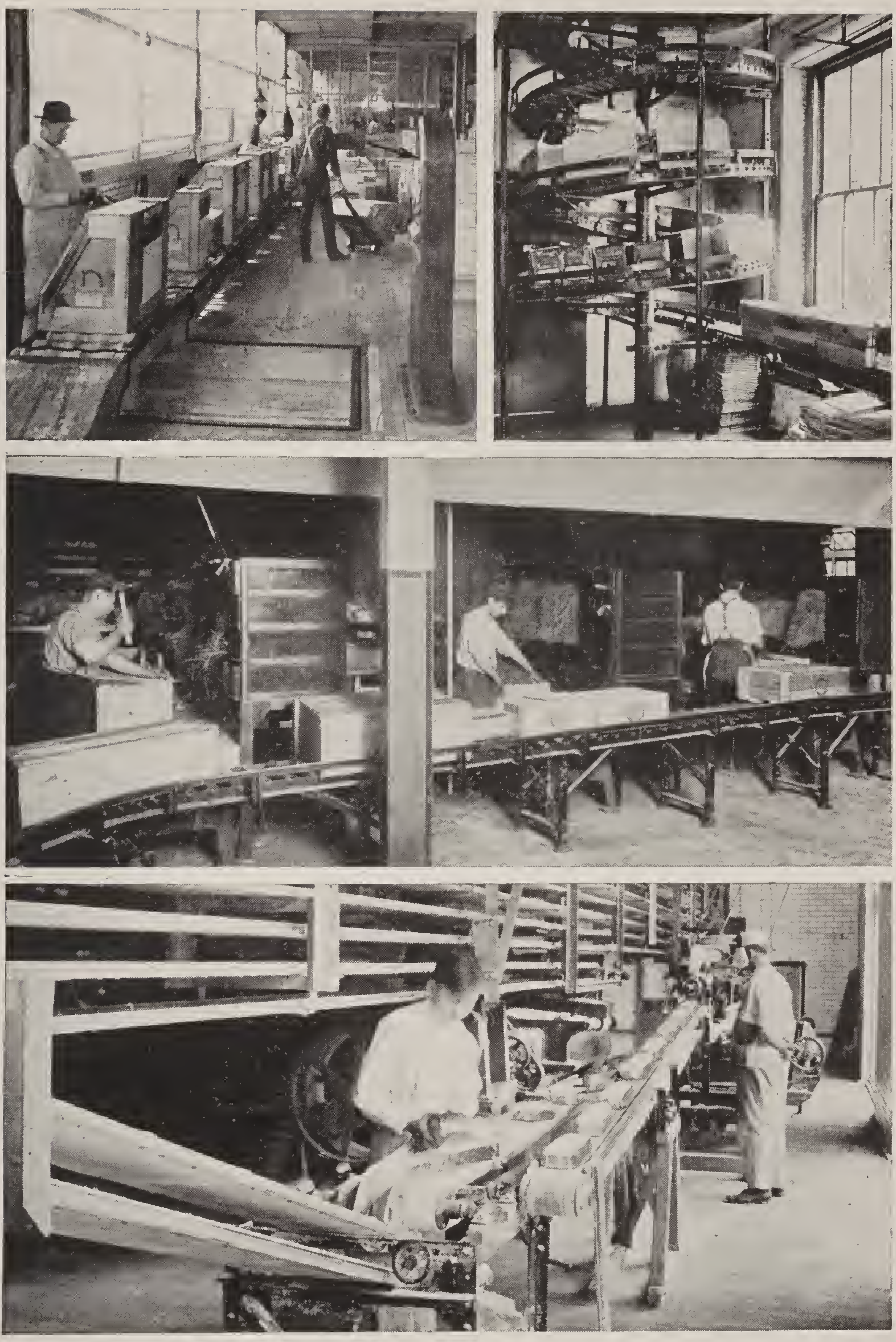
A typical example of the roller-gravity type is seen in the packing and shipping departments of the National Cash Register plant. One line of such conveyors bring in the empty cases from the box-making department. A second line serves to take the cases, as fast as they receive machines and have the covers nailed on, from the packers' benches to the shipping platform. Before reaching the end the cases pass over, and come to rest momentarily on a detached section of the conveyor which is carried on the platform of a dial scale. An attendant notes the weight, marks it on with an automatic stencil, then pushes the case along to make way for the next one (Page 181).

The terminal section of the empty-case conveyor and the initial section of the delivery line are on the level of the packing benches. Machines are delivered at the level of the top of the cases. Thus the packers are relieved as largely as possible of lifting and lugging, and the only effort they must make is to slide an empty box onto their bench, let a machine down into it, and shove the loaded box off. Hence practically their entire time and best energies are conserved for productive work.

This same system could be applied advantageously in the packing and shipping departments of many factories, to the practical elimination of trucking labor and the considerable acceleration of the packing operation. In cases, even the transfer to packing benches could be eliminated. At a biscuit factory, for instance, the products from the several upper floors, packed in the boxes in which they are to be shipped, reach the shipping room on a spiral gravity-conveyor. At the bottom this leads out on a straight, horizontal section facing the windows. Here the boxes momentarily come to a rest while an attendant nails the covers on; after which they at once resume their journey to the cars.

Still another variation is seen in a chemical and drug factory. As it happens, the freight depot of the serving railroad is immediately opposite the factory; and through the courtesy of the railroad, the company has taken advantage of this location to extend their conveyors from the packing and shipping room across two intervening tracks and a roadway to the depot itself. The discharge is within the depot and the freight handlers remove the packages at their convenience. Thus the conveyors serve as a storage, if it is not possible to take away the lading at once. Formerly, it was necessary to load the shipments on trucks and haul them around the block to the depot platform. The immense saving by the new method is apparent.

For downward transference alone, a simple chute of polished maple often will serve every purpose, enabling departments on upper floors to deliver goods to a lower floor with a speed and economy that a platform elevator cannot approach. In an eastern furniture factory where such chutes are in use, in a few minutes each afternoon, by this means, the articles to be shipped



Both at the National Cash Register Company (upper left) and at the Western Electric Company (middle) gravity conveyors remove the production of the packers. At the Ontario Biscuit Company filled cases reach the shipping room on a spiral gravity conveyor (upper right). Conveyors in a Columbus bakery (below) keep the dough in transit while it is rising

At the National Acme Company, small parts are hoisted (lower left) by a gravity conveyor section. Crossing a bridge, they are partly cleaned (middle left), washed in soda baths (E, upper left), put in dry boxes, 'empties'' returned (F), the parts sorted (upper right), sent on gravity conveyor to the packing room (middle right) and shipped out (lower right) that evening are brought down from the storerooms on the second and third floors to the packing and shipping room.

An objection to chutes of this kind, as well as to spiral gravity conveyors and spiral chutes is the space they take out of the floor. Of these, the spiral chute is least extravagant of space. Of course, by enclosing such conveyors in weather-tight housings, they can be placed entirely outside the building and so take nothing out of the floor area. The spiral chute used by the office-furniture manufacturer referred to earlier in this chapter, is of this type. But location outside the building is not always the most convenient location. Moreover, it is often desirable to raise empty packing cases from below about as fast as filled ones are lowered. With chutes of any kind, it is of course necessary either to use the regular platform elevator or a special elevating conveyor for lifting.

A type of conveyor exists, however, which nicely meets this combined need, and, moreover, takes a minimum amount out of the floor area—just enough, in fact, to let the required size of package through.

Platforms carried at equal intervals on endless chains or cables are loaded at the top or upper floors with the packed goods. By gravity the whole mechanism starts to move. Below empty cases, or any lading lighter than that coming down, may be piled on the platforms coming up on the opposite side. Brake devices control the movement, so that no matter how heavily loaded, the speed cannot exceed a predetermined rate. These also make it possible to stop and lock the machine at any floor, thus putting it within the power of the man at the discharge point to prevent congestion. A steel partition divides the two sides, and the whole may be entirely enclosed in a fire-resisting housing if desired.

The platforms are simply steel fingers, so that at any floor level coming down the lading can be unloaded automatically merely by placing in position a landing platform having inclined steel fingers which reach up and interlock, but do not touch those on the platform. In some instances, horizontal moving chain belts are placed at the bottom, intermeshing with the platforms and removing the articles without tipping them.

While the capacity of such a conveyor is hardly equal to that of a spiral gravity type, it has one decided point of advantage, in addition to those already mentioned, namely, that the most delicate product can be lowered rapidly without the slightest danger of injury. Packages following one another in quick succession on a continuous conveyor are liable to jamb occasionally, particularly at the bottom. This contingency is impossible when each parcel goes down on a separate platform.

Where such conveyors are to be employed mainly for lifting material, it is of course necessary to have them power-driven. But as one side is balanced against the other, the power required is surprisingly small, especially if its services are frequently needed to lower materials as well. Automatic unloading of essentially elevating conveyors is achieved by having the platforms arranged to tip on being engaged by a tripping device at the floor level where discharge is desired.

The platforms may be shaped to suit the contour of the article to be handled, as for example barrels or kegs, although in such case they must be double if the conveyor is to lower as well as elevate. Or they may be a series of buckets, spaced closely together, for carrying bulk material, and so hung in the chains as always to be upright whether travelling up or down.

In combination with horizontal moving belts of canvas or rubber, made to assume a trough-shape by the arrangement of rollers underneath, these bucket elevators permit loose granular materials of almost any description to be transported hither and thither, up and down, with practically the same facility as packaged goods. The belt carriers even operate well on a fairly sharp incline.

REARRANGING THE PLANT TO PERMIT BETTER CONVEYOR SERVICE

IN most of the foregoing instances either the factory has been laid out with the use of conveying equipment in mind or its substitution for less efficient carriers has been a simple matter. But sometimes the problem of substitution is pretty complicated and involves radical and costly changes, extending in cases to the entire rearrangement of the manufacturing plant. Even then the savings may be so great as to warrant the expense; in fact the benefit gained by reordering the processes to permit the use of conveyors may alone justify the improvement.

Such was the case in a middlewestern screw-machine products plant. Increasing delay in handling the millions of small parts through the cleaning operations and mounting expense for trucking labor forced the management to a realization that something must be done. Material-handling experts were called in and as a result of their investigation an extensive system of conveyors, mainly of the roller gravity type, were installed. The problem was complicated by the fact that all four floors of the main building are required for the production, relegating the cleaning operations to another building one hundred and forty-five feet distant. The initial link in the system is an endless-chain elevator operating in the first building. It is fitted with special arms to carry the pails in which the output of the machines is collected. The pails are trucked to the elevator openings on each floor and placed one by one on special loading platforms (Page 182), whence automatically they are picked up by the elevator arms and lifted to the top. There, again automatically, the pails are discharged onto an inclined gravity conveyor which leads out across the bridge connecting the two structures, and at the other end delivers directly to the cleaning department.

Here, after the free oil has been removed in centrifugal separators, and the scrap has been taken out by means of a vibratory-screening process, the parts are placed in special steel trays, having perforated sides and bottoms. As fast as the trays are loaded, they are placed on a gravity conveyor, and at the bottom of a short decline, are engaged by a power section and taken through a series of boiling soda-water baths. These thoroughly cleanse the parts of dirty oil and fine chips not removed previously.

Emerging from the baths, the parts pass under nozzles of loom oil, which gives them a rust-proof coating. An attendant then removes the trays, transfers the contents to wooden tote-boxes and sends the empty trays back on an upper return line to the starting point. Only the first few feet of this return is power driven, in order to give the necessary elevation to scale the washing chamber.

The wooden boxes the attendant places on a continuation of the lower conveyor; and at the end of a short decline they are engaged by another power section and lifted to a final gravity section which passes through a hole in the fire-wall to the assorting and inspection room beyond. Here, after the parts have been assorted, inspected and counted, they are again placed in tote boxes and chuted down a spiral gravity conveyor to the second floor. This ends in a long, gently-sloping straight section which conveys the parts to the packing and shipping room at the farther end of this floor. A final line of gravity conveyors, terminating in a portable section, facilitates continuous, speedy and economical loading of the packaged parts on cars for rail shipment or on motor trucks for local delivery.

When it is considered that over forty tons of screw-machine products, aggregating a million parts a day, are handled by this system in ten hours, as against twenty-four hours formerly, and that in the cleaning operation alone the services of eight men were saved, the improvement would have been justified, even at double the cost.

From these instances of cost cutting and flexible use, it is evident that no class of material-moving equipment satisfies better than conveyors the cardinal principle of economical factory operation—''Keep the product on the move.'' Nor does any class conform more closely to the principles of straight-line transference, minimum time-and-space-intervals between successive operations, the keeping of work on the same level as far as is practicable throughout the sequence of processes, the shouldering of the burden of carriage on mechanisms rather than on man and the burden of motion on gravity rather than on mechanical power wherever possible. And in addition to these advantages, the conveyor, in skillful hands, often becomes an efficient tool of production.

Part IV

EQUIPMENT OF CONTROL

AUTHORITIES AND SOURCES

FOR PART IV

Chapter XVIII. Developed from studies made at the following plants: New England Butt Company, Hart-Parr Company, Automatic Electric Company, Arrow Collar Company, Seng Company, Commonwealth Steel Company, and Eberhard Faber Pencil Company.

Chapter XIX. Includes material contributed by George F. Card, of the Fort Wayne Electric Company, Bernard J. Klein, M. E., of the Wisconsin Steel Company, Edward K. Hammond, and H. W. Ambruster. Based on studies of the plants of the Addressograph Company, Chicago Belting Company, a box manufacturer, and others.

Chapter XX. Based on studies made at the following plants: Thomas B. Jeffrey Company, Hart-Parr Company, Pierce-Arrow Motor Car Company, National Lamp Works, Gray & Davis Company, Frantz-Premier Company, Addressograph Company, Burroughs Adding Machine Company, Felt & Tarrant Company, Altman Taylor Company, Continental Motor Company, Commonwealth Steel Company, Autolite Company, Sprague-Warner & Company, Kellogg Toasted Corn Flakes Company, National Cash Register Company, Detroit Lubricator Company, an eastern brass mill, a middle-western plumbing goods factory, and others.

XVIII

MECHANICAL AIDS TO MANAGEMENT

NO captain of a modern ocean-going ship, nor even of a harbor pilot boat is today obliged to co-ordinate the operation of his craft with only the powers of his own voice, the keenness of his own vision, the acuteness of his own hearing and his personal activity. A marvelously ingenious nervous system centering in the pilot-house—the ship's brain—reaches to the most remote points, enabling the navigator to direct its many forces simultaneously and registering its movements before his eyes momentarily. Without the aid of all this highly developed mechanism of direction and control, the industry of water transport today would be inconceivable.

Similar in its need, but tardy in its development, is the industry of manufacturing. Few factories today are without some equipment that mechanically multiplies the efficiency of the executive. But fewer still have availed themselves of every existing mechanical aid which extends his reach and tightens his grasp on the machinery of management.

In time, as competition grows keener and profitable operation becomes even more than now a question of intensive utilization of time and space, the "nervous system" of a factory will become of necessity as highly developed as that on shipboard today.

Equipment of executive control, in the factory as on vessels of commerce and war, broadly is of two classes—devices that automatically register or record what men and machines are doing; and devices that facilitate the transfer of intelligence.

In the first class are meters that measure and integrate the consumption of electric current (for both power and lighting), and of water, steam, compressed air and gases; mechanisms that measure or weigh and record for the manager's eye the true story of wage time and purchases, sales, and shipments; gages that record steam, water, gas and air-pressure; smoke recorders that check upon the efficiency of combustion; recording thermometers and pyrometers that indicate and control the temperature of processing furnaces, cooking vats, and other heat-using apparatus; thermostats and humidostats that automatically control the temperature and humidity of the air; automatic sprinkler alarms and watchmen's clocks; various highly technical special-purpose devices; and recorders that automatically check machine activity and trace out the story of production instant by instant before the eyes of the executive—in effect multiplying his personal presence by the number of his machines.

As yet no instrument has been devised to record similarly the effort of men except as tabbing machine activity also checks that of the operatives. Logically this would appear to be the next development. Already in a few factories the moving-picture camera is being utilized to record the motions of workmen on certain operations over a period. Simultaneously, a clock with a special dial divided to show time to the hundredth of a second, is photographed, as shown in the volume on Labor. Exceedingly close study of motions is afforded by the timed films, and faulty motions are disclosed which even the keenest time-study man could not note. While the main purpose of all this is to raise the skill of workmen and to arrive at more accurate operation times, the manager by reviewing the films is enabled to get a perspective on the activity of his factory which raises the efficiency of his supervision. Carrying the idea further—coupling the principle of the motion-picture machine with that of telephotography may some day maintain in the manager's office a panoramic action picture of the shop.

Time-clocks, together with the proper standards of work, furnish a considerable degree of control over labor. Moreover, they do much, in a departmentalized business, to coordinate the organization. When each man depends on his own time-piece, or on his neighbor's, or relies on some makeshift clock which seldom agrees with any other time-piece in the factory and proverbially is much too fast or too slow, reliable timing on jobs is

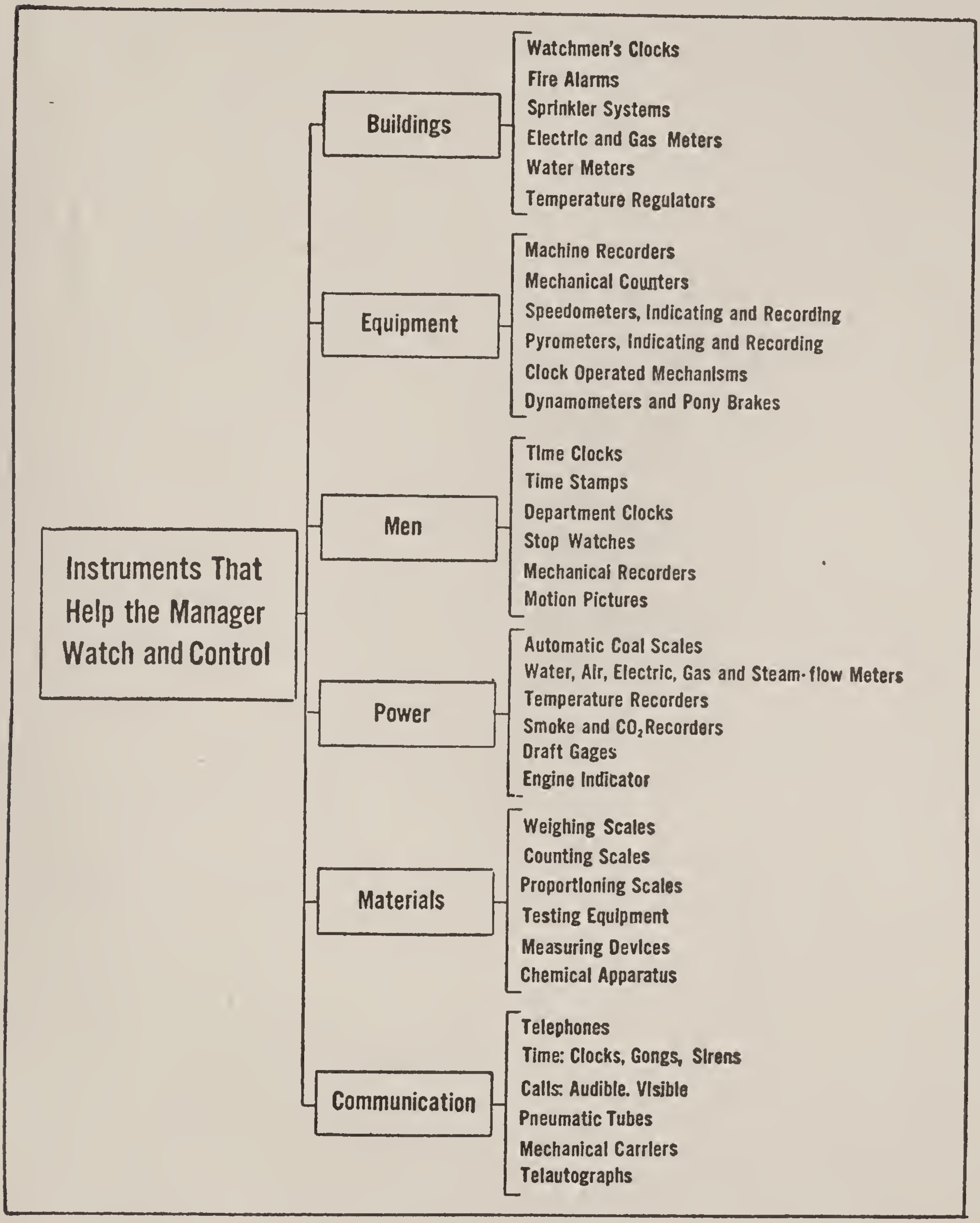


FIGURE XXXI: Shouldering the burden of routine control upon mechanical devices automatically operated, frees the manager for his main functions—those of initiation, decision and inspiration. The efficiency of foremen and inspectors, too, is increased, clerical labor is saved, the entire working force spurred to greater effort, and smooth and economical operation of the factory promoted

impossible and carelessness is promoted throughout the shop. Efficiency is closely related to a proper appreciation of the value of the minutes, and standardized operation presumes standardized time.

Every department, therefore, needs one or more clocks, so placed and with large enough dials so that every man can note the time. These clocks for best results should be controlled by a master clock in the manager's office which in turn is controlled by telegraph. In the operating offices of all departments, many plants also have time stamps which likewise are controlled by the master clock. These furnish practically the only means by which incoming and outgoing orders and communications, and workmen's job cards can be timed accurately.

At the point of entrance and exit, according to the practice which is now almost universal, registering clocks are placed, also synchronized with the master clock. These clocks record on individual workmen's cards or on a contained cylinder roll, the exact time-in and time-out of every workman. Most of these clocks point out late arrivals or early leavers by printing the time, after the starting and before the quitting hour, in red. This distinction facilitates the work of the payroll and minimizes discrepancies, accidental or intentional, in making up credits.

The factory chief, it has been said, is a watcher, an economizer, a pusher, a planner. In proportion as his reach is extended with these devices that enable him to replace tedious watching in person with watching at long distance and automatic records for study at leisure, and in perspective, his ability to economize, to push and to plan is multiplied. More and more he is shifting the detail of his oversight to automatic devices and with each new invention his reach lengthens and he gains in freedom of action. After he has shifted to machines all the watching burden they can carry, however, the executive still needs special information of many sorts from hour to hour. Instruments for the transfer of messages not only round out his watching, but also equip him to spread the inspiration and send the orders which despatch his economies, his plans, and his pressure for results.

Of devices in this second group, which facilitate the transfer of messages to and fro in the plant, electricity has made many possible. First and in practically general use is the telephone. Specialized uses of this means have greatly extended the manager's reach. He can in a few seconds of time confer with any department head or official important enough to have a branch telephone. He can also stay in fairly close touch with his office when making his rounds of the factory, merely by keeping the operator or his secretary posted on his route. One manager has figured out approximately the time required to make each stage of his round. On her desk the operator has this schedule. Upon starting he simply notifies her of the fact. Should anyone desire to reach him before his return, she can usually locate him in a few moments. Another manager makes it a practice to call in at every main station and advise the operator of his whereabouts and his next move. Audible systems of course answer the same purpose except that some find them objectionable on account of the disturbance created in the factory when the call sounds. Under certain conditions, however, such systems fill the need as does no other plan.

At the Hart-Parr plant the ordinary telephone system is utilized for call purposes by having separate rings for the three or four chief officials. When one of these is wanted urgently, the operator sounds his ring on all the telephones. This is effective in reaching the man almost immediately wherever he may be in the plant. If he doesn't hear the ring, someone near a telephone, who has observed his whereabouts, will notice it and summon him.

Even factory conferences are held over the telephone. The ordinary manual system, however, does not afford this facility in the same degree as the automatic systems. These allow the manager to call into the circuit at once any number of his department heads whom he may wish to consult with or instruct. Automatic service also is practically instantaneous, is in readiness twenty-four hours a day, is closed to those who might "listen in," except at the volition of the initiator of the call, and requires an operator only to handle incoming calls.

Telephones, moreover, are in routine use in a number of establishments, furnishing the means of reporting job time stopped and started to the central office without requiring the workman to leave his station. He simply hands his card to the gang-boss, who steps to his telephone and calls the time office. Then the clerk picks the proper duplicate job card from the rack and slips it under the punch of his time stamp.

Many instructions cannot be transmitted verbally, because either too bulky or too important. All verbal instructions, moreover, should be confirmed in writing at the earliest possible moment. In some factories, to handle such communications, regular mail routes are established. Every department has its mail box and the factory postman makes rounds at regular intervals, delivering and gathering department mail. But this service in many cases is too slow. Practically the alternative, for lengthy communications, is a pneumatic tube or mechanical carrier system.

For instantaneous transmission of brief orders as well as calls, a device heretofore used mainly in hotels and clubs, now is finding a field of usefulness in factories. This is the telautograph, or handwriting transmitter. Instructions given verbally over a telephone may be misunderstood and seldom are remembered clearly, unless jotted down in detail at the time. But a telautographed order has the force of a formal communication. Moreover, a record is made simultaneously at both the sending and receiving ends and confirmation in writing, as is necessary in case of orders transmitted over the telephone, becomes superfluous. Few other devices extend the manager's reach as literally and effectively.

HOW THE BUSY MANAGER CAN TRANSMIT HIS WISHES INSTANTLY TO THE SHOP AS A WHOLE

AMONG other contrivances that facilitate the transfer of intelligence are whistles and gongs. These have been in common use in the industrial world for generations. It is difficult to discover when factory workers did not start and stop with the blowing of the whistle. Of late years, however, the noisy factory siren has been growing in disfavor, particularly in the larger communities and, in fact, is prohibited by law in some cities. Instead, gongs are coming into more extensive vogue. When each department has its gong, as well as its subsidiary clock, and the gong, too, is controlled automatically by the master clock, the factory literally starts and stops with clock-like precision. No more does the manager have to depend on the will or whim of the power house. His instruction to the shop when it shall begin work and when it shall cease, is standardized absolutely. Moreover, the gong service furnishes a perfect means of summoning the force together at any instant of the day, should special occasion arise. Its chief intermittent use, however, is to call all hands to man the fire-fighting apparatus should a blaze break out in any part of the plant. A gong system also may be employed to call individuals. As a means of co-ordinating the activity of an organization, it classes with the synchronized clock-system. As a transmitter of instructions it is, within its limits, second to none, for it is instantaneous and absolute. Its only competitor, in fact, is the loud-speaking telephone. This in a very noisy department, however, is practically worthless.

In some plants, in lieu of gongs, visible call systems are employed. These do practically the same work as gongs, in that any simple code of signals can be transmitted by a combination of flashes. While having the advantage of silence, these are not so effective in getting attention as gongs and frequently several repetitions of the signal are required to get attention. Nor are they as effective in announcing the start and stop instants, or in communicating an alarm of fire. Consequently, where a silent call system is desired, the visible signal apparatus generally is installed in addition to, not as a substitute for a gong or loud-speaking telephone system.

The important fact for the manufacturer is not this list of management aids, which is not complete and never will be final. The vital thing is that the manager who frees his time of what machines and equipment can do will be more effective in his true function, that of deciding, initiating, and inspiring. His trained eyes, his resourceful mind and his eager spirit will permeate the organization. The enterprise will pulsate with his personality.

XIX

AUTOMATIC CHECKS ON MACHINE OPERATION

MAKING machines write their own diaries is today a literal reality of vital importance to every manager. Regardless of what the equipment is, so long as it operates mechanically on the product subject to man control, human ingenuity has contrived a practical means of accounting automatically for its activity. The device may be only a simple ratchet counter, geared to the throw of a punch press, which registers infallibly each operation of the machine and totals as it goes. Or, it may be an electrically operated mechanism recording at a distance, which, in addition to counting the output, records indisputably the time busy and the time idle, from whatever cause. Under proper methods, thus, practically any machine can be made to tell when it is a productive and when an idle investment. Moreover, the status of a machine implies much as to the efficiency of operators and shop conditions.

This is exactly the sort of knowledge that the alert manager wishes most to have and which to him is power. He cannot personally watch all his machines. Nor can his supervisors be expected to maintain an instant watch over every machine in the shop. He may avail himself of the services of expert time-study men, and in the course of months or years obtain such facts about what is in relation to what ought to be that he can dictate the rate of production. But this is an expensive and tedious process. Moreover, men who can make absolutely accurate and reliable time studies are rare, and at best carry with them each his own personal equation.

Not so with automatic production recorders. Their evidence is absolute, unsentimental, and indisputable. They tell it instant by instant, not when the day is done or some time next week. Like the automatic sprinkler, they are always on the job and immediate in their action. They tab the activity not for a few hours nor a day now and then, but constantly and continuously; not of one or a few machines at a time, but if desired, of every piece of processing equipment in the factory. And they speak their story in black (or red) and white in front of the very eyes of the manager at his desk (Figure XXXII).

Why then are not automatic machine recorders in universal use? Because many managers do not suspect the discrepancy in their practice between what is and ought to be. The fire alarm of time and capital consumed and consuming at machines has not yet sounded in their ears.

A manager of this type was persuaded to try a recording device on a battery of five machines. So skeptical was he of its

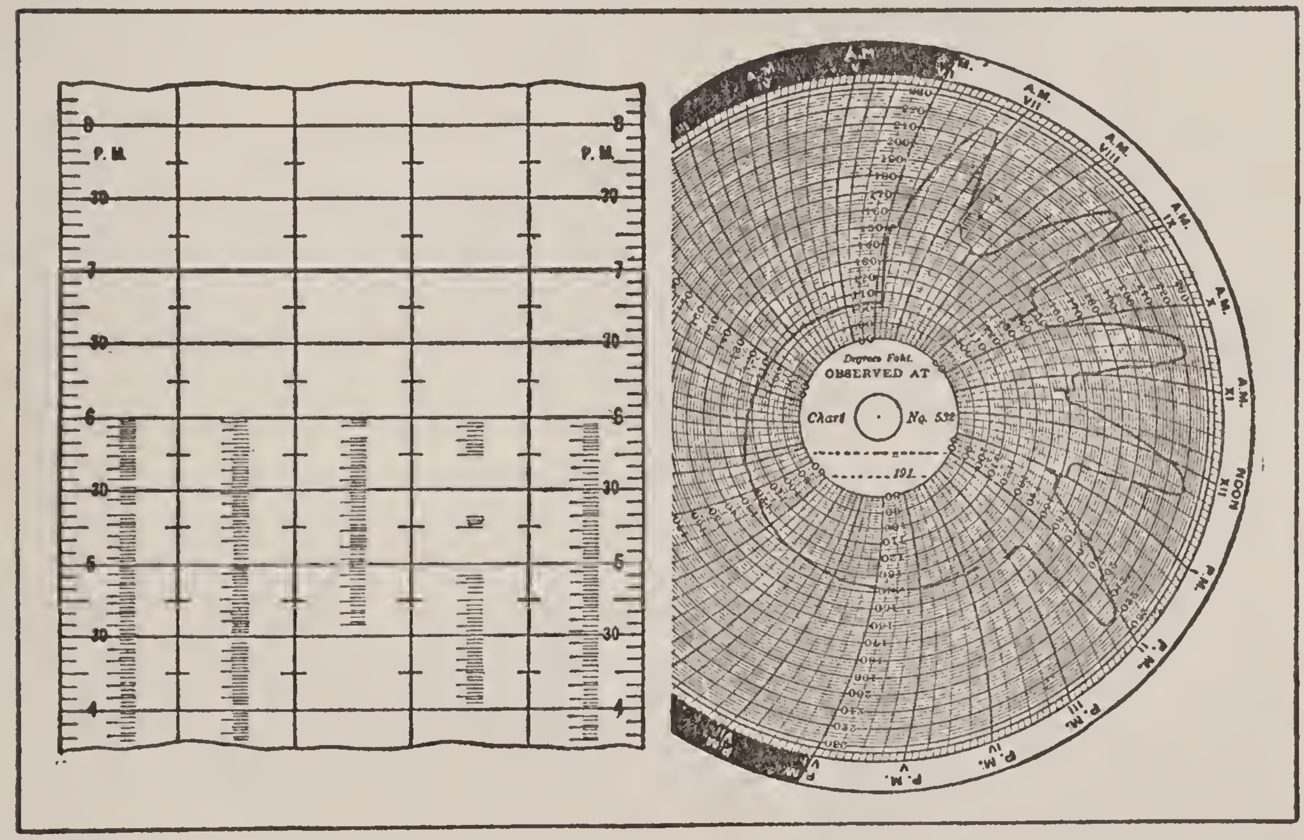


FIGURE XXXII: The series of short dashes on the chart record at the left indicates when machines are producing, and their absence denotes idleness. The recording thermometer record at the right shows plainly to the superintendent the time of starting each mash in a distillery cooler, the duration of the cooking and the temperatures reached

utility that for days he did not deign to notice the record. Nevertheless the little instrument was making its impression on him. Its recording was accompanied by a ticking sound. One day he suddenly became aware that the ticking was not as regular as usual. He looked up to find that two of the machines had stopped.

Almost unconsciously he reached for the telephone and got the foreman on the wire. Whereas he had been skeptical, now he instinctively demanded why those two machines had stopped. He wasted no time asking if they had stopped, he accepted as final the evidence of the needles to that fact. He wanted to know why.

"Lack of material," was the reply. "Did it happen often?" On being pinned down, the foreman had to answer in the affirmative. Yes, it happened frequently, and in this particular case a new supply of material would not be on hand until the next morning.

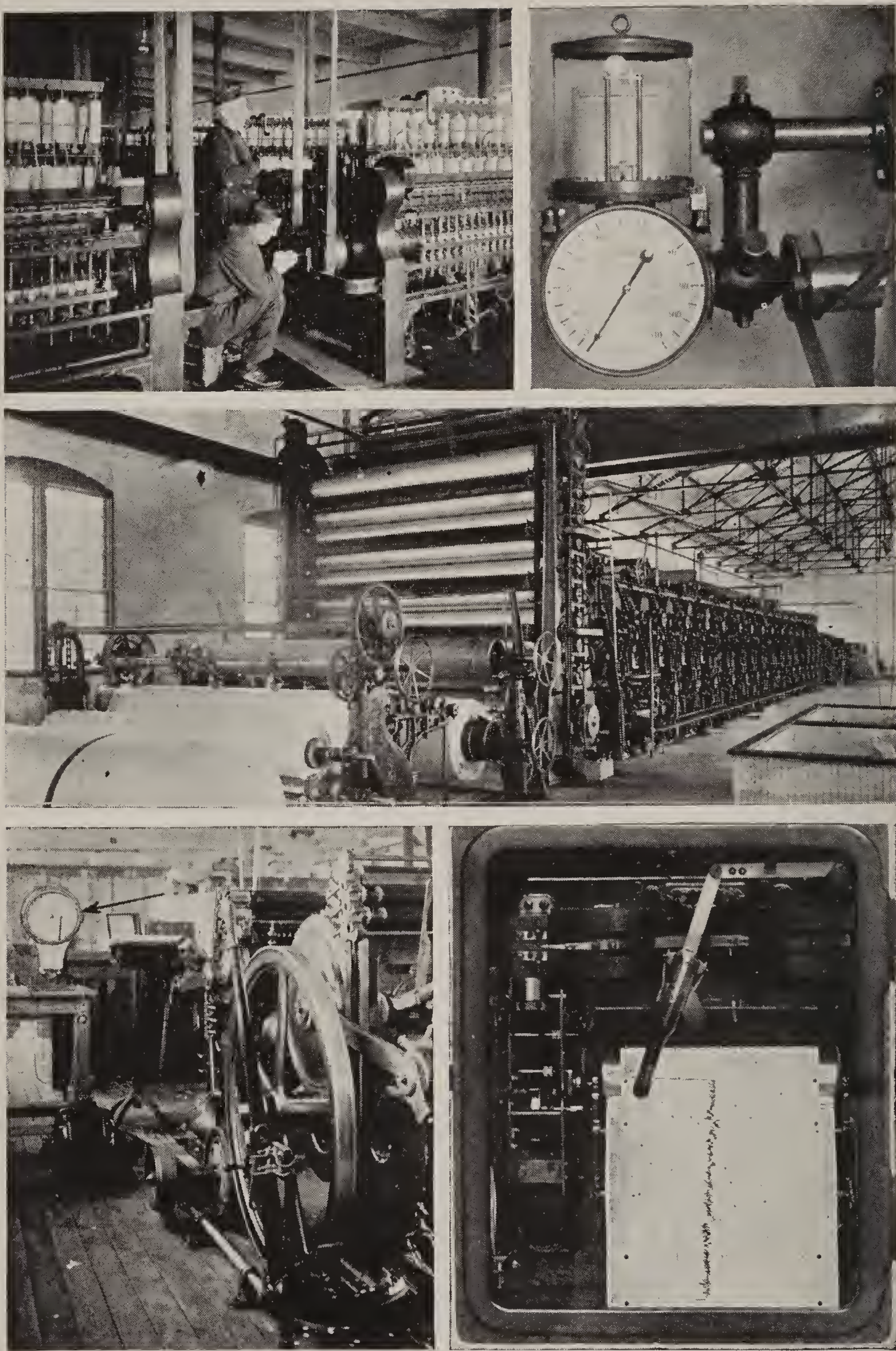
This revelation galvanized the manager into action. He began to study causes of delays at machines, with amazing findings. A general shake-up of the routine shortly resulted, out of which came economies in the cost of production that surprised even the man who had suggested the machine recorder.

HOW UNNECESSARY IDLE TIME IS PUT TO WORK BY "MECHANICAL WATCHMEN"

THIS manager's finding was not exceptional. His shop was above the average in efficiency, and he prided himself on the fact. Nor was his pride without warrant. The reports and records he received indicated a satisfactory condition. Whenever he made a personal round of the factory he found everybody busy. What happened after he got back to his desk he could not know definitely—until he brought each machine into the office where he could watch it currently by means of an automatic electric-recording instrument. Then the sly culprit, idle time, that was stealing his profits, was caught in the act.

Idleness of machinery results from many causes. These in general divide into two classes—one due to workmen, the other chargeable to management. Some managers are inclined to blame the workman entirely. Undoubtedly a share of the fault is his; but inadequate planning, dilatory maintenance, rate cut-

Various indicating and recording devices enable a superintendent (above) to oversee the plant from his office. Audible call devices (middle left) and loud-speaking telephone systems (middle right) afford quick communication. A telautograph (middle left) enables an executive to transmit written orders instantaneously. An outside 'phone (below) coupled with a private exchange further aids control



Hand tachometers (top left) serve to check the speed of revolving machinery. Recording tachometers (top right), write continuous records of machine speeds. On costly machines, as in paper mills (middle), automatic recording devices are especially valuable. The recorder (left below) provides a continuous record of printing-press impressions, and the wattmeter to the right registers power used ting and insufficient thought for the human factor in various ways are vitally inter-related with the problem of getting the largest returns from the investment. Few shops at any rate are using their machinery up to the limit of effectiveness. Evidently the management must determine the actual proportion of this idle time before passing to reasons and remedies. Various methods exist for obtaining this information. Second to none where applicable is the "mechanical watchman" of production.

Nor is the application as limited as some managers are inclined to think. Instances exist of the successful use of automatic recorders in connection with wood and metal-working machinery of all descriptions and in the paper, textile, leather and printing industries (Figures XXXIII and XXXIV).

The successful application of a machine recorder to a planer is related by George F. Card, of the Fort Wayne Electric Company. This machine was driven by a thirty-horsepower electric motor, directly belted. It was operated double shift, planing heavy oak planks at night and other material during the day. The night work especially had proved unsatisfactory. Records from job cards showed a widely varying production, but all attempts to locate the causes had failed. Finally a special electrical recording device was attached. This consisted of a contact-making piece attached to the machine and a recording instrument located some distance away and connected electrically to the contact-maker. The latter was attached to the underside of the planer and consisted of a block of wood and two brass strips set in a direction at right angles to the run of the bed. The ends of the brass strips projected slightly above the bed of the machine so that as a plank passed over the strips it pressed them together and closed the circuit. After the planks had passed the strips would spring apart and open the circuit.

At the chart end, this alternate making and breaking of the current was indicated by a broken red line—the solid portions conforming to the time a plank was being planed and the blank spaces when the machine was running idly. By counting the red sections, the executive obtained the number of planks planed.

The recording apparatus was rigged up one evening in the interval between the day and night shifts, unknown to either gang. The next morning the chart told an interesting story.

The working time was ten hours, the midnight hour excluded. Motor and planer ran without pause, but the machine itself was turning out work only four hours and forty-five minutes, or forty-seven and a half per cent of the total running time. It was 8:15, or one hour and fifteen minutes after starting before

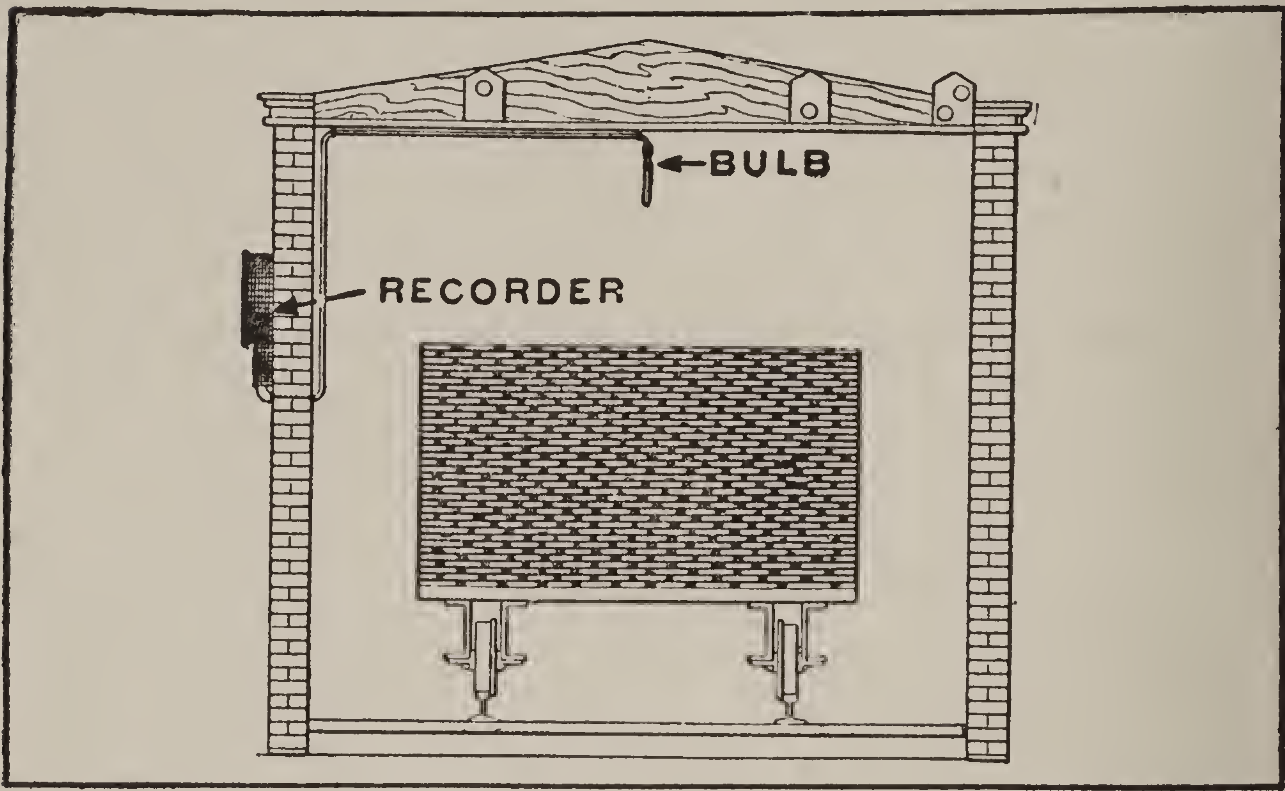


FIGURE XXXIII: A recording thermometer in a dry kiln enables the superintendent in a woodworking plant to look after his drying more carefully. The instrument is installed outside the kiln, as shown, which makes it easy to read and to maintain a more constant temperature

the first plank went through. Thereafter, during the night the following stops were recorded: from 9:25 to 10:10, from 1:00 to 2:12, from 3:15 to 3:55; from 4:10 to 5:03 and from 5:30 to 6:00 o'clock, stopping time.

The time lost at the start was explained to have been taken up in putting on new cutters and in cleaning up about the machine. As this obviously was an excessive amount of time for five men to put on the job, the management arranged for one man to prepare the machines during the intermission between the two shifts. Readjustments on the machine accounted for other stops, but much of the idle time was explicable only on the basis of straight soldiering by the workmen. A rough estimate of the losses was fifteen hundred dollars annually. Fortified by the definite analysis furnished by the chart, the management was able to double the average output and cut down the night shifts to three instead of five a week.

In a wagon and buggy factory, a similar recorder proved extremely helpful in setting just piece rates on a hub-mortising machine. In this instance the records were taken with the full knowledge and cooperation of the men. The contact piece was attached to the treadle of the mortiser so that the chart would show not only the number of hubs operated on, but the number of wheels turned out.

It seemed possible to ''beat'' the instrument by fastening down the treadle and letting the machine run for five or ten minutes before putting in another hub. But since the operation of mortising a hub necessitates turning it from one position to another for each spoke-hole, with a short stop while making the change, it is clear that for each such interval a break should be shown in the red line. Consequently, if the treadle were held down,

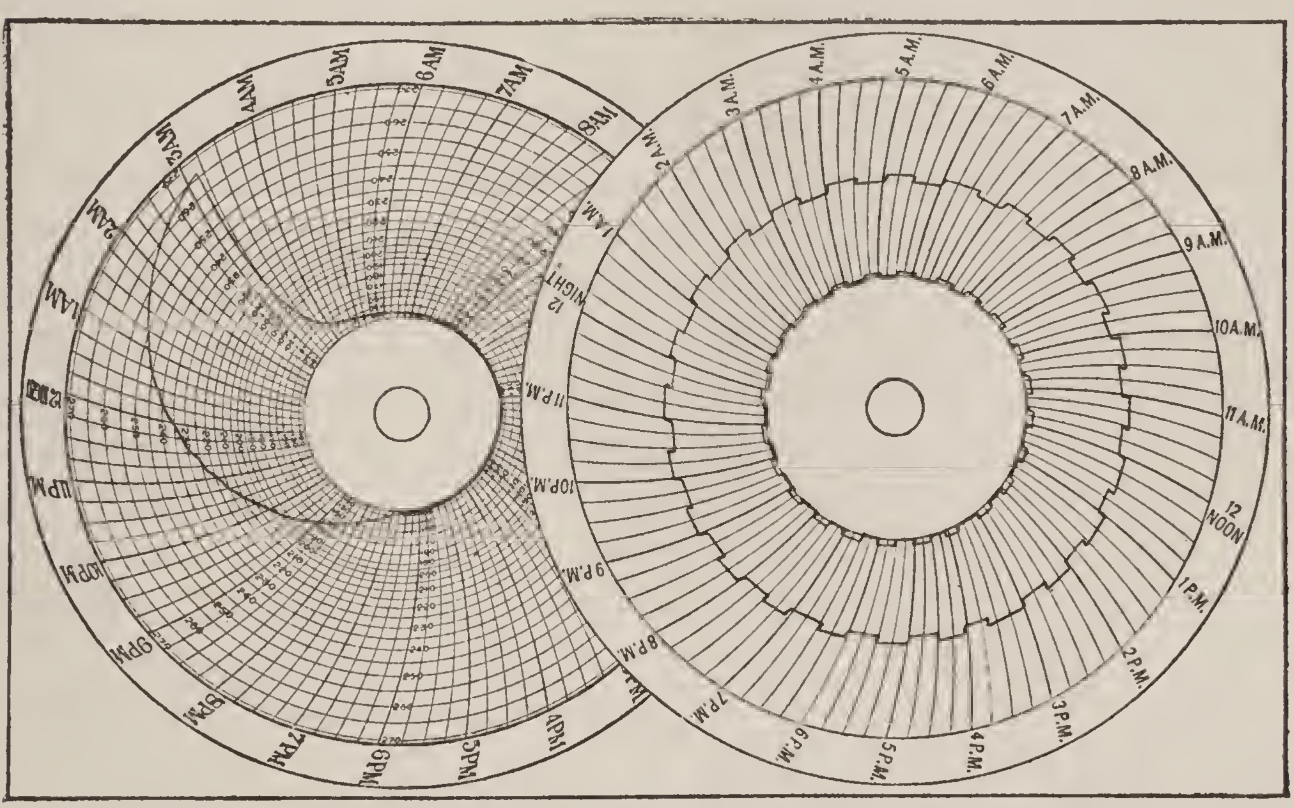


FIGURE XXXIV: How the manager of a rubber shoe factory keeps accurate check on the vulcanizing process in his plant is shown in the chart at the left. This chart indicates the time at which the variations in temperature occur and the degree of heat in the vulcanizing ovens. The whole story of the heat treatment of the rubber is indicated by the heavy line. From the chart at the right the superintendent and engineer at the Wisconsin Steel Company can make certain that the gas and air valves on the regenerator are opened and closed regularly at thirty-minute intervals

so that the chart showed a continuous line, it would represent more time than was known to be required for a dozen holes.

The study made on this machine resulted in a mutual agreement to raise the piece rate on the basis of a thirty per cent greater output and ten per cent increase in pay. This adjustment was made without friction in spite of the fact that the matter had been a bone of contention for months. The record indicated that thirty per cent more production was possible without undue effort on the part of the attendants, but they were given an increase in pay to compensate them for the greater diligence that would be required.

AUTOMATIC RECORDERS MAY BE APPLIED TO A WIDE VARIETY OF MACHINES

SUCH an analysis of machine time is possible in any factory. The same method has proved satisfactory in metal-working plants. The operator of a large iron planer, a conscientious and diligent workman, did not know that someone besides himself should be held responsible for at least part of the poor time he was making. Automatic contact-makers were arranged on the planer in such a way that when the machine was running, a series of short lines and spaces were recorded on the chart, and when not running a long line or space. Another contact also was attached to the belt shifter so that the recorder could not operate when the planer was actually shut down. As a result of the records obtained, improved facilities were provided for handling heavy castings and the quantity of finished parts carried in stock was increased, enabling the planer to operate at considerably higher efficiency.

Similar results were obtained on a forming machine which the automatic recorder showed was spasmodic in operation. Investigation brought out the fact that the attendant, because of poor facilities, was spending one-third of his time needlessly in feeding the stock into the machines.

The application of automatic recorders in paper making is credited with similar value. In one plant, a paper coating machine designed to produce thirty thousand sheets in nine and a half working hours, was watched closely for a period of eight days. At no time did the machine approximate its capacity, though supposedly it was running at its best and attended by a conscientious and skilled operator. Less than fifty per cent efficiency was indicated. Because the recording instrument used gave him a permanent record covering every minute of the working day, indicating all stops, with their exact time and duration, and at the end of the day showed the actual output in number of sheets, the manager was able to put his finger on faulty conditions of the existence of which he had felt conscious, but which he had been powerless to find and correct. In less than a week, he had the machine operating at close to its proper efficiency (Figure XXXV).

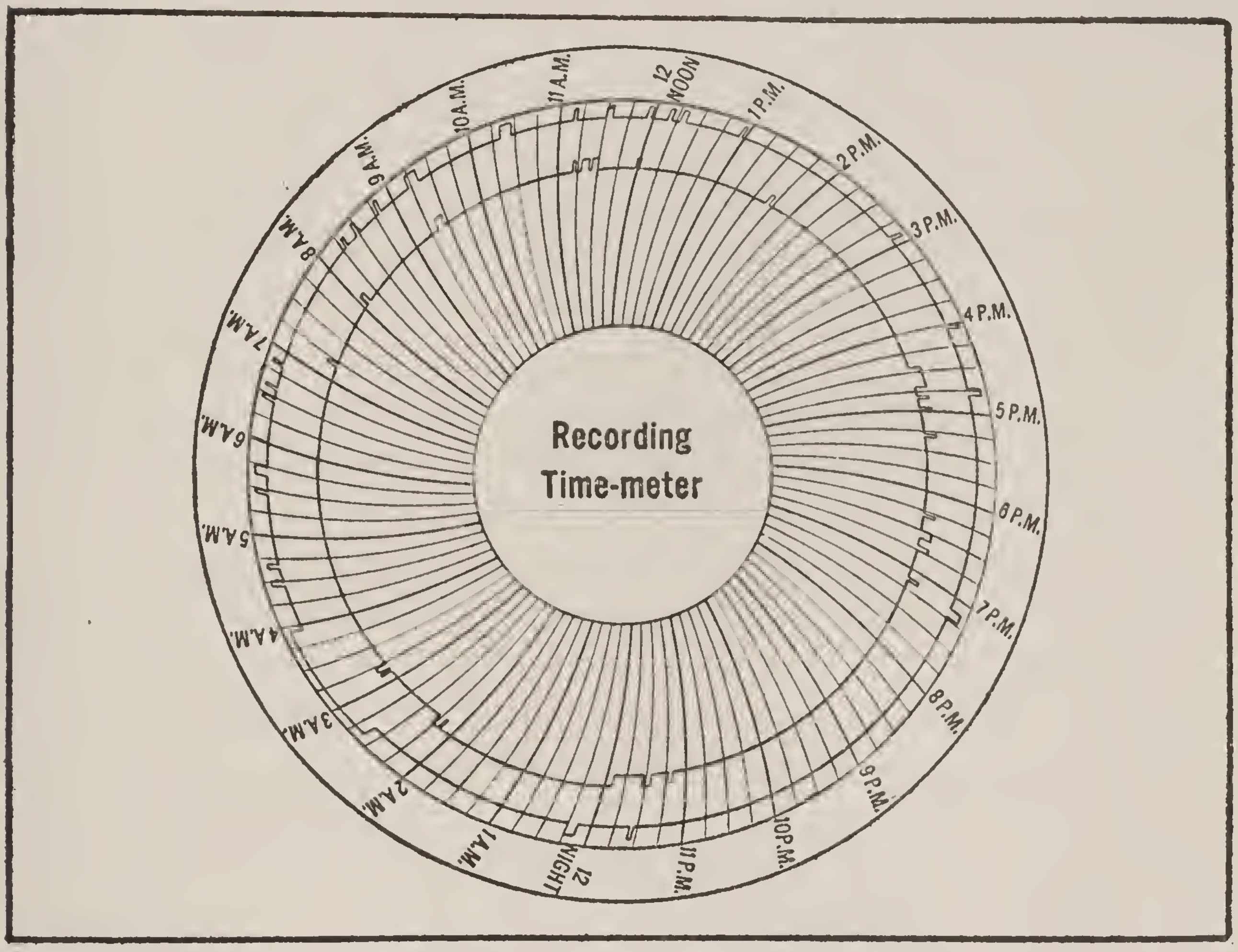


FIGURE XXXV: The line on this chart indicates to the manager of Finch, Ryan and Company, paper manufacturers, the time and duration of each break, the time required to wash the felts and put on new wires. Each line on the chart is a record of one machine. It is possible to have the records of what six machines are doing on one chart

The application of an electric recorder in the works of the Wisconsin Steel Company, to check the time at which the valves on the regenerator to the open-hearth furnace are opened and closed, is recounted by Bernard J. Klein. Instead of making use of an auxiliary water-pressure gage, the main levers when adjusted to open or close the regenerator valves, make and break an electric circuit. A time record is made on a chart in the superintendent's office. The result, according to the chief engineer of this plant, has been to increase the efficiency of the billet-heating furnace twenty-five per cent.

Highly specialized types of recording devices are not always necessary to enable a factory executive to watch machines from the office. Many standard recording pyrometers, thermometers, pressure gages, speedometers and similar instruments need but a pair of wires or a tube to bring the recording part of the device within the office walls. In this way, dry-kiln temperature may be placed directly under the eye of the superintendent and he may watch levels of liquids in tanks, follow furnace operations and review machine speeds from his desk. The reversal of drafts in glass furnaces offers an opportunity for the application of an automatic recorder, of which advantage has been taken by some manufacturers. Conveyors in the crushing departments in mills and smelters also sometimes are checked from the offices in this way.

Blast furnaces are another instance of the use of an automatic means of recording operations, in explaining which a superintendent said: "My automatic record charts show me when a charge of ore is lowered into the furnace. What I want to see is that the men keep the furnace uniformly full, and do not stop filling for longer than twenty minutes at a time, lest the level of the fire sink too low. Moreover, it is bad practice to allow the attendants to rest too long at a time, then work a long interval filling the furnace, then rest again a long period. It is much better to have the alternate period of filling and resting brief. The chart shows me whether the workmen are following instructions in this respect."

Even so simple a device as a counter and ratchet indicator, attached to the feed or to the discharge end of an automatic machine, has proved its value as a finder of waste time in different factories. In one case, recounted by Edward K. Hammond, analysis of punch-press operation was made by this means. The counter merely registered the strokes of the press. As a result, it was found possible to increase the speed twenty-five per cent and still secure a uniform product. In such cases, however, it is always necessary to watch the effect of the higher speed on the tool and die costs, lest these exceed the saving that comes from increased output. With an office appliance company this problem has been worked out to a nicety and a mean speed has been determined for each different operation, at which maximum economy results. One vital factor was found to be the varying thickness of the sheet metal.

Scaly stock also affects the maintenance cost of dies. The supplier of the metal was offered a bonus for meeting a rigid specification. Ten dollars extra on a car of stock which satisfied the specification has netted as much as fifty dollars saving in the cost of working up this amount of material, largely to be credited to the counter.

HOW MECHANICAL COUNTERS MAY BE MADE TO SERVE MANY PURPOSES

A SIMILAR opportunity to utilize a mechanical counter developed in the factory of the Chicago Belting Company. The final process in the manufacture of leather belting, as carried on here, consists in passing the belt over a set of knives which round off the edges. Immediately thereafter the belt is coiled up ready for shipment. The counting device was arranged so that as a belt passes over the roll of the trimmer, a wheel geared to the trimmer is held in contact with the belt. The counter is mounted on one of the spokes of the wheel and, as this revolves, a bevel gear which is carried by a stationary sleeve on the wheel spindle, causes a bevel pinion on an intermediate shaft to turn. This shaft actuates the counter through a suitable arrangement of gearing. The numerals of the counter are steel dies, which are mounted on the rim of the contact wheel. As the belt passes over, these dies stamp on it the length rolled up. As the wheel is exactly ten feet in circumference the length is stamped on the belting at each interval of ten feet.

This plan serves a double purpose—it shows the belting manufacturer the exact number of feet in each roll without the necessity of remeasuring before shipment. And the salesmen are enabled to unroll any required length promptly for a customer, using a yard stick only for the odd feet.

A box manufacturer rigged up a similar counter to check the consumption of paper used for covering pasteboard boxes. The wheel of the counter was arranged to press against the face of the paper roll. It was exactly one foot in circumference. Thus every time a foot of paper was unrolled, the counter marked up one. At each roll was placed a pad of stock blanks and a pencil. The workman marked on one of these blanks the order number and the number of feet taken, then sent the memorandum to the office. The device thus gave a fair check on the consumption of paper against each order without the expense and delay of formal stockroom issuing.

Ingenuity and the right recorder will make many such savings possible in any machine shop. And because these little instruments eliminate the personal equation, they give an important means of control. Indeed, one of the most valuable features of recorders is the moral effect on the workmen. Not only do they assist in establishing standard processing times and incentive wage rates, but when it is known that the machine itself is telling moment by moment the story of production, less time is wasted by the operative than under less exact methods of control.

XX

DEVICES THAT GAGE QUANTITY AND QUALITY

BEYOND an adept pair of fingers and good eyesight, long skilled by the practice of his art, the craftsman needed few mechanical aids to check the quality or quantity of his materials and to test the fitness of his workmanship. A pair of steelyards, a magnifying glass, and a foot-rule comprised his testing equipment. Modern industry, however, has increasingly separated the master mind from his work. How his personal touch over every detail of the business is preserved by ingenious measuring, indicating, recording, timing and intercommunicating devices has been told. Close control over the quality and quantity of his raw materials and of his manufactured product is made possible by correspondingly ingenious weighing and testing apparatus (Figures XXXVI and XXXVII).

Material is bought and sold by weight more than by any other means. At various stages of production, in almost every industry, scales are needed to check the proportion of materials used or the quantity of output yielded in a given time. In the stockroom and receiving and shipping departments, the need for a scale of some kind is almost constant. Except in the case of the delicate balances required in chemical analysis, scales unlike other instruments of executive control break in on valuable processing time. In considering the type to be used for a given purpose, therefore, labor and time-saving arrangements, as well as size and capacity, are factors in the choice.

While scales are used primarily for weighing, they also afford in many instances a quick and accurate way of counting. In fact, an extensive line of special counting scales has been developed. These operate by balancing one or more units of the article to be counted in a small pan against an unknown quantity on the platform. The desired quantity is then read off on the beam—in units, tens, dozens, gross or thousands as the case may be. Or the operation may be reversed, the quantity set off on the beam and the platform loaded until the scale balances. Both in checking receipts and in issuing materials from the storeroom, such a scale is a great time and labor saver, as well as a promoter of accuracy.

When so used the function of a scale as a cost-cutting device is uppermost—is, in fact, the predominating reason for its use. On the other hand, when scales are employed primarily for weighing, all too frequently a cheap type will be bought and set in an out-of-the-way corner. But a scale should be selected and located with the same consideration for use-values as a machine.

A brass mill, upon installing a new cost system, found it necessary to place a scale between the casting shops and the rolls. More or less begrudging the expenditure, they bought a beam scale of rather scanty capacity for the purpose and set it in a dark spot close against the wall near the entrance to the mill. It proved too short for the longest trucks and too light to take many of the loads. Valuable time was lost in squeezing the long trucks on the platform and in "paring down" the loads. The scale-beam was inconvenient to get at and so in the dark that more time was lost and errors in reading were frequent. Congestion at this, the entering point, finally became too serious to disregard. Rather than buy a new scale, the management chose to invest in an outfit of shorter and lighter trucks to handle the trucking at this stage. The error in location, however, remained uncorrected. The scale should have been placed on the direct line between the door and the shears, at a point where the beam could be manipulated from behind in full daylight. A dial-reading attachment would also have expedited matters considerably (Page 127).

Dial scales may often be used to good advantage. They make perhaps their biggest saving when the flow of product is practically continuous. When use is intermittent, a few moments more or less "time out" for weighing is less important and the less expensive beam scale may do just as well. In case of a yard scale, for instance, if only needed occasionally, a dial type would scarcely be justified; but if vehicles were streaming in and out all day long, then it certainly would be a good investment, especially if the vehicles were motor trucks.

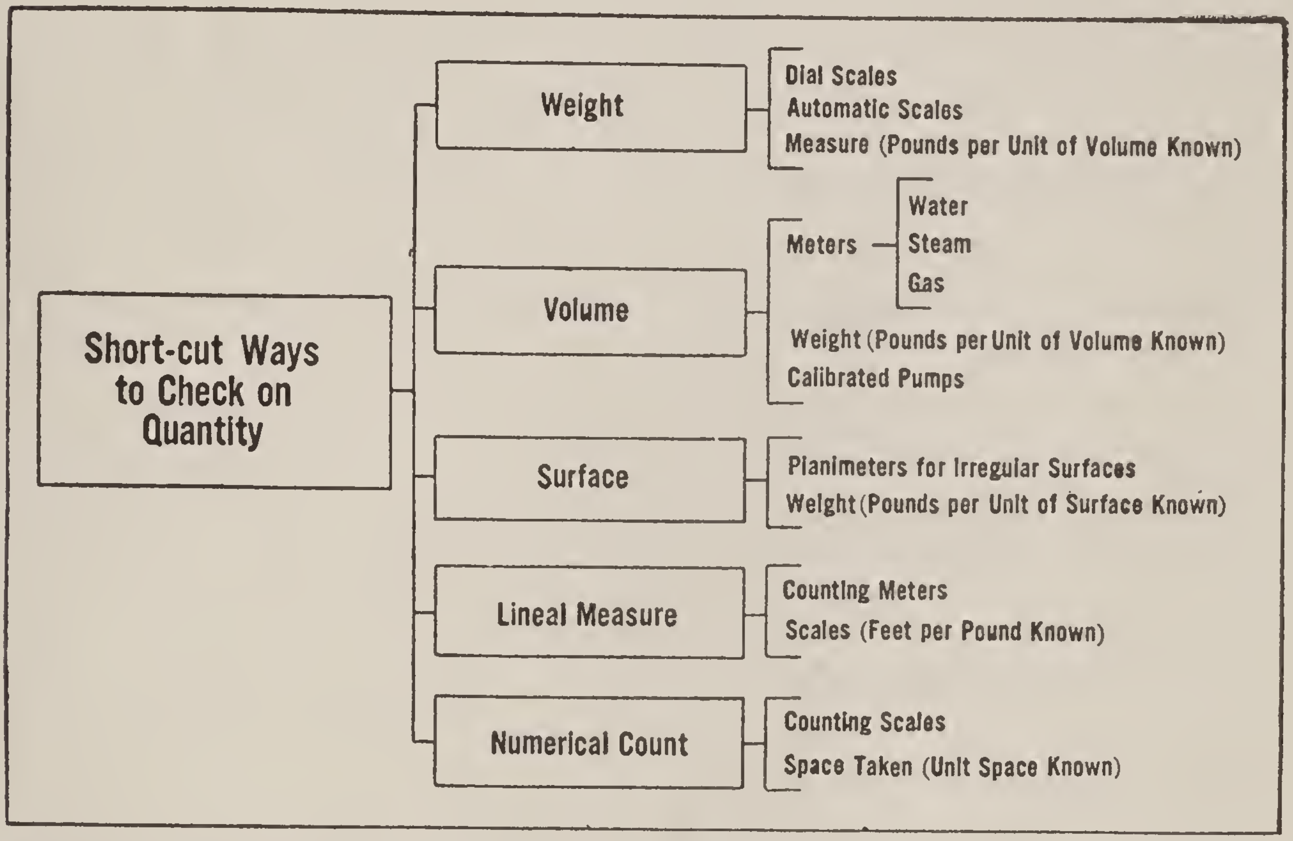


FIGURE XXXVI: Quantity must be checked when materials are bought and sold, and often in between, as a basis for wage payment or to regulate and record the output. This checking takes time. A device, therefore, that shortens the time over the conventional way is a profit-maker. Counting scales furnish a means of ascertaining accurately the numerical quantity in a fraction of the time the pieces could be counted by hand. Calibrated pumps enable liquids to be measured out with unfailing accuracy and no loss of time. Given the number of feet per pound, the lineal feet in a coil of wire can be determined by weighing and a little arithmetic before the coil could be untied

Between the packing and stock or shipping departments, especially, dial scales often prove great labor as well as time-savers. In a plumbing goods establishment the movement of packed goods for several hours every afternoon was steady. Each truck had to pass over a platform scale en route. Frequently four or five truckers would be drawn up in waiting. A dial scale was substituted. The weighmaster could then note the weight while standing on the opposite side with brush ready to mark it on the crate. So great was the gain in time that waiting in line virtually was eliminated and it became possible for four truckers to do the work of seven previously.

Nor was this all. Taking the heaviest truck as a basis, and plugging the lighter ones with lead the tare was standardized. This obviated setting off the truck weight separately each time, or as an alternative, an operation of subtraction, before the net weight could be marked down. Not only was the weighmaster saved this mental task, and greater accuracy ensured, but one more trucker was eliminated.

Still a greater economizer of time and labor when applicable is the automatic self-recording scale. This eliminates absolutely the personal equation in reading, dispenses with attendance and literally grabs its record on the fly, entailing no hold-up of the material whatsoever. Such scales lend themselves particularly to the weighing of articles and materials in transit on conveyors.

In the boiler room of the Commonwealth Power Company, Milwaukee (Page 38) scales of this kind are employed to catch the weight of the coal feeding from bins overhead into the hoppers of automatic stokers. In other instances they are used in connection with an automatic discharging device to empty tanks and bins when the load has reached a certain predetermined point, thus controlling exactly the quantity of material going into process as well as recording its weight.

Such scales find a large application in food-product factories and wholesale grocery establishments, in connection with package-filling machines. Cement and many other materials of both a granular and a liquid nature are now portioned out in this way more accurately and economically than by volumetric means.

TESTING ARRANGEMENTS SHOULD CONSIDER TIME AND LABOR-SAVING FEATURES

IN testing as in weighing, the time factor also is often overlooked or its importance underestimated. To be sure, a testing operation can seldom be scheduled like a processing operation. But that is no reason why it should not be expedited in every way not inconsistent with a careful and thorough job. In the selection and arrangement of testing equipment, consideration from the production viewpoint usually proves profitable. The more practical a test can be made, too, the better. At the Thomas B. Jeffery Company, the power generated in testing the motors is utilized to turn dynamos which pump into the power mains

Instruments That Check on Quality

- **Chemical Composition**
  - Qualitative Analysis
    - Chemical Reagents (Reactions Reveal Complete Composition)
    - Bunsen Flame (By Color of Given Flame)
    - Spectroscope (Detection by Special Spectrum Lines)
    - Electrical Devices (Conductivity a Measure of Purity)
  - Quantitative Analysis
    - Chemical Reagents, Retorts and Balances — Following Quality Determination
- **Physical Properties**
  - Strength
    - Tensile, Compressive, Torsional — By Special Testing Machines in Each Case
  - Hardness
    - Scleroscope (Rebound of Tiny Hammer)
    - Sclerometer (Weight on Needle to Scratch)
    - Files Graduated as to Temper (Hardness of File to Cut)
    - Drilling (Ease of Drilling)
  - Density
    - Specific Gravity Balances
    - Absorption Test
    - Hydrostatic Pressure Rams
  - Structure
    - Microscope
    - Microscopic Camera
  - Endurance
    - Effect of Acids and Alkalies
    - Effect of Moisture; Boiling Water
    - Endurance-test Machines
  - Effect of Temperature
    - Thermometers, Pyrometers, Pyroscopes — To Determine Melting, Flash and Vaporizing Points
  - Elasticity
    - Impact Machines
    - Extensometers (Measure Set after Application of Load)
    - Special Testing Machines (for Springs Particularly)
  - Viscosity (Oils)
    - Viscometer (Rapidity of Flow through)
    - Friction-measuring Instruments
  - Color
    - Matching with Standard Colors (Dyes and Textiles)
    - Color under Filtered Light
    - Special Lights
  - Fineness (Granular Materials)
    - Graded Sieves
    - Centrifugal Separators
- **Electrical Properties**
  - Conductivity
    - Current and Potential Transformers and Meters
  - Incandescence (Lamp Filaments)
    - Pyrometers and Photometers
  - Magnetism
    - Electro-magnets and Galvanometers
  - Dialectric Value (Insulation)
    - Special High-tension Transformers and Electric Meters
- **Workmanship**
  - Form
    - Limit Gages
    - Fixture Gages
    - Templates and Jigs
  - Dimensions
    - Micrometers
    - Calipers
    - Limit Gages
  - Water or Air-tightness
    - Air-compressors and Pressure Gages
    - Hydrostatic Pressure Rams and Pumps
  - Power Developed (Motors and Engines)
    - Electrical and Mechanical Absorption Dynamometers
    - Electrical and Mechanical Transmission Dynamometers

FIGURE XXXVII: Quality of product under a quantity scheme of production involves technical control over the properties of materials and the accuracy of workmanship. Some of the ways employed by manufacturers in various lines of industry for checking on quality are here listed. Many of these devices are indispensable, and by availing himself of the offices of special testing laboratories even the small manufacturer can secure for his materials and product every essential quality check

(Page 127). At the Hart-Parr plant, all the power required to run the factory is obtained in testing the finished gas tractors. The test pays for itself in these instances—is a value-producing operation, not a pure expense.

By testing small gasoline engines without removing them from the truck which is used to transport them from the finished assembly to stock, both rehandling labor and time are saved at the Altman Taylor Company. The product is here literally tested on the move. Rear axles of motor cars are tested similarly at the Pierce-Arrow plant.

In other instances time and labor are economized by transporting the test equipment to the product. When a portable motor is one of the test pieces, as is often the case, the provision of power outlets at convenient points facilitates matters considerably. Large equipment particularly lends itself to this arrangement, but many times small product may be handled similarly with decided advantage.

At the Gray and Davis plant, for example, where large numbers of small dynamos for automobile lighting-and-starting systems must be tried out every day, tables are provided which are fitted with permanently wired outlets for quick plugging in of ammeter and voltmeter connections. The machines are mounted on these tables and coupled to a common shaft. Testing instruments and record sheets are carried along from table to table on a small portable desk (page 127). The arrangement is very compact and so convenient that readings on a hundred or more of the little generators operating simultaneously can be taken by one man in a few hours.

Again, many tests are of such a character that isolation from outside influences is essential. Noise from machines, vibration, drafts and varying temperature and humidity are disturbing factors which for accuracy often must be eliminated. The problem is to secure isolation, if possible, without sacrificing convenience of location. At the Pierce-Arrow plant, a silent place to try out automobile-transmission equipment for noiseless-running qualities was provided by building a small sound-proof room at a convenient point in the department. Disturbing air currents also are thus avoided. At the Nela Park works of the National Lamp Association, in the incandescent lamp-testing room, refrigerating as well as heating and humidifying apparatus is provided, so that any temperature from hottest summer to coldest winter degree can be obtained at will. The lamps may thus be tried out for durability and reliability under every conceivable climatic condition. In another instance, isolation from machine vibration was secured by resting the heavy plank testing platform on massive concrete piers. Concrete piers are often a way out and in cases vibration-absorbing pedestals have been fitted to the legs of testing tables or the apparatus itself.

When electric current of varying amperage, voltage and frequency is employed in testing, some precaution to prevent wrong connections being made is wise. At a middle-western office appliance plant so frequently were motors burned out by errors in plugging, that finally a "fool-proof" switchboard was devised. For each different current a specially formed receptacle was provided, and the plugs made to match. Although there still is chance of error, by selecting the wrong lead, the cases of misplugging have since been very few. The mind is strictly attentive when selecting a lead; forgetfulness comes in while carrying the plug to the board. This is now obviated.

Testing equipment as a rule is best grouped in a special room or department logically situated with regard to the flow of production. Even so, unless the equipment is very complete and under careful management, the test room is apt to prove the "sore thumb" of the establishment. Run by the engineering division, who are chiefly interested in the performance of the articles under test and not in having the test fit into the production schedule, resulting friction with the production division may seriously disrupt the organization. In view of this, taking the production angle on tests—both as to equipment for, and manner of conducting—takes on added importance.

While a separate and distinct test room doubtless is essential in many factories, and has the advantages that go with concentration of similar effort, the principle can easily be carried to the extreme. Often by a little ingenuity the test equipment can be taken to the product rather than obversely. Examples of this practice have been cited. Again, many test operations are of such a nature that they can just as well be conducted out in the shop as in a special room. At the Detroit Lubricator Company such an arrangement is observed very generally. So far as practicable, the testing places are interposed between the successive operations, right in the line of production. Not only is trucking of material back and forth saved, but the testing operations themselves are both pushed from behind and pulled from ahead. The operatives are paid on a piece basis and do not ''lay down'' out of deference to a test as dayworkers are wont to do. Unnecessary lagging is thus kept out of the testing operations.

In addition to special testing devices peculiar to the industry, every well-equipped test department also includes a variety of standard physical and chemical apparatus for verifying both quality of materials and accuracy of workmanship. There are micrometer and ring gages, calipers and templates for checking correctness of form and dimension; scleroscopes for testing the hardness of metals so vital to their proper functioning; torsion and flexure machines for trying the heart-fibre of steel and iron, upon which reputation and human lives hang, and powerful chemical reagents potent to resolve any substance into its elements and to seek out quality-lowering impurities however deeply they are hidden from the eye (Figure XXXVII).

Denied these and other means of impressing his personality upon each single unit of his product, the modern manager would be unable to maintain craftsman-high quality standards under a quantity system of production, in spite of the possession of the best processing and handling equipment mechanical inventive genius has contrived.