WORK ROUTING, SCHEDULING AND DISPATCHING IN PRODUCTION

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PREFACE

Today in manufacturing production, emphasis is placed on planning as the best way to accomplishment, and in the work of planning the details of work routing, dispatching, and scheduling are all important. It is quite evident that no production plan can be realized fully in its results unless all of the included operations are performed in proper sequence, in proper time, and at the lowest cost. Well-organized and carefully executed work routing, dispatching, and scheduling are necessary to bring production through in the required quantity of the desired quality at the proper time and at a reasonable cost. Knowledge of these factors is necessary to obtain maximum accomplishment.

Individual judgment may at times enter into the picture, but such judgment must be backed up by scientific knowledge of the facts. Today with increasing expenditures, increasing taxation, and the possibility of inflation looming in the future, we are becoming more and more cost-conscious. We are anxious to do our work in the one best way, for in that way lies lowest cost.

It is significant that in all of our discussions we take quality for granted. We have reached a high state of perfection in our products of today and we intend to maintain ~~it~~, but this factor should not bring about an increase of costs. We can concentrate on cost reduction in the areas stated in this book.

Throughout the book, care has been taken to state plainly the underlying principle or law for each step in the control of the work routing program, and at the same time to show how these fundamentals are put into everyday practice. The experience of representative manufacturing concerns is drawn upon freely through examples, cases, and allusions.

The book has been written for two groups of readers: executives and others concerned with daily problems in industry, and students of industrial management and engineering in college classrooms. The latter group has greatly increased since the first book on the subject was issued in 1930, more and more attention is being given to the science underlying manufacturing, and it is the hope of the authors that what this edition offers may be of help and benefit to them.

JOHN YOUNGER
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January 1942

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WORK ROUTING, SCHEDULING AND DISPATCHING IN PRODUCTION

CHAPTER 1

WORK ROUTING

It is only within recent years that the study of Works Management has become scientific in its nature. This study has led to the development of a branch of engineering known as Industrial, Administrative, or Management Engineering which expresses itself simply as the Science of Manufacturing. This branch has grown rapidly and many universities have incorporated such courses into their curricula.

One of the important phases of this work is in Work Routing, a subject which demands a great deal of attention at present in that in its successful use the problems of economical manufacturing can be satisfactorily solved. On work routing devolves the satisfactory planning of work to be accomplished, the determination of the path the plan must follow, and the setting in motion of the plan along the path. The sequence of machine tools is studied. The proper use of tools and fixtures, the most economical machine tools to use, and the most economic lot sizes in which the product may be routed must all be studied.

Many shops do not use scientific methods in settling these problems. They use judgment, but it is believed that judgment can be better influenced by a proper understanding of the scientific factors behind the work. B. F. Hutchinson, of the Chrysler Corporation, reveals this when he says: "Common sense and good judgment is the real basis for decision influenced by all the scientific background, technical training, etc., that can be brought to bear on the problem at hand."

It is, therefore, particularly valuable for the young man entering the field to get a sound knowledge of the scientific principles involved, while even the older man cannot help gaining a background of value from such a study.

Intelligence Required.—The old days are gone when a tracing or blueprint was placed in the hands of the craftsman or journeyman with instructions to "go to it." The only survival is in our toolrooms where expert men are still employed, and where it is still practical and feasible to allow one man to carry out the various operations of toolmaking under his own control. In our production industries we so subdivide the operations that labor has to perform, that we reach a stage where the skill and mentality required are so small that from preference we select relatively unintelligent men. Actually these men may be intelligent in politics, or in religious matters, or in some hobby, but to all intents and purposes they are regarded as unintelligent from the viewpoint of work.

Someone, therefore, must supply the intelligence required to direct operations so that they may be performed in proper sequence at lowest cost. You cannot place a blueprint in the hands of one of these operators, for the chances are, he is totally unable to read such a print, and at times even incapable of reading and writing the English language. In visiting a bearing manufacturer, I was impressed with the work on a Blanchard grinding machine. This machine was taking races one at a time from a feeding table, holding them in a magnetic chuck, and passing them under a large grinding wheel where they were surfaced automatically to a width varying no more than half a thousandth of an inch. Thence the bearings were caught in a chute and led through a demagnetizing device and again through a washing machine, being delivered in the finished state in perfect condition. I asked the operator of this machine a question and received the reply, "No spik."

Now here was a case where the operator had just the intelligence needed to place races on a table and no more. Indeed, no further intelligence was required. Obviously, you cannot place in the hands of such operators any initiative to direct even their own operations. Nor can you let material drift through a shop in a haphazard fashion, process after process. You might drill first and then turn in a lathe, but it does not necessarily follow that this sequence of operations is the least costly, unless you had deliberately thought out the proper planning ahead.

Planning Necessary.—Machine tools must be planned intelligently in their layout, and work must be routed through them accordingly. By so doing there will be saved considerable effort and money otherwise lost in material handling, and an emphasis will be placed on the value of time, one of the most important factors in production. You might, for example, route a job from a drilling machine in one corner of the shop to a milling machine in another far corner, and thence back to a lathe in the center of the shop. Half the distance of handling might be saved by routing to drill press, to lathe, and thence to the milling machine. Grinding, to quote another and more obvious example, should rarely precede lathe operations, and such machines should be placed in their proper sequence. Similarly for all other machines.

Work should be analyzed carefully, first for the operations to be done, and secondly for their sequence. Material and tools should be routed and planned to meet the jobs at the proper strategical points as the work comes through.

For instance, in the assembly of automobile chassis there is a particular station or place where axles must be assembled to the frames. Clearly the axles should be delivered to this station and nowhere else, so as to avoid material handling and its attendant cost. In brief, to use broad terms, the maximum economic economy should be obtained by proper routing.

Machine Considerations.—Many considerations will enter into these problems. One machine may lend itself better to fixtures than another. Specialized machines, for example, are designed for special work and rarely lend themselves to general use of fixtures. On the other hand, standardized machines can be so equipped with fixtures that they may be adapted for a variety of work.

Again, one machine may be idle when a better (for the purpose under consideration) machine is thoroughly busy. One machine may have a high factory cost (machine-hour rate) compared with another machine equally capable of doing the work. Or to quote a further example, one machine may have better handling facilities surrounding it. All of these factors are of importance in arranging for work to take effect at specified machines.

The factor of material routing as a means of "setting the pace" should not be lost sight of. At the River Rouge Plant of the Ford Motor Company this factor can be seen in work to the fullest extent. Material flows at a predetermined rate through the plant. In the manufacture of 7,000 cars a day, for example, it is necessary to make 56,000 connecting rods, 56,000 pistons, 7,000 camshafts, 7,000 crankshafts, 7,000 cylinder blocks every working day, no more and no less. If a man makes one connecting rod per day too few, obviously one chassis with its multitude of other parts cannot be completed. If he makes one too many, it represents just so much money expended on material that cannot be used. Hence we have a definite pace set by the flow of material. So powerful is this incentive that Mr. Ford has disregarded the effect of other incentives, such as money, and pays his men straight day wage.

The machine shop is not the only problem. There are many similar problems in foundry, forge, and pattern shops. Machines today are being installed more and more in such shops. They are being conveyorized and the need for skilful planning is becoming more and more evident.

At this point definitions of planning, scheduling, routing, and dispatching may clear up some of the terms used. Unfortunately, there is a vagueness in use. Production men refer to planning when they mean routing, and in some shops the term "planning engineer" is given to the scheduling or dispatching agent.

Planning is the thinking ahead and the initial layout of the work to be done.

Scheduling is the incorporation of this plan into the general scheme of manufacturing, so that the plan may develop in its proper sequence.

Routing is the determination of the path the plan must follow and also the setting in motion of the plan along the path. (Thus from one machine tool to another, and so on, and thence to the assembly bench.)

Dispatching is the placing of time standards, or stations, along the route so that the plan may proceed at the proper time intervals and dates.

Stock chasing is the follow-up or check-up of dispatching to insure that the job continues to flow through its appointed stations as planned.

Problems

1. Why is it necessary to plan the work of mass production operations?
2. Are unintelligent workers to be preferred or are they necessary in our mass production shops? Can a man be too good for his job?
3. Why is work routing so essential?
4. What is the law on the subject?
5. Discuss your opinion of the payment of men by straight day wage in a mass production shop. What is the big incentive to produce a day's work?
6. What departments are interested in the work of the routing department? Why?
7. Why is emphasis placed on cost and processing today rather than on design?

CHAPTER 2

BLUEPRINTS

Blueprint Department.—The blueprint department is one of the most neglected but one of the most important units in a planning organization. On it devolves the responsibility of providing throughout the plant blueprints which express material, shape, dimensions, and quality accurately and are up to date.

This department is the intermediary between designer and shop. It conveys the instructions that put the designer's ideas into concrete form. It should be the storeroom of all records that affect the relationship between design and production. Its equipment should include a blueprint machine, preferably of the continuous rotary type, if the work be heavy. A photostat machine will be found of value for the sundry sketches and reports that often have to be circulated.

Recording Blueprints.—The department's most important records are "live" blueprints actually available for processing. Such prints should be recorded as carefully as a bank records money, and care should be taken to see that no obsolete prints are kept in the shop files to cause spoilage of work. Simple systems to effect this can easily be devised. One method is to have a card index and receipt file for all prints issued, so that a knowledge of the location of all prints is at hand. Prints replacing those already out or obsolete can then be exchanged and the replaced ones destroyed. New prints can be issued to the parties concerned and a receipt taken.

It is sometimes difficult to decide whether copies of all prints should go to every department or only to those concerned. If the latter is the policy adopted, then the head of the planning department rather than the head of the blueprint department should be the judge of their destination to insure that the requisite number of copies are transmitted. All prints should, of course, go to the planning department.

The blueprint department should also concern itself with the proper distribution of bills of material. These bills should go to the purchasing, manufacturing, accounting, and planning departments as well as to others specifically interested. These bills should be treated just as blueprints, and no obsolete ones allowed to be kept in the shops. Drafting rooms are sometimes negligent in keeping them up to date in accordance with changes made in drawings. Laxity of this kind should not be allowed to develop as it may lead to serious losses in the shops.

Incidentally, the cost of making changes should be studied as it will be found to mount to a considerable sum if freedom in this respect is granted. Planning or routing departments often ask for minor changes for temporary reasons when there is little justification.

When one remembers that a change in a drawing represents a change in the subassembly, perhaps in the main assembly, and in the bill of material with new blueprints issued and the old ones recalled; when the tool department has to scrutinize such changes and see if the fixture is affected; when the time study department has to see if the piece-work piece is affected, and the routing department has to check up on machine sequence, then the cost may run close to $100 for each change.

Recording Department.—The blueprint department may also keep all records pertaining to the contracts of the design, purchasing, sales, planning, and tool departments. It is the recording branch of the engineering department. It can often act as a service department to the various parts of the shop by being the logical place in which to install a library of pertinent books and magazines. The photostat machine will be found valuable in distributing copies of valuable articles to the departments interested. Another function allied perhaps more strongly with the designing work than with the planning is that of getting out instruction books dealing with parts and maintenance.

It is within the memory of many workmen as to the time when blueprints did not exist as we know them today. The engineering department would issue a drawing or sketch to the shop, and as these represented so much money, they were handled with great care. Dimensions were not always expressed and it was a common sight to see a workman lay his calipers or his rule alongside the drawing and take the dimensions from it. Material was expressed by different colors on the drawing, such as purple for wrought iron, blue for steel, yellow for brass, and so on. Tolerances in discussions were absolutely unknown and it was left to the man to make his own calculations for the proper fit. In my own experience I have seen a man walk the length of the shop to caliper up an axle bushing so that he could get the right dimensions for his axle shaft.

Naturally much time was lost in those days and the cost of the product was high.

Then came the invention of blueprinting. Early work consisted in putting a frame with a glass cover, with the tracing underneath and below it the blueprint paper, out in the sunlight and letting it photograph through. It was a case of relying entirely on the weather and on dull days there were no blueprints available.

Then came the invention of the arc lamp inside the glass cylinder and these prints therefore became independent of the weather.

Finally there came the invention of the continuous blueprint machine, in which blueprints could be made in quantities. This one factor caused a tremendous change in the shops. Blueprints or drawings which formerly were handed out with reluctance only to the foreman now became available for each man on the job—and with this possibility came another. Instead of the completely assembled drawings which were formerly the usual thing, now one subject could be expressed on each drawing sheet. Finally tolerances were introduced and material clearly stated. This factor meant that the workman no longer had to run around the shop checking his fits, but could be at his bench on the job the majority of the time. We learn, therefore, that it pays to make blueprints available for each man doing the job, and with all factors expressed.

A simple organization for doing this can be given in the sketch of Figure 1.

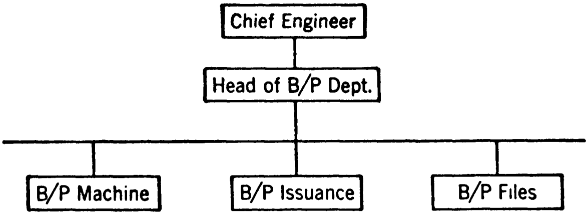

Figure 1. Simple Organization for Convenient Blueprint Issuance

It is important that the issuance department keep records of blueprints so their whereabouts can be traced. The engineer's office has an unfortunate or awkward trick of making changes in blueprints which render the old prints obsolete. Obsolete prints must be immediately recalled and replaced, otherwise defective parts will result, with resultant scrap losses. The blueprint department should be efficiently organized. It is no place for old pensioners past their effectiveness.

Blueprints have their weaknesses. First of all, they express only the finished part; they say nothing of the raw material or at any rate do not illustrate it, and they say nothing of the processes that lead up to the finished results. A simple illustration will show what is meant.

Take the spindle given here. The blueprint shows only the finished part (Figure 2). Now this piece may be made from an individual piece of bar stock 2⅛″ diameter x 12¼″ long, which is completely rectangular in section like Figure 3—nothing like the shape of the finished piece. Or it may be made in a turret lathe from bar stock, in which case the raw material is some 16 feet long (Figure 4). Or further it may be made from a drop forging or upset forging (Figure 5), in which case it slightly resembles the first part.

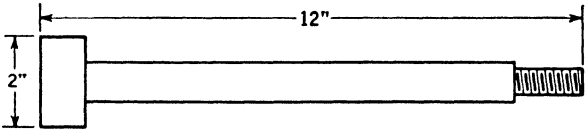

Figure 2. Finished Part of Spindle Shown in Blueprint

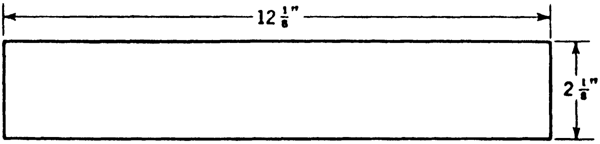

Figure 3. Rectangular Section of Bar Stock

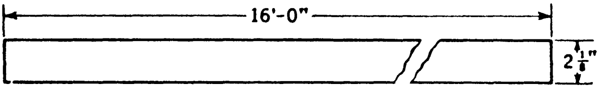

Figure 4. Longer Bar Stock Used in Turret Lathe

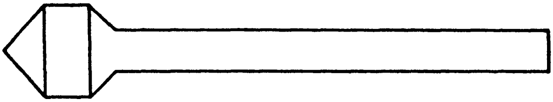

Figure 5. If Made from Drop Forging or Upset Forging

In no case, however, are the processes given which lead up to the finished part, and these processes are quite different from each other. Often this is left to the judgment of the foreman or the man in the shop, but it is far better to have the planning department make out an instruction sheet giving all the data necessary. Perspective photographs or photostats can be used where further detailed information is necessary. These are especially valuable in the case of complicated structures where photographs with captions attached give clear information.

Sometimes small subsidiary or secondary sketches or prints are made showing one or a few details taken from the bigger print. Such sketches are very useful on assembly lines to show up the particular operation required.

All help possible should be given the man in the difficult task of reading a blueprint.

Problems

1. Outline a history of the development of the work of sending sketches or blueprints into shops.
2. Why is it necessary for each man to have a blueprint of his own for the work he is doing?
3. Why do we express one subject on each blueprint?
4. Why are tolerances stated on blueprints and material recorded instead of colored?

CHAPTER 3

THE INSTRUCTION FORM

Full information must be given the worker as it is better for one man to do the thinking for 100 men. This thinking should be done in the planning or routing department. In general, nothing should be left to the imagination of the worker. He should not have to think of the machine tool in which he will do the job, nor of the cutting tools, nor fixtures, nor speeds or feeds, nor depth of cut to be used. All that requires effort on the part of the man, and can be done better in the planning or routing department.

Such information should preferably be given the foreman so that he can properly instruct the men and have the job done the one best way.

Figure 6 shows a typical instruction sheet for a machine shop. Note that fixtures and cutting tools are specified by number.

Operation#	Machine#	Cutting Tool#	Fixture#	Speed	Feed	Depth of cut	Time per operation	Piece-work price	Remarks

Figure 6. Instruction Sheet for Machine Shop

This practice is used in the case of fixtures but not as much as it should be in the case of cutting tools.

Every cutting tool should be numbered in the same way as blueprints. The workman can then be informed as to what particular type of tool is suitable for his work and can thus do his best job. The man left to his own resources is not likely to select the best tool.

Note also that the man is given the time and the piece-work price. This practice enables him to realize that something is wrong if he does not make the time. The time should be calculated by the planning department in cooperation with the time study men. They should express the idea of the "one best way." Naturally failure to make the time shows that something is wrong with the work. Perhaps it is the material, perhaps the man's own slowness, perhaps even the time study is wrong, but whatever it is it should be adjusted and corrected so that the time may be met or even bettered.

Such instruction sheets are not peculiar to the machine shop. They may be and indeed should be used as far as possible in other departments. An instruction sheet for a foundry, for example, might contain information as to the size of flask to be used, the number of risers, the use of facing sand, and any other pertinent information that will prove valuable in the effort to produce satisfactory castings.

The use of such sheets need not be confined to mass production shops. The job shop can usually afford a planning department or at any rate the semblance of one where work can be planned in accordance with the best thought. This subject will be treated later in our discussion of the job shop.

CHAPTER 4

MATERIAL

There are often considerations of cost that enter into the use of materials apart from considerations of strength, and it is a wise thing to consult with the planning department as to the cheapest material that can be used with satisfactory results. The reason for this is that material must be considered along with the other factors of machining to determine the "one best way."

"Typical Analysis."—Take as an illustration the clevis illustrated in Figure 7. It is a simple thing used by the thousands in all branches of engineering. Let us neglect strength for the moment. First it can be made of cast iron molded in the shape of the piece. It is a material which can be machined readily, and if a rough job is desired only the shank need be turned and threaded and the holes drilled.

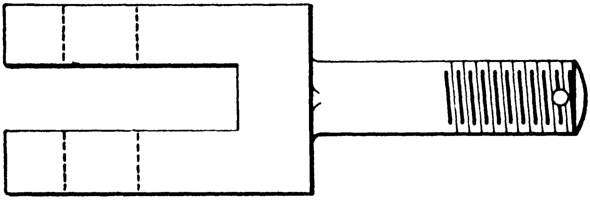

Figure 7. Common Clevis

The malleable casting follows, a little stronger it is true, but the same factors of machining apply as they do to the cast iron type. Both types require simple patterns which can be prepared at low cost and for a reasonable number a low cost can be achieved. Where resistance to corrosion is desired, the innumerable cast alloys of brass and bronze can be substituted with equal results.

But it also can be made from a drop forging, in which case the initial cost of the dies must be considered although the final cost per piece may be low. The machining is also relatively simple although the central slot may have to be machined, and the shank turned and threaded.

The same remarks apply to the forging made by the forging machine.

Finally we come to consideration of bar stock—square or rectangular bar stock which can be obtained in long lengths. This stock can be turned, threaded, and faced on a turret lathe or automatic lathe, and later milled and drilled. The set-up cost is low, the price per piece relatively low, and the accuracy and interchangeability very high.

A chart (Figure 8) will serve to illustrate the results. The chart shows that where drop forging costs cross malleable iron, the crossover point, one may use malleable iron for consideration of cost below the point and drop forging above the point.

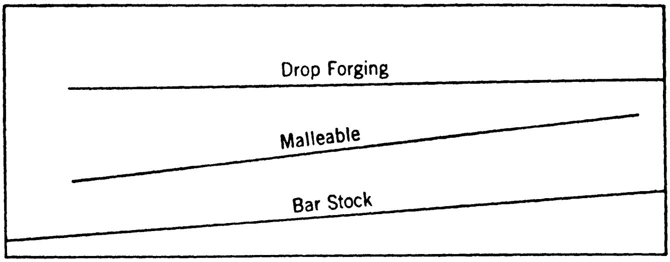

Figure 8. Cost of Clevis

The above analysis is offered as typical of a survey of the factors that enter into final judgment. Usually common sense based on experience will dictate the material to be employed.

However, to a draftsman one interesting detail emerges. Take a diagram similar to Figure 8 and place on its lines the base or average prices of steel, lumber, and aluminum, for example. Only the base prices or broad prices should be used. The result will be a diagram as in Figure 9. We know that the price of lumber has been steadily rising, and that the price of steel has been constantly dropping. A time will come when, broadly speaking, the cost of steel should cross the cost of lumber. At this point we should seriously consider the use of steel as a replacement material for lumber. It is our belief that we passed this point a few years ago and that we have seen an increasing tendency to use steel in place of wood. Steel bedsteads, steel furniture, and innumerable other subjects are all indicative of the fact.

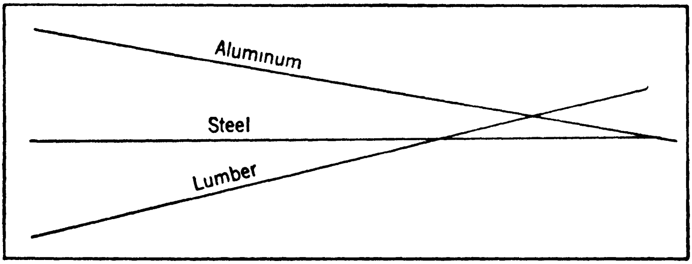

Figure 9. Prices of Raw Materials

Similarly, the broad cost of aluminum has been dropping and these are indications that weight by weight, and strength for strength, we are approaching a time when aluminum will be substituted for steel and wood. These are all tendencies already seen in our aluminum furniture and so on.

Routing of Material.—Material, however, has other problems. It should be so routed:

First: As to insure its reaching the men at a specified time.
Second: As to reduce handling costs.
Third: As to insure smoothness of operation of assembly lines.
Fourth: As to set the pace.

If material reaches men too easily, it is clear that there will be an excess of material representing money lying idle with attendant unnecessary increase of capital expenditure and outlay of interest. Obviously if material comes in too late men or machines will be idle, representing another waste.

Many plants today try to attain the ideal of having no storeroom. Instead material comes in at the exact time required and is immediately placed in progress through the plant. One large firm specified an order somewhat as follows: "so many forgings to be delivered 4:30 P.M., August 9." If the forging or other material comes in too early, the truck waits, and—well, they simply don't come in late. It is impossible to obtain the absolute ideal of no stores but steps taken in this direction will be found to pay.

L. P. Alford gives a law on the subject: "The highest efficiency in the utilization of material is obtained by providing the required quantity of the required quality and condition at the required time and place." The significance of "time" and "place" should be specially noted. Factor two is almost obvious, yet sometimes one sees an insufficient number of hoists or cranes around a shop whereas a few more would save needless delays and tie-ups. Some of our machine tools are equipped with hoists integral with the machine so that heavy loads can be handled easily on the machine. Small hoists placed at logical points will often prove of great value in preventing back-breaking and time-taking efforts.

Factor four deserves a word or two. Conveyors have two functions: one is clearly recognized—that of carrying material, but the second factor is not so clear, namely, that conveyors set the pace. One sees in our shops small articles that can be handled easily by being transported by power-driven conveyors. At one plant of the General Electric Company, for example, small switches are assembled on motor-driven conveyors. One could easily pick up a part with two fingers of one hand, but the significant function is that the motor turning its allotted number of revolutions per minute causes the material to flow at a steady set pace. Thus a switch is assembled in a definite, specific time, and the workers are compelled to maintain the pace.

In handling material, questions arise as to the proper quantity or lot size to be put through. It seems almost obvious that if your shop has a capacity of 10,000 pieces and you want only 7,500, the best way to do the work will be to put the whole 7,500 through at once. Yet considerations which we will discover in a later chapter show that the seemingly obvious does not hold true and that oftentimes much money can be saved by routing the work in smaller lots. Scientific procedure and estimating is always better than taking the matter for granted. A scientific estimate is better than a "guesstimate."

CHAPTER 5

ANALYSIS OF OPERATIONS

Let us take the clevis repeated here again as Figure 10 and consider the operations required to finish the job. Just simply list them not necessarily in sequence, but in any way just as they appear. No operation is too small to be disregarded. For instance:

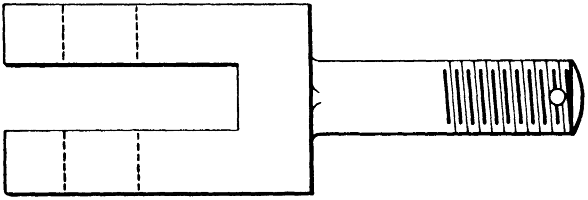

Figure 10. Diagram of Clevis

1. Drill clevis hole
2. Drill cotter pin hole
3. Mill clevis
4. Turn stem
5. Thread stem
6. Round end of stem
7. Round end of clevis
8. Cut off
9. Remove barbs
10. Inspect

Sequence of Operations.—Now let us consider the operations in sequence. Common sense tells us that as this is bar stock we must, first of all, place it in the turret lathe or automatic lathe and rough out a blank by turning, so the first operations in sequence become:

1. Turn stem
2. Thread stem
3. Round stem
4. Cut off

These operations give a blank, turned and threaded. Shall we mill the clevis first and drill the hole after, or shall we drill the hole first and mill the clevis later? If we mill the clevis first, then we shall have the drill forming two barbs, and also the drill might possibly be unsupported during the second piercing of the clevis jaw. If, on the other hand, we drill first, then we have an unnecessary drilling time in the jaw of the clevis. These seemingly are very fine points but it should be remembered that the requirement of accuracy demands such fine points.

The Ford Motor Company states that it reasons costs out to 0.01 per cent. The Packard Motor Car Company has stated that it will not hesitate to make a change if the saving of one-quarter cent per piece is involved. Expressing these costs in terms of time, we find that they represent fractions of a second, so that the need of great accuracy in reasoning out costs is self-evident. Let us assume, then, that we drill first, then mill the clevis, then round the end, B, and finally drill the cotter pin hole. This procedure leaves the final question of removing barbs and inspection to be settled.

Inspection.—In mass production it is best policy to employ "preventive" inspectors or, as they are usually called, "roving," "floating," or "floor" inspectors. Such a man in the case under consideration will be in attendance at the automatic lathe when piece number one is being produced. He will place his micrometers, gages, or scale on the piece, and, if accurate, will give a release for further production. If inaccurate, a new resetting of the tools is demanded. The inspector then "roves" down the production line, checking each first piece as it leaves its machine and then returning to the first machine to check the continuity of accuracy.

Possibly there may also be a final checking inspection after the pieces are completed. Barbs may conveniently be removed at this point so that completely usable pieces can be placed in the stockroom.

In making out the above sequence of operations, due consideration should be given to the jigs, fixtures, and tools required in complete detail. The term complete detail is used deliberately, as it is often thought that a fixture is complete in itself. It is not complete until its holding-down bolts and other accessories, if any, are provided. The machine tool operator should not be allowed to waste time chasing up some forgotten detail such as a clamping bolt.

Final Chart.—We now arrive at a routing chart somewhat as follows:

1. Turn stem
   Thread stem
   Round end
   Cut off
      Use standard lathe tools and special die head number, etc.

2. Drill clevis hole in square end
      Use ...... inch drill
      Use fixture number ......

3. Mill clevis
      Use cutter number ......
      Use fixture number ......

4. Round clevis end
      Use milling cutter number
      Use fixture number ......

5. Have "roving" inspector examine work before release at first piece, and each hundredth piece thereafter.

6. Check, inspect, and remove barbs

The above illustration of the clevis is taken as a simple, everyday illustration to show how many points arise even in so simple a machine part. Obviously, a more intricate piece further complicates the routing and the instruction sheet as may be observed in the example of a connecting rod.

Connecting Rod Practice.—The past few years have marked an almost complete revolution in the manufacture of connecting rods for passenger cars. Apart from the normal advances in methods over a period of years, the radical improvement in techniques may be credited to the introduction of surface broaching, the adoption of coining methods, development of improved methods for the automatic weight-machining of parts, precision boring, and the general use of special purpose, high output machinery.

Although Buick is one of the few engine builders in the motor industry to continue the use of spun-in babbitt bearings in the connecting rod, the machining line is an excellent example of current practice. It may be noted at the outset that there are two methods for tooling rods—one in which the rod and cap are forged in one piece and later cut apart; the other in which the rod and cap are forged separately. The Buick rod is an example of the latter method.

Perhaps the best way to visualize the steps in the production of the Buick connecting rod assembly is to follow the step-by-step routing of operations as listed below. As indicated, this covers all of the steps in the process, starting with machining of the rod forging, machining of the cap, babbitting of the cap and the rod in separate operations, then the final machining of the assembled rod and cap.

In following the outline of operations it may be of interest

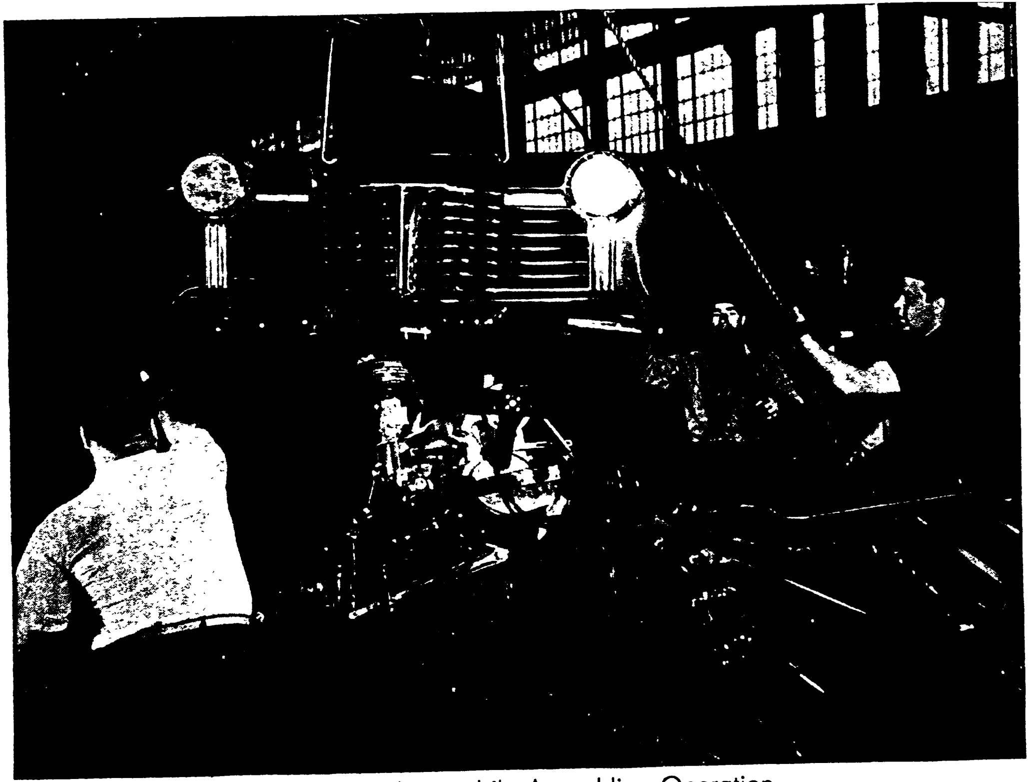

Figure II. Automobile Assembling Operation to emphasize some of the important steps in the process. Note, for example, the first operation on the rod—the coining and straightening of the rod forging. The function of this operation is to produce a straight piece of work, properly sized so as to effect a uniform degree of stock removal. The first major machining operation is that of broaching both sides of the crank end. This is accomplished in one pass of the broach, eliminating numerous milling machine operations, reducing the number of times the work has to be handled, and producing a fine surface finish of exact dimensions. One of the major contributions of the surface broaching technique in rod manufacture is the operation on the Cincinnati Duplex broach which broaches the half bore in the crank end and simultaneously finishes the joint face. Note that these same operations are repeated on the cap.

The piston-pin hole is rough-broached by hole broaching on a new type American internal broaching machine, taking four rods at a time. It will be noted that this hole was previously drilled in a 12-spindle continuous drilling machine. The hole is finish-reamed in a 6-spindle drill press.

The babbitting and machining operations need no further explanation, save to draw attention to the use of specialized multiple-spindle and multi-station machines designed to handle a large number of work pieces at one time, in a fully automatic cycle.

At the final assembly stage, the rod and cap are assembled together, then proceed through the final machining operations. Note that the crank bore as well as the chamfering of the bore are handled in the special multi-spindle machines to promote high productivity. The grinding of both sides of the small and large ends of the rod is done in the new type 4-wheel surface grinder so arranged as to take both ends of one side in one setting, then the rods are turned over to repeat the operation on the other side. The reason for having four wheels is to have a pair for the small end and a pair for the large end, the

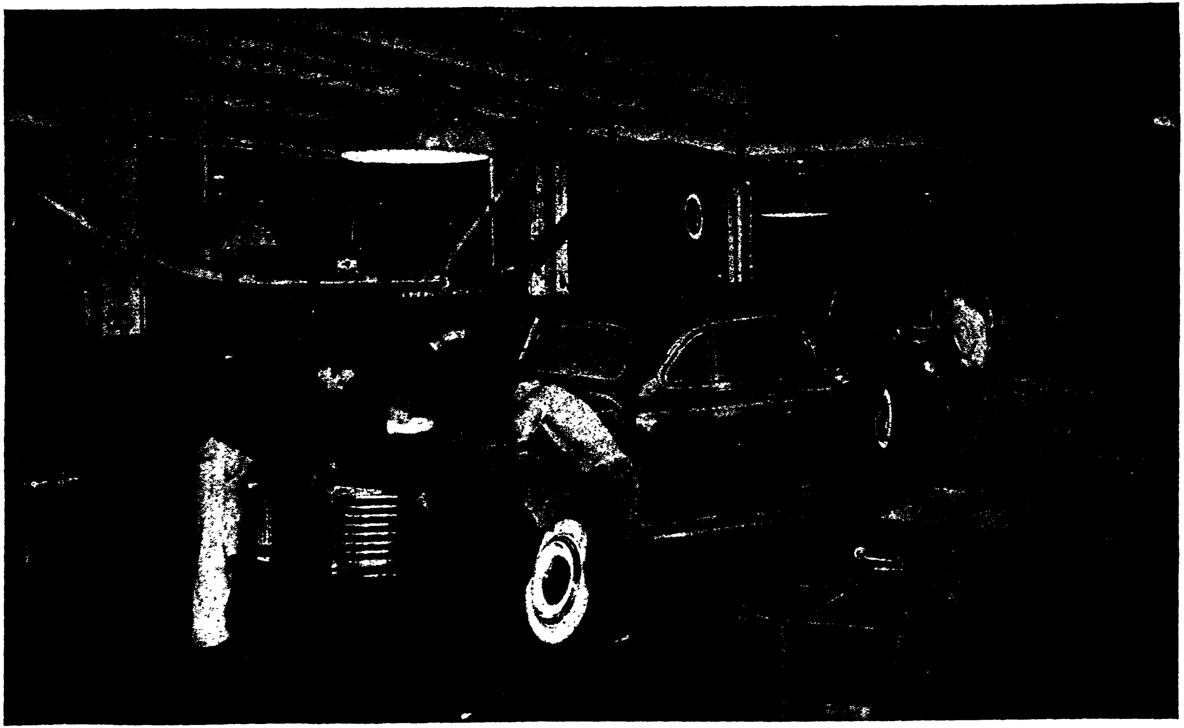

Figure 12. One of the Final Car Operations

first wheel in each pair taking the roughing, while the other wheel handles the finishing cut.

Following the grinding operation is the automatic weighing or balancing operation in which each end of the rod is weighed with respect to the center of gravity of the entire rod, and the proper amount of material is milled off each end, removing the metal from special weight bosses provided for this purpose on the forging. Not only is this a rapid and automatic process but it provides a simple means for producing rods of uniform weight, thus eliminating the necessity for selective assembly.

The final operation is that of precision-boring the crank hole on an 8-head Heald Bore-Matic fitted with cemented-carbide single fly-cutters.

It may be noted that the foregoing represents an outstanding example of current mass production method in which the steps in the process have been finely subdivided into a large number of simple, individual tasks. This is done to take full advantage of specialized equipment for each kind of function, permitting full automaticity of every step, and transferring the various skills to the machine itself. Thus the modern process simplifies the work of the operator, leaving to him the sole functions of loading and unloading the work and giving undivided attention to the proper performance of the machine and its tooling.

In contrast to the Buick rod is the process developed for the production of the rod for the small, high production Nash car. This, too, is a newly tooled machine line, exemplifying the latest techniques known to the art. Moreover, the Nash rod is of the type in which the forging for the rod and cap is made in one piece, later cut apart.

Again the major steps in the machining of the part are outlined in the form of the job routing listed below.

As in the case of the Buick rod, the first operation is that of coining. Here again you will find the surface broaching

Buick Factory Routing—Connecting Rod

OPERATION	EQUIPMENT
CONNECTING ROD MACHINING	
Coin and straighten	1,000-ton Minster coining press
Inspect and straighten when necessary	Bench
Broach sides of crank end of rod	10-54 Oilgear Twin Ram vertical surface broaching machine
Drill piston pin hole	Sommer & Adams 12-spindle continuous rotary drilling machine
Chamfer both sides of piston pin hole	Kingsbury double-end machine
Rough-broach piston pin hole	American 10-30" vertical hydraulic internal broaching machine
Broach bore and joint face	10-ton 66" Cincinnati vertical duplex broaching machine
Broach locating pad and bolt head clearance	5-42 Colonial dual ram broaching machine
Drill spotface and tap pinch bolt hole and drill 5/32" hole in web	Kingsbury automatic drill spotface and tapping machine
Burr 5/32" and pinch bolt hole	Leland-Gifford drill press
Finish broach piston pin hole	American 10-30 vertical hydraulic internal broaching machine
Straighten	Bench
Finish-ream large hole	No. 17 Foote-Burt 6-spindle drill press
Mill pinch bolt slot	24" Cincinnati plain automatic mill
	18" Cincinnati plain automatic mill
Burr complete	Bench
Wash	Niagara washer
Inspect	Bench
CONNECTING ROD CAP MACHINING	
Broach sides of connecting rod cap	10-54 Oilgear twin ram vertical surface broaching machine
Broach bore and joint face	10-66 Cincinnati vertical duplex broaching machine
Broach locating pads	36" continuous American surface broaching machine
Finish-ream large hole	No. 17 Foote-Burt 6-spindle drill machine
Disc-grind face and sides of cap	Marschke electric grinder
Wash	Niagara washing machine
Inspect	Bench
CAP BABBITTING	
Put on acid and tin caps	Cincinnati electric lathes
	Gas-operated tinning furnaces
Preheat babbitt in pot to proper temperature and move to pots at spinning machine as required	Gas-operated babbitt pot furnace
Spin in babbitt at 840-860 rpm.	Buick spinning machine
	Buick babbitt furnace
Remove excess babbitt	Bench
	Shop-made hydraulic broaching machine
Grind joint face of cap	Blanchard 16-A-2, 2-wheel continuous grinder
Drill, ream, and chamfer bolt holes	Greenlee 5-station hand index trunnion type machine
First position—load	

OPERATION	EQUIPMENT
CAP BABBITTING (Continued)	
Second position—drill bolt holes	
Third position—rough ream bolt holes	
Fourth position—chamfer bolt hole on joint face	
Fifth position—finish ream bolt holes	
Spotface and chamfer back of bolt holes in cap	Krueger Feedex 4-station machine No. 2 Avey 3-spindle drill press
File face of cap	Bench
Wash	Niagara washing machine
ROD BABBITTING	
Put on acid and tin rods	5" Cincinnati electric lathes 5" gas-operated tin pot furnace
Preheat babbitt in pot to proper temperature and move to pots at spinning machine as required	Gas-operated babbitt pot furnace
Spin in babbitt at 840-860 rpm.	Buick spinning machine
Remove excess babbitt	Bench Greenerd hydraulic arbor press
Grind joint face of rod	Blanchard 16-A-2, 2-wheel continuous grinder
Drill, ream, chamfer and finish ream bolt holes	Greenlee trunnion type 5-station hand index drilling machine
First position—load	
Second position—drill bolt holes	
Third position—rough ream bolt holes	
Fourth position—chamfer bolt hole on joint face	
Fifth position—finish ream bolt holes	
Chamfer back of bolt holes in rod	No. 2 Avey drill press
Drill 1/8" and No. 55 oil holes	Kingsbury 3-station drilling machine No. 1 Blount grinder
File burrs from oil hole and file face	Bench
Wash and blow out	Niagara washing machine
FINAL ASSEMBLY	
Assemble connecting rod and babbitt assembly, connecting rod cap assembly, connecting rod bolts, nuts, shims	Bench
Retighten bolts	Bench
Rough-bore crank hole	Davis-Thompson 12-spindle rotomatic continuous boring machine
Chamfer both sides of crank hole	Krueger 12-spindle double end rotary chamfering machine
Grind both sides of large and small end	Hanchett 4-wheel continuous grinder
Wash	Niagara washing machine
Weigh large and small end	Toledo scale Model No. 9519
Mill large and small end of rod for uniform weight	GM special balancing machine
Burr oil hole inside of rod and blow out	Cincinnati electric speed lathes
Burr weight bosses on both ends	Cincinnati electric speed lathes Marschke floor grinder
Precision-bore crank hole	No. 42 Heald Bore-Matic precision boring machine
Inspect for blow holes and blow out	
Inspect	Bench Exact weight scale

equipment—first for broaching the large end and bolt bosses, then for cutting apart the cap from the rod, again for finish-broaching the joint face of the rod, and later, that of the cap.

The Nash rod is typical of current practice in the use of replaceable precision bearings. To assure a proper seat for this type of bearing, it is necessary to take special precautions in finishing the crank bore. Thus we note the operation of semi-finish boring, then broaching of the bored hole, then honing to size with a Micromatic, hydraulically operated honing tool.

It will be observed that the operations are skilfully subdivided into simple basic functions, each one scheduled over a specialized piece of equipment tooled for maximum output.

Generally speaking, it is universal practice to use specialized inspection devices of the latest types. For example, the large and small bores, which are precision-bored to extremely fine tolerances, are inspected for size with gages typified by the Pratt & Whitney Electrolimit gage or the Sheffield gage which has an amplification of 5,000 to 1 or 10,000 to 1. More recently some of the manufacturers have adopted a method of checking bores with the use of an air-operated gage. Here the bore is checked by using a standard plug with a calibrated leakage of air pressure for a given dimension. The air pressure is read on a gage, the limits in proportion to fine dimensional variation being held most accurately.

Artillery Shell Operations.—To illustrate further, the points that arise in connection with the manufacture of a part, we will take the example of a 75 mm. shell and outline broadly the steps to be taken to get the finished article. Like other parts it may be made from a forging—a machine or upset forging or from their bar stock, or from tubing, all of which methods are in use. Let us take the forging as made by the machine, and we take much of our material from the book *Artillery Shell Manufacture.*[1]

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[1] Published by the *American Machinist.*

Nash Factory Routing—Connecting Rod and Cap

OPERATION	EQUIPMENT
Coin	Verson No. 400 KT steel single crank, single action — single gear, single drive press
Check and straighten	
Broach large end and bolt bosses	Cincinnati No. 5-42 duplex vertical broach
Drill and ream piston pin hole—drill oval	Greenlee 1-way vertical rear column 3-station hand index drill-ream and elliptical bore machine
Chamfer large end—one side	20" Barnes drill
Chamfer pin hole—both sides	Nash double-end machine
Cut apart	Cincinnati 5/54 vertical duplex hydro-broaching machine
Finish broach joint face of rod	Cincinnati 1/24 vertical duplex hydro-broaching machine
Drill ream and chamfer bolt holes	Greenlee one-way horizontal hydraulic feed 5-station hand index multiple-spindle drill and ream machine
Chamfer bolt holes	Single-spindle Leland-Gifford machine
Drill—squirt holes	Kingsbury special 3-spindle drilling machine
Mill spots on small end	Bilton hand milling machine
Finish broach joint face of cap	Cincinnati 1/24 vertical duplex hydro-broaching machine
Drill ream and chamfer bolt holes	Greenlee one-way horizontal hydraulic feed 5-station hand index multiple-spindle drill and reaming machine
Chamfer bolt holes	Single-spindle Henry & Wright
Mill bearing notches	No. 1—14 Kent-Owens hydraulic milling machine
Finish grind joint face	Porter cable type 5-15" horizontal disc grinder
Press in bushing and burnish	No. 6 Toledo punch press
Gun drill rods	Leland-Gifford 2—4-spindle, 2—6-spindle drill presses
Burr oil hole	Bench
Grind joint face of rod	Porter cable type 5-15" horizontal disc grinder
Wash	
Mill bearing notches	No. 1—14 Kent-Owens hydraulic milling machine
Press in bolts	Flexible power press
Assemble cap and tighten	Rotary table
Grind sides of rod	No. 36-A Hanchett rotary surface grinder
Semi-finish bore. Chamfer both sides large end	Davis-Thompson machine
Broach large hole	Oilgear horizontal XL-12 broach
Hone large end to size	305-R Barnes single-spindle hydraulically reciprocated honing machine
Finish bore pin hole	Heald No. 49 double end precision Borematic machine

This 75 mm. shell is made in large quantities. In order that production could be carried on rapidly, existing facilities had to be used to the best advantage rather than the high production equipment which will undoubtedly be used at a later date. The forging is shown in Figure 13a as it is taken from the forging machine. The pointed machined shell is given in Figure 13b. It is worth noting that when forgings are made accurately, leaving little stock for machining, roughing operations can be reduced to a minimum and the production rate in the machine shop increased materially. These forgings should be cleaned carefully before delivery to the rough turning operations, either by pickling or shot-blasting operations as the roughing tools will wear rapidly if the scale is heavy. Because of the differences in machines and methods for shell production, there are

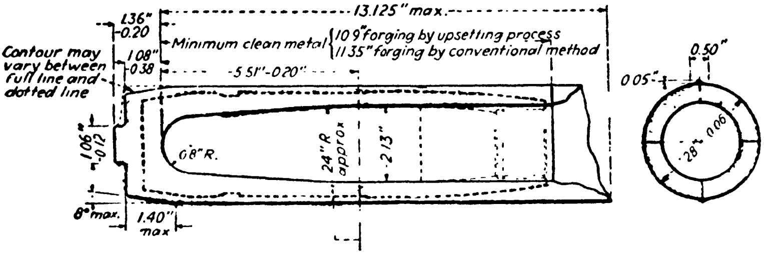

Figure 13a. Steel Forging for Shell

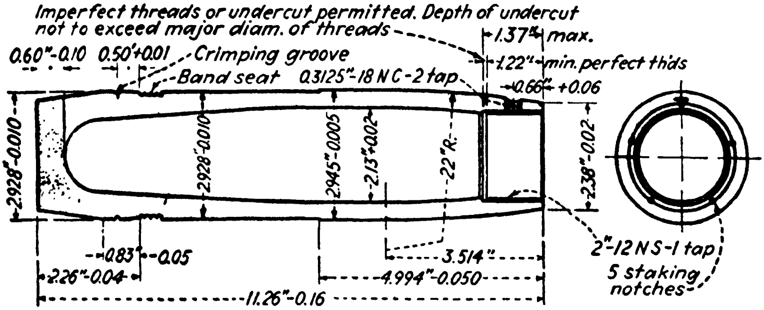

Figure 13b. Finish-Machined Shell Body

a number of variations in possible sequence of operations, and in the number of operations done on any one machine. Developments in shell manufacture are still in the making; in fact, the Ordnance Department is continuing experiments with materials and methods that may bring about important changes in the future.

The following sequence of operations, discussed in a recent article,[2] is used by the Frankford Arsenal to produce 3,000 shells of the 75 mm. size in an 8-hour day with only 41 machine operators. Many of the operations performed on this size of shell are similar to those used on larger and smaller sizes. The Frankford Arsenal sequence is:

1. Shotblast interior surfaces of forging to remove all scale.
2. Center accurately to insure concentricity, as all succeeding operations are dependent upon it.
3. Cut off, rough turn and face in automatic single-spindle machine.
4. Cold nose in crank press.
5. Finish turn exterior surfaces in a vertical 2-slide machine.
6. Drill and tap setscrew hole, using locating fixture on 2-spindle sensitive drill press.
7. Finish both ends and band seat, using an 8-spindle double indexing machine.
8. Notch in hand-miller using indexing fixtures.
9. Stamp with year of manufacture, size and style of projectile, and the initial of the manufacturer.
10. Knurl band seat.
11. Assemble and press rotating band into place.
12. Rough and finish turn band, groove band and trim to width.
13. Spot or seam weld base cover in position on closed end of shell.
14. Wash shell to remove all oil and grease so that paint will adhere without peeling.

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[2] *American Machinist*, Vol. 84, p. 667.

15. Final inspection, performed 100 per cent on all shells.
16. Insert setscrew and grease threads.
17. Paint exterior and interior surfaces.
18. Place six shells in a carton for shipment to the loading depot.

A line-up of a typical conveyor equipment for performing the operation is shown in Figure 14.

"Where shells are being made in any quantity, the problem of chip disposal is as important as the problem of transferring a shell from one operation to the next. Not only must the machines be arranged so that chips easily can be removed to trucks or conveyor lines, but arrangements for transportation of the chips through the plant must be provided. Here our experience with under-floor chip conveyor lines in some American plants will be of value. It probably will be necessary to provide for extraction of cutting oils from the chips, as well as breaking up or crushing the chips so that they can be delivered to freight cars. Equipment for such operations can be placed at the delivery end of the conveyor lines carrying chips from the machine shop.

"It is also recommended that several complete sets of cutting tools be provided for each machine set-up. The operator should have at hand at least one set of ground tools ready for installation in the tool holders should the set in use become dull or broken. And there should be two or three more sets either in the toolroom being sharpened or en route between the machine and the toolroom. In no case should the operator be required to go to the toolroom for a set of tools. These should be brought to him, and the dull tools taken away by some inexperienced helper. The operator, whose skill is of prime importance in the proper use of machining equipment, is far too valuable a man in the present emergency to make it necessary for him to spend any portion of his time doing work that can be performed by an unskilled, untrained worker." See Figure 15 for set-up of cutting tools on lathe.

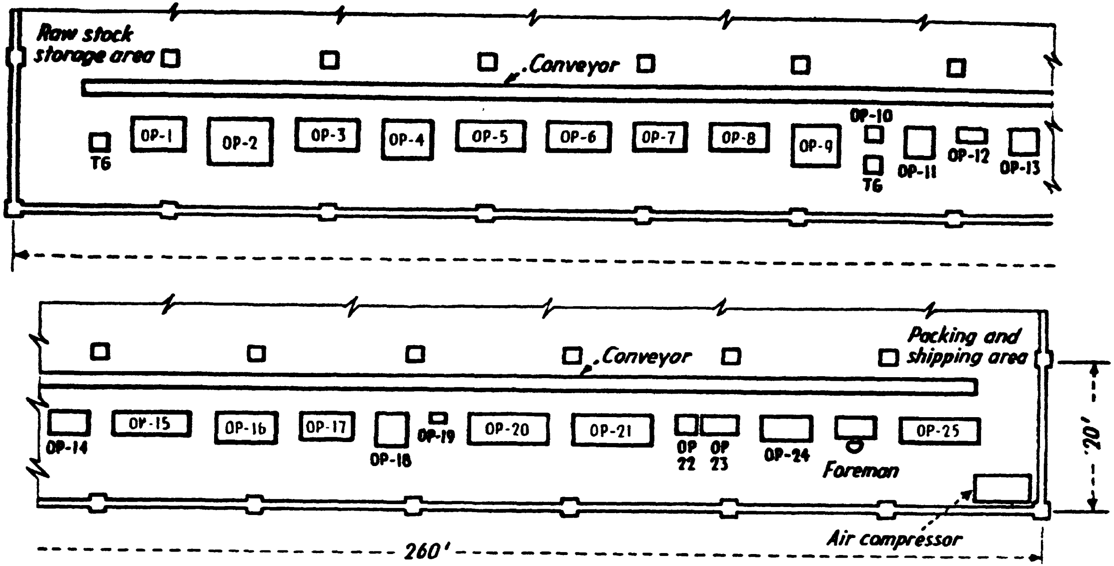

Figure 14. Layout of Conveyor Equipment for Shell Operations. (Layout shows straight conveyor line. These set-ups will produce 342 shells per 8-hour shift—one shell every 70 seconds.)

Full treatment of this subject cannot, of course, be covered here, but the above is offered as a suggestive outline of the procedure to be followed.

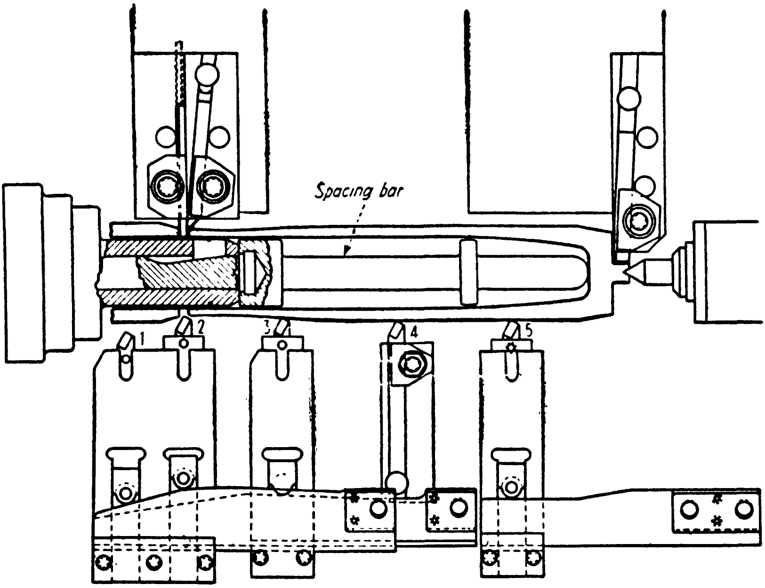

Figure 15. Set-Up of Eight Cutting Tools on Lathe for Rough-Turning of Shell

CHAPTER 6

IMPORTANCE OF THE MACHINE

Varying Production.—In the foregoing discussion we have neglected consideration of the machine; and yet we find on study that it plays an important part in reducing costs. For example, if your production is small, a simple, low-priced machine will be adequate. Such a machine will have a low machine-hour rate (proportionate cost of power, heat, light, supervision, and building charges per hour). When production increases we must consider a more specialized and more costly machine of higher machine-hour rate, but possibly having potentialities of lowered production costs per piece. To take specific examples, a Bullard Mult-Au-Matic lathe occupies little more space than a single-spindle lathe, takes up no more light, no more supervision, and little more power, yet is capable, by means of its many spindles, of cutting the work time per piece to a small fraction of that required on the simple machine. A similar difference in time of production exists between a 4-spindle lathe and a single-spindle lathe, or between a Cincinnati Hydromatic Milling Machine and an ordinary milling machine.

In order to solve the problems relative to the use of such machines, there is needed only a knowledge of simple arithmetic, and a close cooperation with the time study and accounting departments. No detailed time study is necessary, only the simple final result of the time of a complete cycle, from start to finish and ready for start again. In this time cycle there should, of course, be incorporated the usual allowances for fatigue rest, personal needs, intermediate setting of tools, and percentage of machine delay factor.

The machine-hour rate was mentioned above. This rate represents the cost of the machine as distinguished from the cost of labor. To arrive at the factory cost, assemble the cost of material, the cost of labor, the cost of the machine, and the cost of supervision and similar personnel overhead charges. We should, therefore, examine what this machine-hour rate consists of. In the first place, the machine has a projected floor area, but this does not cover all the area the machine tool really occupies. For example, if the machine is 10′ x 10′ projected area, then there must be allowed a space for the operator to control the machine, say 1′ 6″ x 10′. Then there must be allowed the proportionate space for the trucking aisle and the material space; finally there is the allotted proportion of indirect space not utilized for production, such as the space occupied by foreman's office, manager's office, engineers' office, laboratories, storerooms, etc. This addition will swell the proper proportion of space allowed the machine, so that our original machine occupying 100 square feet may now be found to take up three times that space.

This final space is now proportioned to the whole building space as a percentage, so that the costs of the lot, the interest on the building, the depreciation and obsolescence of the building, the repairs on the building, the taxes, and insurance premiums, in short all building costs, may be apportioned in proportion to the space occupied by the machine. We may, therefore, now state that the building costs per year of the machine tool space are so many dollars. Divide this sum by the average number of hours worked each year and you get the building costs per hour of the machine tool. Now we take the cost of the machine itself. First we take the interest on the purchase price, the cost of depreciation and obsolescence, the cost of repairs, of power, and possibly of small supplies. These costs may be taken yearly and prorated hourly as before until finally the machine-hour rate is arrived at.

This procedure may be considered very lengthy and very involved but most of the figures will be found in the accounting department anyway and where they are not approximations may be had. The final result, however, is invaluable as we will see in getting the true value of the machine, whether from the purchasing or from the using standpoint.

A single-spindle lathe will do all the functions of a multi-spindle lathe, yet there are times when the use of the multi-spindle machine is of more value. It is not the first cost that counts; it is the final cost and often the lowest price machine may be found to be the most expensive. A few illustrations will serve as a background on which judgment may be made.

Comparison of Machines.—As a specific example let us assume two milling machines, the one of an older type A costing $3,000, and the other a new semi-automatic type B costing $4,500. The time cycle on A for perfecting a particular operation is 16 minutes. On B it is 12 minutes. In other words, there is a relative productivity of 3.75 pieces per hour and of 5 pieces per hour. Which is the better machine? Getting the figures for the accounting department, we find that A has a machine-hour rate of $1.20 and B $1.50. The labor cost on each machine is 70 cents an hour. We now find that our costs are as follows:

Cost on old machine A per 100 pieces:
Labor cost $0.18 × 100 = $18.00
Machine-hour rate (27 hours) 27 × 1.20 = 32.40
Total $50.40

Costs on newer machine B per 100 pieces:
Labor cost $0.14 × 100 = $14.00
Machine-hour rate (20 hours) 20 × 1.50 = 30.00
Total $44.00

Or the saving is $6.40 per 100 pieces saved on doing the work on the newer machine. Let us examine this $6.40 savings. Assuming a 16-hour day and 200 days per year, machine B would make 16,000 pieces. Assuming this number could be marketed, we would have a potential profit of $1,024, more than enough to pay the interest on the newer machine.

The Crossover Point.—Let us consider the question of when it pays to use one machine rather than another in terms of the number of pieces. A simple chart or simple equation is all that is needed, and the overall complete cost should be considered. In the above example we have the cost of A as interest at 6 per cent on $3,000 equal to $180, and the cost per 100 pieces as $50.40. B interest cost on $4,500 equals $270, and the cost per 100 pieces is $44. Taking the simplest equation, $y = mx + c$, we have M equal to 50.40 and 44.00 respectively, and c equal to $180.00 and $270.00 respectively.

$$\begin{array}{rl} \text{or} & y = 50.40\,x + 180.00 \\ & \underline{y = 44.00\,x + 270.00} \\ & 0 = 6.40\,x - 90 \\ \text{or} & x = \dfrac{90}{6.40} \end{array}$$

or roughly at 1,400 pieces

In other words, we find that it pays to substitute the newer machine when over 1,400 pieces have to be made; below that it pays to use the older machine.

A simple graph (Figure 16) will show the procedure equally well.

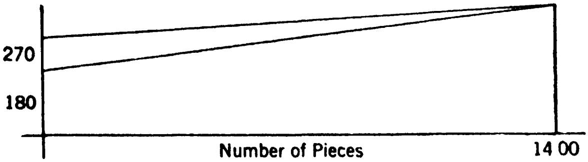

Figure 16. Crossover Point as to Which Machine to Use

Production to Make Investment Pay.—The converse of this problem is as easily worked out, the assumptions being: the cost of the machines, their estimated production rates per hour, their estimated machine-hour rates, and their labor rates, to find what gross amount of production is necessary to make the investment pay.

Assume a 4-spindle automatic C, price \$6,000, production rate 300 pieces an hour, estimated machine-hour rate of \$1.50, in competition with a single-spindle turret lathe D, price \$1,800, production rate 100 pieces per hour and machine-hour rate \$1.10. Assume a labor cost of 60 cents an hour and that one man operates three automatic machines.

Production from machine C:	
Cost per 300 pieces:	
Machine-hour rate	\$1.50
Labor cost	.20
Total	\$1.70
Production from machine D:	
Cost per 300 pieces:	
Machine-hour rate	\$3.30
Labor rate	1.80
Total	\$5.10

These factors give a saving of \$3.40 per hour on a production of 300 pieces per hour. The differential in price on the two machines is \$4,200. Therefore, $\frac{4,200}{3.40}$, or 1,235 hours, or roughly a period of six months, represents the hours of production necessary to make it worth while to purchase the automatic. The above considerations do not take into account such practical factors as the speed of completion of a piece of work where a contract specification stipulates that work must be performed in a definite time. Nor do they take into account the practice often observed in mass production shops, taking a machine and driving it hard to a point where it becomes depreciated before it becomes obsolete. Such work often demands overtime or working 24 hours a day.

Another factor is that, instead of taking the total amount saved and considering it as applied to the total cost of the machine, this saving is sometimes regarded as the interest at

10 per cent on a total sum. Thus a saving of $6.40 might be regarded as equivalent to the interest on $64, and this difference in cost price could be allowed. Some firms calculate this way, especially if there be a continuity of work, and every belief that such machines will stand up to their work. Such a method might be used in an instance where a battery of forging machines have been in continuous operation for 15 years without any serious obsolescence and with little depreciation.

The Policies of Industry.—Having discussed the mathematical interpretation of the results of alternate machines, let us now consider the actual practice in this work and find out what the various leading firms are doing in replacing machines.

The *American Machinist* conducted a symposium on such practice and received reports on many illuminating instances.

The Gleason Company states that seven years is the average age of machine tool equipment in its plant. New equipment must pay for itself in a very short time. "To determine whether or not additional equipment is needed we check our production program from time to time, the intervals between checking depending on the volume of business we have. With a given time to get out a known volume of business it is not difficult to decide that more equipment is or is not needed." "The more work there is ahead the better can the concern afford to discard machines that are worn out, inferior to a later design, or superseded by new inventions."

The policy of the Chrysler Corporation in purchasing new production equipment is governed primarily by the possible reduction in direct labor, and by the necessity of eliminating highly skilled operators. The type of machine that interests this company is the one that, after being loaded by the operator, goes through its functions and then stops in the unloading position. Chrysler discounts the toolmakers' production rates liberally, particularly when deciding to replace existing equipment. "A machine even though it be quite old and of an obsolete design, if it is producing parts that are up to the standard of quality day after day, is an asset that in our practice is not replaced unless the points in favor of the new machine are worth while after having had their advantages evaluated in our own analysis."

The policy of L. C. Smith & Corona Typewriters, Inc. is this: "The first cost of a machine is of minor importance. What we are interested in is the machine's production capacity, its ability to perform under our conditions, and to stand up satisfactorily under such conditions, and of course, its flexibility from the standpoint of tooling. If it can be shown that the purchase of a machine will result in savings that will cover the purchase price and interest in a period of two years, it would have an immediate appeal. If the machine had a utility beyond the immediate reasons for purchase, it would be a factor weighing in its favor, and against a single-purpose machine. We like flexibility in this respect."

The Timken Roller Bearing Company states: "It is part of the policy of the company to work its machines to the limit of their capacity because of the rapidity of development in design. Automatic machines, as rapidly as they are developed by builders, are acquired to replace hand-operated machines."

Problem

1. Work out some examples using your own assumptions or obtain the facts by correspondence regarding the following:

Milling machine versus planing machine
Surface grinding versus surface milling
4-spindle automatics, one man per four machines, versus 6-spindle automatics, one man per six machines

Use a specific piece of work with which you are familiar.

CHAPTER 7

ECONOMIC CONSIDERATIONS

The question is often debated whether to retain the old tool or purchase a new one and of course there is the question of what kind of new one to buy. At the time of writing, when there is a premium on new machine tools and delivery dates are far ahead, the question of delivery date is most important. It may often be found advisable to order a machine tool of earlier delivery date but not quite what is wanted, and get the work under process rather than wait for the more desirable machine and not have the work done at all. Sometimes it will be found better to retain the old machine and improve it as far as possible and then wait for the new one. Here judgment plays a most important part and no rules can be laid down as to procedure.

Sometimes the firm may not have the money available to purchase the new tool, and therefore the old tool must be continued.

In any event, the possibilities of the older tool should be exhausted by a careful study and analysis. The full use of the newer cutting tools should be taken into account as a means of speeding up the old tool. Sometimes it will be found that there is insufficient power available, and possibly an increased motor with larger belting can be substituted. At times a survey of the line shafts may show that the driving motor is too small and that a larger motor will materially help relieve power shortage. In one Cleveland shop there was a battery of 18 machines built around the year 1900. These machines were capable of producing electric welded steel tubing at speeds of around 10 feet per minute. Efforts had been made at intervals to increase this speed, but the workmen objected and tests were rarely carried out. Then came a Mr. Johnston in 1920 with a patented process for producing such tubing at a speed up to 100 feet a minute. Out of curiosity an old machine was taken, and with some minor but significant changes—such as changing over the driving gears so the bull wheel drove the pinion—it was possible to produce tubing at 80 feet per minute. Naturally the machine made a terrific noise at this speed as it was not designed for it, yet the operator stuck to it and successful high speed tubing was produced. The significant point is that for 20 years this machine had the potential increase latent in it, but undiscovered until a study was made of its possibilities. Such speeding up should be done with skill and care, but it may be found that there are many old machine tools that can stand it.

Use of Fixtures.—Another possibility lies in the increased use of fixtures so designed that the man may be unloading and loading the fixtures when the machine is working. Older machines are guilty of the fact that too often the man is working when the machine is idle and the machine working when the man is idle. Obviously, for efficient results both should be working simultaneously. This follows the law of simultation which will be discussed later.

An illustration of this factor is found in the use of a simple drill jig for drilling the two holes in a pipe flange. Many a firm feels that its duty has been done when it builds one jig or fixture to take one flange and one flange only. Obviously, with such a fixture, the machine is idle while the man loads and reloads. True, it may have been designed to promote standardization, interchangeability, quality, and the other factors, but it is none the less an inefficient fixture, and if increased production is required at lower cost, a newer type should be designed, provided of course the quantity of production warrants it. A simple fixture of this newer type will have a rotary table with two fixtures on it each diametrically opposite the other. The machine can then be working on one fixture while the man is loading and unloading the other—truly a saving in economy. Even the expense of the rotary table can be done away with and merely two fixtures used.

Generally speaking, a study of idle machines should be made, as to how they can be brought back into production. Oftentimes a new fixture will rejuvenate an old machine tool.

Use Existing Buildings Where Possible.—Allied with such factors is the practice of the routing engineer who takes the easy course of recommending a new building, with a new layout of machine tools to accommodate a change in process or product. The more difficult and the more economical course is to study what can be done with existing facilities and how they can be improved. Often a new arrangement of existing machines will yield enough space to take care of the new load. Such an incident happened in the Standard Welding Company's plant when the manufacture of a particular type of automobile rim was undertaken. The first thought was to build a new building and completely equip it for the purpose. Actually contracts to the extent of some half-million dollars were entered into and proceeded with.

A later survey showed, however, that there was considerable space to be gained in the existing factory by a comparatively inexpensive rearrangement of tools, so this change was entered upon. It was found to lead to lessened supervision costs, lessened building costs, and lessened power costs, so that when the new building had been completed, it was not occupied but sold and a total saving of some $150,000 resulted.

Keep Machine Tools at Work.—The above discussion leads to the fact that the idleness factor of a machine should be considered just as seriously as the working factor.

The Gantt chart, which will be discussed later, is a valuable graphical method of studying these factors and should supersede the inaccurate method of recording job data for machines by means of the control board with circular discs representing jobs tagged to it. Study and effort should always be made to keep all the machines working to 100 per cent of their capacity.

Constant analysis of the preceding factors will tend to keep one's machine shop, or forge, or foundry up to competitive standards. The use of machine tools is constantly changing. For production purposes the milling machine has displaced the shaper and planer. The grinding machine has displaced the lathe for fine work. The centerless grinder has displaced the center type grinder for many purposes. The automatic machine has displaced the individually operated machine, and so the process goes on. The stimulus to the machine tool industry is evident, and its response in recent years has been wonderful as shown by the new designs of higher productive capacity.

The Influence of New Processes.—The constant development of new processes, new production machinery, new techniques and instrumentation—all make it of vital importance for engineers and production men to follow such developments closely and to take advantage of them wherever it is feasible.

Consider, for example, that the proper cooperation between the designer and the production department makes it possible to make the ofttimes small and even subtle changes in the product, in its form or tolerances, so as to attain all of the advantages offered by the new methods at hand. The mere adoption of a new process does not imply that the most favorable costs may be achieved unless the product itself is made to conform.

How far this practice may be extended and to what degree it can be employed in planning depends largely upon the volume of work in process. In job-lot routing it is usually necessary to move parts around from one department to another, since the manufacturing functions in such operations are centralized in specialized departments such as—milling, grinding, screw machines, drill presses, punch presses, etc. On the other hand, where mass production volume is the rule, it is economical to have straight-line procedures in which the routing of each part can be done most expeditiously on a specialized line-up of equipment over which the individual part can be completely finished.

Consider, for example, the impact of a new machining process such as surface broaching. When judiciously used, surface broaching may replace a large number of milling machine operations, grinding operations, boring operations, etc. The modern method of machining connecting rods in mass production is the best example of this. The same is true of cylinder block machining where one large surface broaching machine handles all of the multiplicity of milling machine operations usually required. In most cases a single machine of this type is used to finish the half round bore of the main bearing gallery while it finishes the crankcase gasket surface simultaneously.

Advanced gear practice also has changed the picture of precision gear manufacture. For example, in the automotive industry the making of fine transmission gears has been greatly expedited by the adoption of the gear "shaving" process. The gear is hobbed, then form-corrected in the "green" on the gear shaver. No further finishing is required after heat treatment, the industry having abandoned all finish grinding operations except on heavy duty gearing. In a few instances it may be necessary to use a gear lapping operation after heat treatment but this is a very rapid process.

Proper cooperation between the planning department and engineering can lead to the adoption of die casting procedures where this is feasible. Die castings of zinc alloy or lead alloy or aluminum or magnesium or strong brass are widely employed, and provide an excellent means of producing highly intricate precision parts which require little processing for immediate conversion to the finished condition.

The growing use of special hard cutting tools such as the cemented carbides, cast carbides, and Haynes-Stellite, greatly increases the productivity of a metal-cutting machine, expedites the finishing of even the heat-treated alloy steels. Job routing must include a study of the possibilities of special tool materials since their use increases productivity to such an extent as to relieve the burden on machine tools and frequently to make it unnecessary to provide additional facilities even when extra output is required. In addition, such tooling produces a better surface finish and in some instances may eliminate finish-grinding or polishing operations.

Welding to replace riveting and other forms of joining should be given due consideration in analyzing process routing. And here again it is necessary to work with the designers so as to make the alterations in product design which may be necessary to accommodate it to an economical welding procedure.

Mechanized materials handling is one of the most important attributes of mass production. The proper use of monorail conveyors, gravity roller conveyors, belt conveyors, and assembly conveyors not only reduces time and labor but it permits of the layout of tightly knit production departments in which the material flows smoothly and rapidly. Needless to say, mass production layouts could not be achieved without mechanization. Not the least of the rôles of mechanization is that of expediting the proper scheduling of raw materials to machine lines, and the timely feeding of component parts to fast moving assembly lines.

Completely automatic processes for electroplating, for spray painting, for the formation of chemical coatings, and the like have speeded these operations, and have made it feasible to include these technical processes right in the line-up of steps in the routing of a given part.

The few examples given above constitute but a sampling of the sweep of technical development which must be studied by both the designers and production executives. Unless such techniques are rapidly adopted wherever economically possible, it will be difficult if not impossible to keep pace with the quality and cost levels of competitors in the same field.

Problems

1. Make a time study of a planer and of a milling machine, removing, say, 10 cubic inches of metal from a flat rectangular surface. Then discuss with figures why the planer has been replaced by the milling machine for productive work.

2. What is your idea of resourcefulness in machine tools? Why is the lathe so flexible? Explain some of the operations it can do.

3. Discuss multi-station fixtures and give a sketch of one where one station is drilling, a second tapping, and a third loading.

4. Discuss the potential losses that accrue when you have to put work on a machine not so well fitted for the job as another. If the other machine is busy on profitable jobs and the first machine has a tendency to be idle, is there not a gain instead of a loss?

CHAPTER 8

LOT SIZES

What Quantities to Put Through Economically.—Plants often find themselves confronted with the problem that they have an excess capacity over and above their demand, and that they are puzzled as to how to put through this smaller number through the factory.

No such problem exists when the demand is equal to the capacity; then the situation is that the work is put through steadily and regularly. The obvious way is not always the most economic, and a simple analysis is necessary to decide which is the cheapest way. Sometimes considerable money can be saved by such a study.

In our problem of lot sizes manufacturing one lot once a year gives a powerful impulse but the effect is lack of smoothness of operation. More impulses or more lots give smoother flow but there are limitations that come up.

The governing factors are:

1. Plant capacity
2. Sales demand
3. Cost of raw material per piece
4. Cost of finished material per piece
5. Interest charges on material raw and finished
6. Set-up charges
7. Storage charges

The situation at times is somewhat analogous to the torque curve of a gasoline engine. The 1-cylinder engine of specific horsepower gives one heavy impulse, and then for three-quarters of the two revolutions does nothing. The 2-cylinder engine of the same horsepower gives one impulse each revolution and the torque curve is relatively smoother. The 12-cylinder engine of the same horsepower gives an impulse every one-sixth of a revolution and the torque curve is almost similar to a smooth straight line. The more impulses per revolution the smoother the torque curve. So is it at times with the number of lot sizes, but, as we have said, there are limitations. The more often we put through our lots the higher do our set-up charges become and the less the interest on the materials. So we must strike a balance. How this work is done is shown in the following example. Assume a quantity of material to put through a plant, and that there is an excess production capacity to take care of it. In figures the sales rate of the product is 20,000 pieces per year; the production capacity is 125,000 pieces per year. That is, pieces made in one unit of time leave 5.25 units of idle time unless, of course, this time is occupied on other products. The cost of setting up tools, preparing the machine, setting up fixtures, and, in general, getting ready for a new lot is assumed at $605. Material cost of raw materials going into the stores (purchase price plus freight and handling charges) is assumed at $2. Value of the finished part is $10. The labor cost per unit is taken as the factor *T*, including overhead charge but not material burden.

Now, if manufactured all at once, the total cost is made up of $605, plus labor cost equal to 20,000 *T*, plus interest on the material for the remainder of the year. This latter factor is made up as follows: The capital on which interest is payable is $2 (the cost per piece) × 20,000 (the number of pieces). The interest rate we will assume as 6 per cent. The period over which this rate is effective is

$$\frac{5.25}{6.25}, \text{ or } \left(\frac{125{,}000 - 20{,}000}{125{,}000}\right)$$

of the year. But this material is not idle throughout the whole year, since we assume that it is being sold off at a uniform rate, so we must take the average time of capital tie-up, that is, ½ of the total time. Thus this last factor will become

$$\frac{5.25}{6.25} \times \tfrac{1}{2} \times 0.06 \times 20{,}000 \times 2 = \$1{,}008$$

Question of Interest on Stock.—Now at this step we introduce the suggestion which we believe logical, that if you are entitled to charge interest on raw material held in store, you are also entitled to charge interest on the values added to the raw material held in stock. We therefore have an additional charge on money locked up in completed parts at the assumed rate of interest of 6 per cent. This amount equals:

$$\frac{5.25}{6.25} \times 1/2 \times 6\% \text{ of } (10 - 2) \times 20{,}000 = \$4{,}032$$

So that the total cost, manufacturing all at once, is

$$\$605 + 20{,}000\,T + 1{,}008 + 4{,}032 = \$(5{,}645 + 20{,}000\,T)$$

Let us take the cost of manufacturing in two lots per year. In this instance, only ½ of the capital is expended for material and only ½ the quantity kept in "average" storage, but the setting-up costs are doubled.

By working this out in similar fashion to our first set-up, we find a total cost of

$$\left\{2 \times \$605 + 20{,}000\,T + \frac{5.25}{6.25} \times 6 \times 1/2 \times 1/2 \times 20{,}000 \times 2 + \frac{5.25}{6.25} \times 6 \times 1/2 \times 1/2 \times 20{,}000\,(10 - 2)\right\} = 20{,}000\,T + 3{,}730$$

Similarly, the cost of putting through for

3 lots is $(20,000 T + 3,462)
4 lots is $(20,000 T + 3,680)
5 lots is $(20,000 T + 4,033)
6 lots is $(20,000 T + 4,470)

Omitting the factor "20,000 T" which is common to all, we draw a curve (Figure 17) from which we see that making lots in equal quantities every four months or three times per year gives the most economical production. In fact, we find that in this particular instance, we have made a saving of $2,183 by putting through three lots instead of one.

From observation it is clear that many firms are losing money by not following this procedure. The above method, while not strictly scientific, being an approximation, is simple and sufficiently accurate for general purposes. It has the advantages of clearly visualizing the savings that can be made.

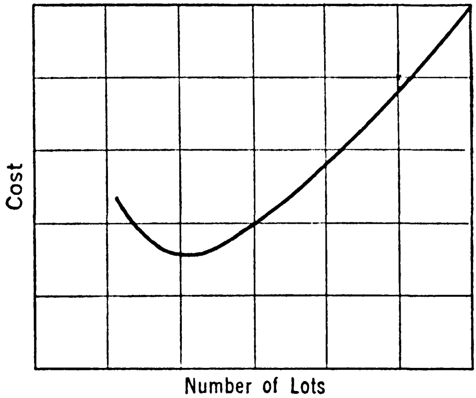

Figure 17. Relation Between Production Costs and Number of Lots

The Lehoczky Method.—Paul N. Lehoczky[1] has developed a simple formula that can easily be applied, giving sufficiently accurate results for all practical purposes.[2]

Let X = Number of lots to be produced per year

M = Interest on raw material, if purchased once a year

L = Set-up charge

$$J = \frac{\text{Output}}{\text{Capacity}}$$

$$S = \frac{\text{Cost of finished product}}{\text{Cost of raw material}}$$

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[1] Ohio State University.

[2] See *Laws of Management Applied to Manufacturing,* by L. P. Alford, The Ronald Press Co., p. 225.

Using these symbols, the Lehoczky formula is:

$$X = \sqrt{\frac{M}{L}\left(\frac{S + J - SJ}{2}\right)}$$

This formula is derived as follows:

Total cost is made up of:

(1) Constant costs independent of lot sizes (rent, insurance, overhead, labor, etc.)
plus (2) Set-up charge times the number of set-ups
plus (3) Interest on raw material while in storage
plus (4) Interest on finished product while in storage

The first two of these items are self-explanatory. The third must be weighted, that is, taken as all the raw material over half the period of manufacture or as half the raw material over the whole period of manufacture. The fourth item must be weighted similarly and consist of the average interest rate over the whole period of sales, less the rate for the time during which it was in the form of raw material. While (2) increases directly with the number of set-ups, (3) and (4) increase inversely with the number of set-ups.

Hence we have,

$$\text{Total cost} = K + LX + \frac{M}{2X}(J + S - SJ)$$

This equation, after the substitution of the appropriate values, will contain two unknowns, i.e., total cost and X, the number of lots per year. Assuming different values for X and calculating the total cost accordingly, we will obtain a series of values that can be plotted with X as an abscissa and total cost as an ordinate. An examination of the resulting curve will show a low point in total cost for a certain value of X. This, of course, is the value of X that we will want to use.

The whole matter of judging X is, however, very much simplified if, instead of plotting the equation, we differentiate it with respect to X (the number of lots) and equate the differential to zero. This is so because the first differential gives us the slope, and the part of the curve we are after has a slope equal to zero.

Hence, differentiating the above equation and equating to zero, we have:

$$L - \frac{M}{2X^2}(J + S - SJ) = 0$$

Solving for X, the number of lots per year,

$$X = \sqrt{\frac{M}{L}\left(\frac{J + S - SJ}{2}\right)}$$

To get the period, divide the number of days in the year (working days or 365) depending upon the answer expected by X.[3]

Problems

1. Making various assumptions, draw out curves of cost of varying lot sizes and also work out the lot period by the Lehoczky formula.

2. Find the most economical lot size, given the following data: sales per year 10,000 pieces; capacity per year 50,000 pieces; set-up charge $1,000; interest rate 6 per cent per year; cost of raw material $1 per piece; value of finished product $5 per piece.

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[3] See also the work of Professor Fairfield Raymond, in Proceedings of the American Society of Mechanical Engineers, December, 1929.

CHAPTER 9

INTERRELATION OF WORK ROUTING, STANDARDIZATION, AND COST ACCOUNTING

Order of Starting Work.—The functions of planning, routing, standardization, and cost accounting are so closely interrelated and interdependent that the order in which they are developed is a matter of considerable importance. The situation is akin to that which often faces one in maintenance practice, when a main line bearing gives out and an immediate repair is necessary. The obvious thing to do is to put in a new bearing but the better way is to realign the main shaft, and determine the cause of the trouble. Similarly, in overhauling a plant and bringing it up to scientific standards, trouble will develop in one function which can be traced back to an error in a totally different place.

When the engineer attempts to reconstruct a plant, he may be faced with troubles which seem to have obvious relief in one direction but which need careful tracing back to their prime causes to obtain lasting relief. Hence arises the necessity for considering which of the above functions to install first. To give another analogy, it is like a draftsman faced with the design of an automobile. Shall he design the engine first, or the axles first, or the frame first? If he designs the axles first, he will be immediately confronted with the question of how much power will have to be transmitted, and this factor will inevitably lead back to a consideration of the engine.

Similarly, he may proceed with the frame but will have to take up the question of the units at once as their carriers or brackets will be an important part of the structure of the frame. Study should, therefore, be given to the best way to tackle the scheduling of the design of the parts so that the whole assembly will be produced in an economic length of time.

Therefore, there should be a "one best procedure that will tend to most efficient results." Shall we install our cost accounting system first, or our standardizing function first, or our work routing? Sometimes, of course, they can all be installed simultaneously, but even then that might not be the most economical method. It is a waste of money to install a cost accounting system at such a time that its only function is to record data that will shortly be obsolete.

Make Obvious Savings First.—However, common sense can be brought into play. You can rectify errors which your own judgment and experience tell you are costing money and be satisfied with the fact that the result shows that you are saving some money, though you need not know exactly how much it is. An early start in job analysis and planning would seem to be the best procedure. Sometimes the policy of our leading manufacturers trends this way. The obvious gross savings are made first and the net amount calculated later. This policy needs to be discussed somewhat here, as it deals with the advisability of trusting to one's instinct which is fundamentally based on experience.

Common Sense Applied.—Some engineers will advise you to consult the cost accountant on every move and place no trust in instinct. This policy may be all right from the scientific point of view but it is all wrong from the common sense outlook.

Common sense still plays a large part in our production operations, and as a policy should be followed. Savings in cost can be attained more quickly this way than by waiting for the verdict of the cost department. Further, cost departments which are too finely detailed are expensive as an overhead charge and may not always justify themselves.

Again, there is little to be gained by the cost accounting department working up detailed costs on an operation that will be changed radically later. Such a course will be a needless expenditure of money.

Our first procedure, therefore, may be to develop planning based on past record performance (possibly as shown by a previously established cost or record system). Second, observations should be analyzed, recorded, and standardized. The idea of standardizing operations is important. Most of us are born with the desire to experiment somewhat, and we often do so at the expense of cost.

Take the case of a foundry superintendent, for example, who makes no record of his various heats, whose quality of metal is constantly changing, and contrast him with a superintendent who records each heat and its charges, and, when he finds one which gives him good results, sticks to it, and countenances no departure. Uniform quality is only possible by recording and standardizing, and is an absolute necessity when mass production is attempted. If the quality of material varies in a shop, the whole system of wage incentive payment breaks down due to the departures from standard times.

Standardization.—Standardization in itself leads to better planning and this brings us to the third sequence, namely, "Perfect planning through use of standards." Knowing that a certain process is going to repeat itself indefinitely, by the use of standards the times and other factors of this process can be planned for accurately. For example, take a gear blank going through the processes of turning, hobbing, broaching, heat treatment, and grinding. If each of these processes is standardized, then the time for a given quantity is standardized for each. Thus can be planned a uniform total time, a uniform cost for the completed gear, and also plans for a definite space to be taken up by the various processes. It is even possible to plan for the specific machines to be used with definite rates of production on each machine.

Finally, the cost accounting system should be developed and made to tie in with the company's books for consideration of executives and stockholders.

It may be well at this point to consider the question of costs and cost accounting from the planning point of view. Cost accounting has two functions. The first is that of merely recording the actions that have been taken. The second, a more dynamic function, is that of doing research work into possible costs before action is taken. This latter function is the more important to the planner. By using the cost department as a tool, he can get valuable forward-looking information on what will happen provided he makes certain changes. He can determine possible machine-hour rates and machine-hour production and thus weigh one machine against another. He can determine how much he will save by installing automatic machines with one operator for several machines against simple machines and thus determine if he can afford the costs of the installations.

Costs must be interpreted in terms of action to get results that are beneficial. Costs are merely stepping-stones to better production. A cost department not utilized in this manner is an uneconomical expense. A little more expense added will make it a tool to get valuable results.

Problems

1. You are making steam pipe flanges which are bored, faced, and drilled. What results will you gain by standardizing the processes?
2. Discuss the two functions of cost accounting and explain fully the benefits to be derived from "research" work in costs.

CHAPTER 10

COST ACCOUNTING FOR PLANNING

Prorating Overhead.—It is well to consider the amount of cost accounting with which a planner or work router should be familiar. The books on cost accounting are usually not written from the engineer's standpoint and are often filled with matter which confuses the engineer and disguises the valuable work a properly installed cost system can do.

The matter of prorating overheads, for example, is of intense importance to the engineer who wishes to make comparisons for ultimate savings. The direct labor method is probably the most widely used method and the simplest. This method is based on the idea that all overhead charges are to be borne by labor, the individuals that play a direct part in fabrication. The rate is found by dividing the total indirect expense of the whole plant (building charges, supervision costs, money charges, taxation and insurance, inspection, maintenance, tool charges, etc.) by the direct labor cost for the same period. The result is usually expressed as a percentage; thus overhead expense is said to be 170 per cent of direct labor. Care should be taken that this percentage is not set up as a measure of efficiency. Many individuals still think that a low overhead is a signal of great efficiency but a simple example will disprove this opinion.

Low Overhead Not Always Wise.—Assume 12 single-spindle, simple type lathes each with its individual operator, each operator being paid 60 cents per hour. Assume an overhead charge of $10.80, covering cost of heat, light, supervision, and other charges. The overhead cost in this case is 150 per cent and the factory cost of the pieces turned out is *M*, (the material) plus $7.20 (the labor charge) plus $10.80 (the overhead), or $18 plus *M*.

Now let these machines be replaced by three 4-spindle automatic lathes capable of turning out the same production but operated by one man at the same rate. Assume they occupy the same floor space and that the light, heat, and other charges are the same. The inspection charge will be the same, but the supervision charge will be slightly lower. However, let us assume an overhead charge of $10.80. We now have an overhead charge of $\frac{10.80}{1.80} \times 100$ or 600 per cent. But the cost of the same number of pieces is now: *M*, material, plus $1.80 for labor plus $10.80 for overhead, or $12.60 plus *M*. Truly quite a saving in net cost per piece although accompanied by a considerable increase in overhead rate.

Projecting ourselves into the future we can visualize a large plant filled with completely automatic machinery having a very small number of men engaged in actual productive work and, of course, having a tremendous direct labor overhead percentage but turning out work at a very low cost. This percentage, therefore, cannot be taken as a criterion of efficiency.

Certain problems will naturally arise, such as how this percentage is balanced up as the labor and the production fluctuate. These problems can easily be taken care of by the cost accountant as they arise, and need only concern the work router in an academic way.

Prime Cost Rate.—In the chemical engineering plants where material is a very high factor and labor is a comparatively unimportant one, the prime cost method is often used. In this method the overhead rate is found by dividing total indirect expenses by total costs of direct labor and material for a given period. The result is called the prime cost rate. The overhead of a particular order is found by multiplying the costs of material plus the direct labor by the prime cost rate. It is possible that as shops become more and more mechanized, and as productive labor decreases, this method may be used in metal working plants.

However, metal working shops are large users of machine tools and it would seem as if the machine-hour rate would come in as the most scientific method of prorating overhead charges. In this case the machine is looked upon as the bearer of the burden of overhead, and all charges are placed on its shoulders.

The machine is supposed to occupy a definite amount of floor space, including operating space and aisle space, and as such is supposed to "rent" that space from the company. The situation is analogous to that which pertains in a power building where power and machines are rented to small users of machinery.

If the building has a floor space of 10,000 square feet and the machine occupies 100 square feet, or 1 per cent, then is it fair to prorate the heating, lighting, and building charges on this percentage basis? Power charges should be prorated as scientifically as possible. Some firms even take a power survey of each machine to determine its power absorption accurately and thus find the proper amount to charge each machine so that the summation of these charges will add up to the power bill.

Prorating Power and Supervision.—In cases where this expense is too great, a common sense judgment of the power charges will be found fairly accurate. Thus, for example, a line shaft operated by a 50-hp. motor may have 10 machines on it. An intelligent survey will show that one machine is practically using 7 hp., another 3, a third 5, a fourth 4, and so on till the 50 hp. has been accounted for and then the current consumption expressed in terms of money can be prorated to each machine.

Supervision is a difficult charge to prorate. Sometimes the supervision is expressed as a percentage on direct labor and only the machine charges such as power placed on the machines. Other firms, however, often prorate their supervision on the machines and assembly benches and so get one inclusive rating.

Thus the first method would produce a factory cost of *M* for material plus (*L* times supervisory percentage) plus labor plus machine-hour rating. The second way would be simpler: *M* plus *L* plus machine-hour rating.

One advantage of the machine-hour rate method, and the one that leads to accurate results, is that the costs of the machine tool itself can be charged directly against itself. Such factors as obsolescence, depreciation, maintenance, and interest become individual factors against individual machines. Thus if a firm decides to run a particular machine at its full output all the time, that machine bears the resultant depreciation and no other.

Obsolescence.—Often obsolescence is a bigger factor than depreciation; so big has the former factor become that machine tool users are learning not to "baby" their machines but, on the contrary, to get the utmost from them by forcing them to the limit. As stated previously, many tool users seek to get the utmost from their machines to pay their cost in a short period of time.

The maintenance factor includes such items as the cost of repairs on machines, overhaul of machines, and the cost of general upkeep. Many firms keep individual records of their machines to aid in determining this cost.

As shown previously, this machine-hour rate can be used for many calculations involving installation and replacement of machines, as well as those comparisons which must be made between machines. Machines are understood to include not only machine tools, but also conveyorized assembly lines or benches which can be treated in the same way as machine tools.

Problems

1. One plant of the old-fashioned type employs simple machines individually operated. It employs 100 men getting an average day rate of 55 cents an hour and turns out a specific

product at a specific rate of 50 per month. Its overhead charges are $16,500 per month. It works 200 hours a month.

A second plant is of the more modern type and is equipped with automatic machines of the latest type. It employs 50 men on piece-work, the average piece-work rate being 75 cents an hour, and it turns out 75 products per month of exactly the same quality as the first plant. It also works 200 hours a month and has an overhead charge of $18,000 per month.

What are the respective overheads of the first and second plants? Assuming a material cost of $500 per product, what is factory cost per product in each case? Which is the more efficient plant?

2. Work out a machine-hour rate based on the following assumptions (supervision not included):

Cost of machine is $5,000.
Interest rate is 6 per cent per year.
Obsolescence and depreciation are 20 per cent per year.
Floor space occupied is 120 square feet.
Capital invested in floor space is $4 per square foot.
Interest, depreciation, maintenance, lighting, heat, etc., on the building is at rate of 20 per cent per year.
Power used is 7½ hp.
Cost of current per hour is 1½ cents per kilowatt-hour.
Machine works 3,000 hours per year.

CHAPTER 11

JOB SHOP PLANNING

The Small Shop.—The foregoing chapters have been devoted to work routing and planning in general but with particular attention to the problems of mass production shops. There are many who think that the job shop does not lend itself to planning treatment, and unfortunately the attitude of a large number of our job shops would seem to bear out this statement. Far too many of these shops operate on a hit-or-miss principle and trust in a benevolent deity to keep themselves straight. Such shops feel competition bitterly, and are in fact a menace to the industry they represent. Due to lack of efficient planning, they can only feel their way along instead of proceeding confidently.

Planning can be as successfully applied to the job shop as to the production shop, and its basis rests on the estimate that is first made when quoting for a possible order.

It is unnecessary to have the elaborateness of the complete planning department with its staff of clerks as found in our larger shops. The time, or even part-time, of one man will suffice, the necessary fact being that there shall be at least one person responsible for the planning function.

In jobbing shops the customary procedure is to make out an estimate of cost when bidding for a customer's order to the specifications. The usual procedure, unfortunately, in many shops is to disregard and forget this estimate once it has been made and the foremen proceed with the work in their own way.

Value of the Estimate.—It is far better to make the estimate a basis of future planning. In preparing it the material cost and the labor cost, primarily, have to be found. This procedure means that for the latter purpose time study records or ordinary records based either on studies or judgment must be made of previous jobs, and the new job calculated thereon. Always the jobbing shop should keep records of past performance. They are invaluable for future reference.

The machines on which the jobs are estimated to be done should be rated and all pertinent information recorded. If the engineer or estimator thinking out the theoretical job should come across some process or scheme that will save money, he should make a complete note of it. If he sees where some weight of materials can be trimmed off, this should be noted, for the essential part of this type of estimate is that it is not forgotten but used as an essential planning tool.

When the order is received, take up the estimate from the record file and carefully consider it, point by point. Have the purchasing agent scan the material and see that he orders it and no more. Have the plant superintendent issue instructions that the job is to be done as the estimate planned, and only where clear savings can be foreseen should this be departed from. By such procedure the actual working out of the order will be reconciled with the estimate, instead of as usual being at variance. At least a profit will be assured to the company by this method instead of the proceeds of a gamble.

Importance of Records.—If records are not available, then it should be the function of someone to see that such are put into existence and carefully filed. Records should be made of such fundamental work as the turning of shafts, the planing or milling of flat surfaces, the cutting of standard screw threads, and so forth. From these records simple proportional calculations will derive the time for similar work on similar machines.

Another record should be kept of jobs available for different machines. This record, usually in simple chart form (Figure 18), will help solve one of the main problems of the job shop, namely, that of idle machines. It is exceedingly difficult in such a shop to schedule work so that all of the machines will be busy all of the time. The variables of customers' schedules and specifications are too great to permit of this, but a strong effort should be made to solve this problem, as on it depends the maximum revenue to be derived from the facilities of the shop.

Sometimes taking work at a cost low enough to take care of the overhead costs, but no more, is indicated. It is usually better policy, however, to seek out the weak points in the schedule and have the sales office try to fill in the gaps. It is just as essential to balance up the order in a job shop as in a mass production shop. The busier a shop can be kept, the greater the turnover. The greater the turnover, the greater the profit.

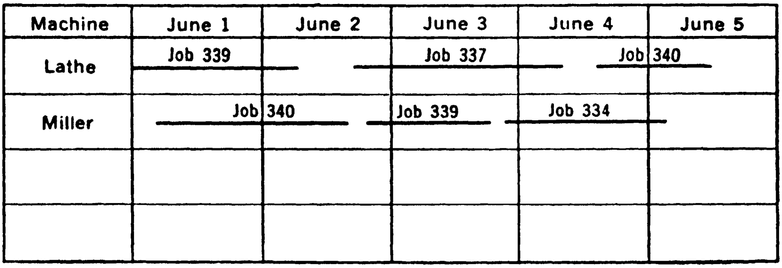

Figure 18. Record of Jobs Ahead of Machines

To repeat and emphasize, jobs should be issued with instruction sheets. There is no reason for assuming that the workman in a job shop is more skilful than his colleague in the production shop. The contrary is often the case because the usually higher pay of the latter has in a measure drawn the cream of workmen from the former.

Jigs and Fixtures.—It will usually be found in jobbing work that the relatively low price at which the order is taken, and the fact that there are usually so few to be made, will prohibit the use of jigs or fixtures. This fact means that in estimating ample time should be allowed for setting up the job. Sometimes, and indeed quite often, the time taken to set up a job and the accompanying tools will take longer than the actual time of machining. In the mass production shops this work of setting up is often done by special men and the operator can be busy on some other job. This policy is not possible in the job shop, and is one of the reasons why costs run high, and why more resourceful and versatile men should be employed. Incidentally, it is difficult to subdivide labor operations in this type of shop as is found more profitable in the others.

Another problem that will arise in this shop is that of whether to wait for the least costly machine, or place the job on the machine that is virtually idle. In all cases it will be found profitable to keep the machines at work, and so a policy of placing the job on the idle machine is the better to follow. Sometimes one has to be resourceful in doing this work. For example, the lathe is a most versatile machine. By strapping or clamping work on the saddle and by traversing the work with the saddle while a boring bar is rotated between the centers, a very good boring job can be accomplished. Sometimes a job that could most suitably be done on a shaper can be done on the lathe by proper chucking or fixing on a face plate. Resourcefulness of this kind usually pays, and should be encouraged within reason. If a machine is idle a great percentage of the time and its work is being done or can usually be done on another machine, then the alternatives of the policies of keeping this machine or selling it should be seriously considered, as the money tied up could perhaps be used to better advantage. On the other hand, it will often be found necessary in this work to have some machine for the unusually profitable job which only occurs once in a while. Care should be taken to see if the profit made is more than the loss sustained by the idle time of the machine. Examples of this policy are usually found where big planers or lathes are kept for the unusual job of large size. Such work must be done and the customer should be prepared to pay the cost of keeping the equipment available in addition to the costs of machining, etc.

Arrangement of Machine Tools.—The arrangement of machine tools in a job shop is not at all the same as in a production shop. Instead it will be found that all lathes will be segregated together, all milling machines, all shapers, all planers, all grinders, and so on, each kind in its respective department. A foreman should be in charge of each department if the size of the shop and the department warrant it. This foreman is in charge of a particular type of machine tool instead of being in charge of a product as he is in the production shop.

This arrangement, of course, necessitates trucking, and if pieces were done individually and then trucked, the expense would mount considerably. It is usually better policy, therefore, to send the work through in lots, if there is sufficient quantity of the one kind, or to take miscellaneous truck loads if there is not. Because of this trucking expense, care should be taken to arrange the machines in such sequence of departments and in the departments themselves that a minimum of handling will take place. For example, grinding always follows turning. Therefore, the grinding department should follow the turning or lathe department as closely as possible. Similarly, all machines engaged in heavy work should be arranged along the crane runway so as to give minimum handling of the crane.

A study should be made of an existing shop to see if conditions can be improved. A layout of the shop with cardboard plans of the tools in position should be made and thumbtacks placed on each machine. Threads of various colored silk can be wrapped around these tacks to show how the work progresses; this is called the flow of work. The resulting chart should then be scrutinized most carefully to see how backtracking and crowded lines can be avoided. Often a relocation of an offending machine tool will simplify the work and cut down some of the trucking expense considerably. This relocation can be tried out repeatedly by changing over the cardboard plans of the tools until the desired effect can be obtained. The machines should then be set up in their new position with resulting benefits.

Rush Orders.—Another problem confronting the job shop is that of the rush order. The rush order is usually distinguished from the others by having a red ticket attached to the job. Some shops simply bristle with such tickets and usually this display is a sign of inefficiency. A well-arranged, well-controlled shop will have very few rush orders and then only those that are vitally necessary.

Sometimes a rush order is necessary, as in the case of a serious breakdown, but this order can be planned for just as the others and only a slight dislocation caused instead of a major disturbance. It should always be remembered that it costs money to disturb routine and the customer cannot always foot the bill.

In this connection the use of stock or material chasers is often indicated. Perhaps to one man can be delegated the job of seeing that material flows from machine to machine without too much intervening delay. Foremen in job shops are often prone to let work they do not like lie around until they must perforce start on it. In a controlled shop this delay would not happen and work would move smoothly.

Delays become most serious in the assembly department where it will be found that much of the work is ready but held up for want of some piece that has been delayed along the line. Valuable space is taken up for idle work and idle material. The material itself is eating its head off, so to speak, in interest charges and the rate of material turnover is materially decreased, all for want of a part which could have been ready in time if only some one had been in charge of control and had chased it through. Even if you cannot afford the time of one man completely, at least give over part of the time of one man to this work of material-in-process chasing.

Inspection.—Inspection in this type of shop cannot be an elaborate affair. It will usually suffice to have one or a few inspectors checking up the work as it is finished, rather than having roving inspectors checking up each operation. Workmen should have the responsibility placed on them of having the work turned out to specification and blueprint without an inspector at their elbows. Probably in most shops the chief part of the inspector's work is that of checking the functioning of the completed product to see if it conforms with the order.

Salvaging is an important division of such inspection. Where only a few pieces are made at a time, the replacement of a defective piece by a sound one may take far too long a time and delay the execution and completion of the order. It is wise, therefore, to consider how such a defect can be repaired and the piece salvaged and so expedite matters. The use of the oxy-acetylene torch or electric arc welder will be found most valuable in preventing the scrapping of what would otherwise be rejected. Plating to add on thickness is often of value in taking care of pieces that have been machined slightly under size. Even large companies are using the chromium plating process to cut down their scrap losses in this direction.

Incidentally, the use of the welding process is often found valuable in the job shop in building up cheap fixtures out of structural shapes. A welding outfit can usually be made to pay in the small shop for the emergency job.

Problems

1. (a) Discuss the difference between job shop and mass production shop as regards placement of the machines. (b) Discuss the difference as regards the functioning of the foremen.
2. How is inspection controlled in a job shop?
3. What is the policy of fitting work in with the idle machines?
4. How would you set about providing work for a number of machines which are expected to be idle?
5. How can you find out when machines are expected to be idle?

CHAPTER 12

THE GANTT CHART IN WORK ROUTING

Understanding Records.—Information for shop use is of little value unless it is recorded, and the matter of records is of great moment. Until recently, information was recorded in tabular or columnar form. That is to say, the figures involved were written down in columns with their appropriate captions alongside. Data of this nature are difficult to grasp quickly, generally, or broadly. One must almost memorize many of the figures to get a clear picture of the meaning. Where many figures are involved, it is almost impossible to get a clear understanding of the trend which, after all, is the most important feature to study. Hence some kind of chart is indicated.

It is easy to chart the relationship of two variables by means of a curve of simple mathematical equation. Where there are three variables, such as the machine, the job, and the time element, then it becomes increasingly difficult, and it is to the credit of Henry L. Gantt[1] that he devised such a chart which is of inestimable benefit to the understanding of production or similar records.

The Gantt charts have been developed in practical use since 1918. They give comparisons between performance and promises. They aid in making plans, and are highly effective in putting the plans into successful operation. They emphasize the time element which has been found so vitally important in today's work, and help materially in cutting down idle time by bringing this phase forcibly before the executive's attention. They aid in increasing material turnover. They show how the

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[1] *The Gantt Chart,* by Wallace Clark, The Ronald Press Co.

work of individual employees compares with a standard of performance, and emphasize any reason of failure. They aid in increasing production and in reducing inventory. They are just as much tools of production as are the machine tools, and should be used just as fully.

In the Gantt chart, a division of space represents both an amount of time and an amount of work to be done in that time. Lines drawn horizontally through that space show the relation of the amount of work done to the amount scheduled. Equal divisions of space on a single horizontal line represent at the same time: equal division of time—varying amount of work scheduled—varying amount of work done. These three variables are taken care of by changing the widths of the line.

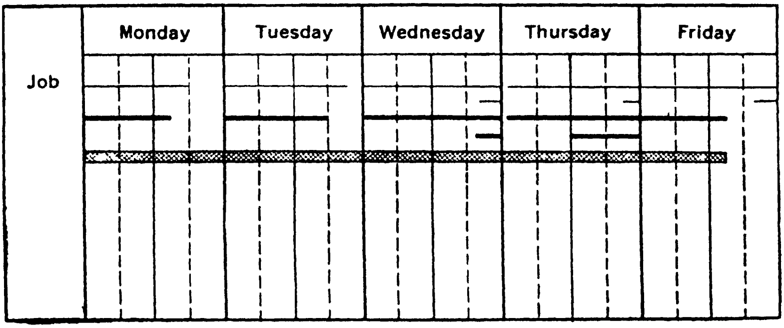


Figure 19. A Gantt Chart

Let us suppose a week's work is planned thus:

Monday	100 units
Tuesday	125 "
Wednesday	150 "
Thursday	150 "
Friday	150 "

These data are plotted on the chart of Figure 19. It will be noticed that the working day is taken as 8 hours long divided into four periods of 2 hours each. The production rate is assumed as 33⅓ pieces per 2 hours. Now suppose the work actually done is respectively 75 units, 100 units, 150 units, 180 units, and finally 75 units on Friday. This accomplishment is represented by a slightly heavier line in each day's space as shown. Finally, the heaviest black line indicates the cumulative week's work.

It will pay to study this chart. Note how clearly the gaps show up indicating the actual idle equipment each day. Note how easy it is to compare the light and the medium lines and get a comparison of planning and accomplishment. In brief, note how inefficiencies show up.

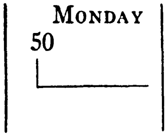
Gantt charts may be drawn on paper of any size or shape. The most satisfactory size, however, is 11 x 17. This size gives ample space for a year's recording under daily spacing and for a two weeks' spread under hourly spacing. Incidentally, this size folded goes into a standard letter file for easy access. For such charts, it will usually be found advisable to buy sheets commercially ready-ruled and marked off in divisions. Paper of such weight and texture can be bought that blueprints can be made from the original chart.

There should always be ample space at the top of the sheet for recording the necessary fundamental data of the work being started. This record should be filled in fully as later on the information will be invaluable when the details are practically forgotten but have to be restudied.

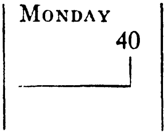
Use of Colored Inks.—Gantt preferred to work with ink of one color or even pencil to make the charts as simple as possible. Others have introduced variations in his original thought by using different colored inks to represent different factors.

In addition, Gantt introduced several symbols to make the work of reading the charts more easily understandable. The columns on the left side of the chart always describe the detail of the work to be charted on the various lines. The date or hour on which work is to begin is indicated by a right angle thus └ ; the time when completed ┘. The line connecting the two indicates the total time scheduled └──────┘.

The amount of work scheduled for any period of time is shown by the number in the upper left corner, thus:



The amount of work done up to any specified period of time is indicated by the number in the right-hand corner.



Other symbols to be placed on the lines or in the gaps show the reasons for what is happening:

$R =$ Is machine ready to run?
$O =$ Is there an order for the machine?
$M =$ Is material ready?
$T =$ Are there tools?
$P =$ Is power available?
$H =$ Is there an operator for machine?

Reasons for idleness are specifically:

$E =$ Waiting for set-up
$H =$ Lack of help
$R =$ Repairs called for
$V =$ Vacation

Other symbols may be added at the discretion of the charter.

The working out in detail of some charts will clear up the idea and firmly fix its value in mind. Note again that in Gantt charts no lines cross each other and that emphasis is obtained by varying the widths of lines.

Uses for Gantt Charts.—There are three classes of production work for both mass production shops and job shops that Gantt charts can be used for profitably:

1. Man and machine record charts
2. Layout and load charts
3. Progress charts

Sometimes it is advisable to have both a man and a machine record chart. The chart provides a mechanism to show the variation between what is done and what could be done by a man or a machine. The gap between actual and possible accomplishment is idleness or neglect to make full use of time or due perhaps to some breakdown or other unavoidable delay. Such a chart will aid in keeping machines busy up to their maximum capacity.

The Layout Chart is Gantt's idea to plan work ahead so as to avoid idleness of man or equipment and to get work done in order of its importance. This chart shows the amount of work in hours or days ahead of a plant or any of its parts.

The Progress Chart shows exactly how work is progressing in relation either to itself or to a plan.

It must not be thought that these charts are confined to the machine shop. They can be used in foundry, forge, heat treatment department, sales department, and in the drafting room. Use will be found for them in almost any sphere of activity.

Let us consider a typical chart in detail, the Machine Record Chart. First the chart should be ruled to show four columns per working day representing 2-hour periods in an 8-hour day, or four 2-hour periods and one 1-hour period for the 9-hour day, or five 2-hour periods for the 10-hour day. Care should be taken that lunch hours and vacation days are accounted for. A column should be reserved on the left-hand side for noting the particular machine being studied. Opposite this notation the planning or routing department notes whether or not the machine has been running by drawing a light line across the space to indicate how many hours the machine has run. The line can be continued to show what planned time is ahead of the machine. Gaps in the line indicate idle time that happened or was planned for. A symbol can be placed in the gap to show the reason for the delay. Under the light line is placed a heavy line to indicate the cumulative running time for the whole week. The length of this line equals the sum of the light lines for the various days. The ratio of this heavy line to the length of the week shows the percentage of time the machine has been busy and, more important, the length of time it has been idle.

By charting the various machines in the shop, a glance at the heavy lines will show immediately what machines have been carrying the load, what machines are holding up production, what machines are idle too long, and, in addition, work for the future can be planned in a more balanced manner.

Similar charts, as stated before, can be made out for foundry machines, forging machines, and, by considering a conveyor as a machine or a system of machines, work can be charted for it.

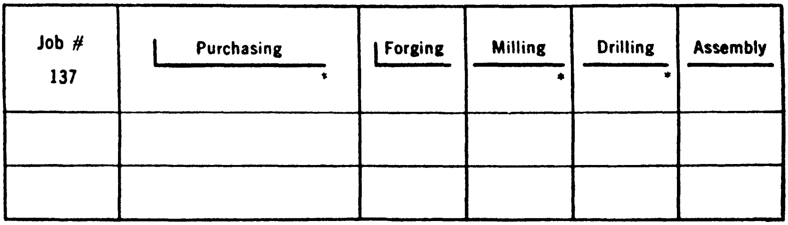


Figure 20. Gantt Chart Used in Tracing Work

One of the important uses of these charts is that they can be discussed in conferences and steps taken to improve the records.

The Gantt chart also lends itself as a tool to the job chaser in the shops. Certain stations can be marked out as shown in Figure 20, and the chaser can be on the look-out for any deviations in time at these stations.

For example, in the planned chart as shown in Figure 20, the chaser on this order number can visit the department somewhat before the time stated and see if the job is moving through on time. If not, special efforts, such as working overtime or putting on an extra man, can be put in force to keep the job on schedule.

Problem

Make out a Gantt planning chart based on the following data:

Machine tool lathe No. 221: To start work. on Order No. 2317, February 7, 9 A.M., planned time 26 hours; thence Order No. 2321, February 13, 8 A.M., planned time 28 hours; thence Order No. 2323, February 17, 4 P.M., planned time 18 hours.

Actual performances are:

Order No. 2317, started February 7, 8 A.M. Machine out for repairs February 8, 2-4 P.M. Order finished February 11, 5 P.M.

Order No. 2321, held up for lack of materials, started February 13, 1 P.M. During this period machine was out of use one hour, 10 A.M. till 11 A.M. on February 14, for belt repairs. Finished February 17, 1:30 P.M.

Order No. 2323, work started February 17, 3 P.M. Note the machine was being set up and retooled from 1:30 P.M. till 3 P.M. On February 18 operator met with accident necessitating machine being idle till February 19, 8:30 A.M. when new operator started on job. Work finished February 21 at 9 A.M.

Data assumed—8-hour day, 8 A.M. to 11:30 A.M.; thence 12 noon till 4:30 P.M.; Saturdays 8 A.M. till 12 noon; no overtime.

(a) Show scheduled orders in detail. (b) Show cumulative scheduled orders. (c) Show actual accomplishment in detail. (d) Show cumulative accomplishment. (e) What is percentage of accomplished work to scheduled work?

CHAPTER 13

CENTRALIZED VERSUS DECENTRALIZED PLANNING

Giving Responsibility.—In the organization of a number of plants it is generally wise to decentralize responsibility. Each plant manager should have as much responsibility as he can shoulder with a financial tie-up linking him to the whole organization. Such a type of organization is evidenced very strongly and successfully in the General Motors Corporation. For example, in this company the manager of each plant has his financial budget set before him and he is free to exercise his own ideas inside of the money limitations set forth.

He can, for example, buy new models, or institute research, or change production methods in accordance with the findings of his own staff. What he must do to satisfy the parent organization is to regulate his expenditures and arrange his income so that he brings in the desired profit or more.

An individual plant is a collection of departments which may, in a sense, be looked upon as miniature plants and the question arises as to how far decentralization can be carried out in departments without disorganizing the structure.

Generally speaking, each department should shoulder a large share of responsibility and should be given a fairly free rein, but it is true that its work must be tied up to the whole plant by a comprehensive plan.

It is a waste of time and material to have one department proceed ahead of another department without a general plan which will bring about smoothness of flow of materials with only incidental pauses. One foreman may be and will be more efficient than another, but such a man should be toned down in certain respects to meet the time element of other departments whose foremen are not so speedy. It is as wasteful for work to be completed ahead of time, out of schedule, as it is for it to be late.

It is a fault of many managers to give local orders which have a far-reaching effect by disrupting the whole plant routine. Managers will see work which they know is in a hurry lying idle temporarily in a department and will give orders to the foreman in charge to expedite it without thinking of its effect on the other work. Such individual conferences with the foremen, resulting in decisions without reference to the planning department, will result eventually in disorganization. At one automobile company, for instance, the planning department had arranged a schedule for windshields which were urgently needed to complete a certain roadster model. The president of the company going through the plant saw one of the windshields practically completed and did not like it. He instructed the foreman in charge to stop work on it and intended to tell the planning department of his action. Stress of other duties caused him to forget this, and the halt was not discovered until a serious delay had occurred.

Work that had gone so far should have been allowed to proceed. Management mechanism should have been in existence whereby the design would have been checked up at an early stage and full approval given at this time. The president should not have halted an individual foreman; he should have called up the planning department. Many instances of this kind led to the eventual disruption of the company with serious loss.

Decentralization Indicated.—In very large plants a measure of decentralization is advisable. Representatives of a central planning department can be stationed in each department, and it is the function of these men to put the work through their department with dispatch and economy and in reference to the general plan. In the case of local trouble or delay, this departmental unit should call up the central headquarters and keep them in touch with all deviations from the original plan. In certain cases the original plan can be modified but only at the desire or power of the central authority.

In medium-sized and smaller plants, a centralized system is vitally necessary. The planning or routing staff will see that material is routed through each department in a most economical manner. A follow-up should be maintained in each department so that the general plan is followed out. Such a system will put the plan into effect and still give each department a measure of self-initiative.

However, the system to be employed depends largely on individual circumstances. The important point is that there must be a central planning authority of some kind.

Note also in this work, again, that in small institutions the planning may be done by the part-time services of one man, or the departmental assistant may give part-time service to this work.

Some plants have the engineering department act as planner and when the bill of material is obtained it acts as routers or planners for each item.

Other plants rely on their inspection force to do the routing. As the orders come through the inspection department after each operation, they are routed to the next in accordance with the master instruction sheet.

Still other plants combine time study or rate setting with the planning position and often set up a clerical force for the two classes of work.

Functions of Planning.—A centralized planning department should function as follows:

(a) Receives copies of each sales order and analyzes it to see if the factory can accept it according to specification and price.

(b) Sees whether all information necessary is given to manufacture the order promptly. If not, the sales department is asked for additional information.

(c) Reserves or requisitions from purchasing department the amount of material required for the order. Schedules the delivery time for such material.

(d) Plans the operations necessary for the work and the exact sequence necessary to bring such parts together at the same time at assembly points. In some cases work is assigned directly to a particular machine or even a particular workman.

(e) Controls the jobs each machine or workman works on by issuing directions from the department.

(f) Issues orders which if followed by the plant will provide materials, tools, and equipment when, where, and how needed by the factory.

The law of this function is:[1]

"The highest efficiency in the utilization of materials is obtained by providing the required quantity of the required quality and condition at the required time and place."

Surely this law can only be met by having a centralized unit perhaps acting by itself but possibly coordinating with subsidiary departmental units. If each foreman is a law to himself then this law must suffer as the required time will certainly never be adhered to.

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[1] *Laws of Management Applied to Manufacturing,* by L. P. Alford, The Ronald Press Co., p. 143.

CHAPTER 14

COMPANY POLICIES

Value of Set Policies.—Firms must have policies expressed or unexpressed to guide them just as a compass and log are necessary to the navigator. Sometimes the unexpressed policies are just as important and effective as the unwritten laws. It is wise, however, to formulate all policies in a code for instruction of all concerned. Incidentally, "all concerned" should include not only the executives but in many cases most of the rank and file.

Delivery promises offer a simple illustration. Should a firm take the attitude that delivery promises may be made casually to be broken at will, then that firm will earn an unenviable reputation. Delivery promises should be made only by the sales department in cooperation with the routing or planning department and, once such promises have been made, they should be held sacred.

The planning department should see that all promises made even by the cub salesmen are kept to the spirit of the promise as closely as possible. This idea may seem difficult to some who believe that the sales department should function in complete independence of the factory. A salesman may be sent out from his factory on an extended trip, but there is no reason why he should be out of touch with it. If a salesman finds he cannot give a promise, due possibly to lack of all the data, then he should get in touch with his factory and have the planning department prepare an estimate of time. Again, planning departments should budget well ahead by Gantt charts, or otherwise, and keep the sales department well instructed as to what deliveries can be expected.

A policy such as outlined above will create goodwill for the company, a valuable asset.

Quality Policy.—A rather typical example of what is too often unwritten policy lies in the formulation of quality standards. One of the most pathetic cases in industry is where the sales department preaches by advertisement and other literature the gospel of quality only to have the production department tear the structure down by giving inferior workmanship, material, or design.

Such was the case with a well-known concern a few years ago. Advertisements reiterated the fact that quality standards ruled in the establishment. Workmanship was quoted as being of exceedingly close accuracy. Design and materials were advertised in superlative phrases. The facts contradicted the claims. Design had been stinted to meet prices. One particular subassembly had been cut down in size till the factor of safety was almost negligible. Material in important parts which should have been high-grade chrome nickel steel was made of inferior alloy. In order to meet the demands of production, inspectors were passing products nowhere near the limits prescribed.

The results were that the using public rapidly became aware of these defects in the product and shunned it. The situation grew so serious that an imperative need for an actual living up to the policy of quality was manifested and radical steps were taken to cure this situation. Today the company enjoys an enviable reputation for the quality of its product but the cost of learning the lesson was terrific.

The planning department can assist greatly in seeing that quality standards are upheld in many ways. If its executives know, as they should, that the spoilage of a particular piece is some 5 per cent, then they should make up orders for 105 pieces for every 100 to be used, and not have the production department in wrath because of insufficient pieces coming through. Further, the mere fact of having pieces come through on time and in sequence is a strong incentive to quality by preventing the production department from pushing inspectors to release material which should never be allowed to go through.

The planning department can assist by making sure that all machine tools are kept up to the best possible maintenance and by having all jigs, tools, and fixtures kept ready and efficient for service.

When a fixture or tool is returned to the tool crib, it should be inspected immediately and all defects rectified. If this work is postponed till a call is in for the fixture, then the resulting delay or inattention may be very serious.

Inspection Policy.—The planning department can insist on having an adequate staff of inspectors properly distributed. Proper time should be made in their studies for the function of inspecting the first piece off a machine tool and no work continued until the release is given on this first piece. Often the provision of an extra inspector may save much scrap and poor material.

In conference the planning department can insist on an employee of adequate skill being taken on. Such an employee will often be found to pay, in the sense that he can do the job in less time and with less spoilage of material. Incidentally, care should be taken to see that the man is not too good for his job. Such a man will rapidly become bored, disheartened, and will quit, leading to labor turnover that will be too expensive.

One of the most difficult situations that arise is brought about by the seeming conflict between the desires of the engineering department for something they deem essential to progress, and the desires of the planning department to keep costs down. Oftentimes a serious disagreement is brought about which can only be solved by the intervention of the general manager. A simple example from the automotive industry will illustrate such a condition.

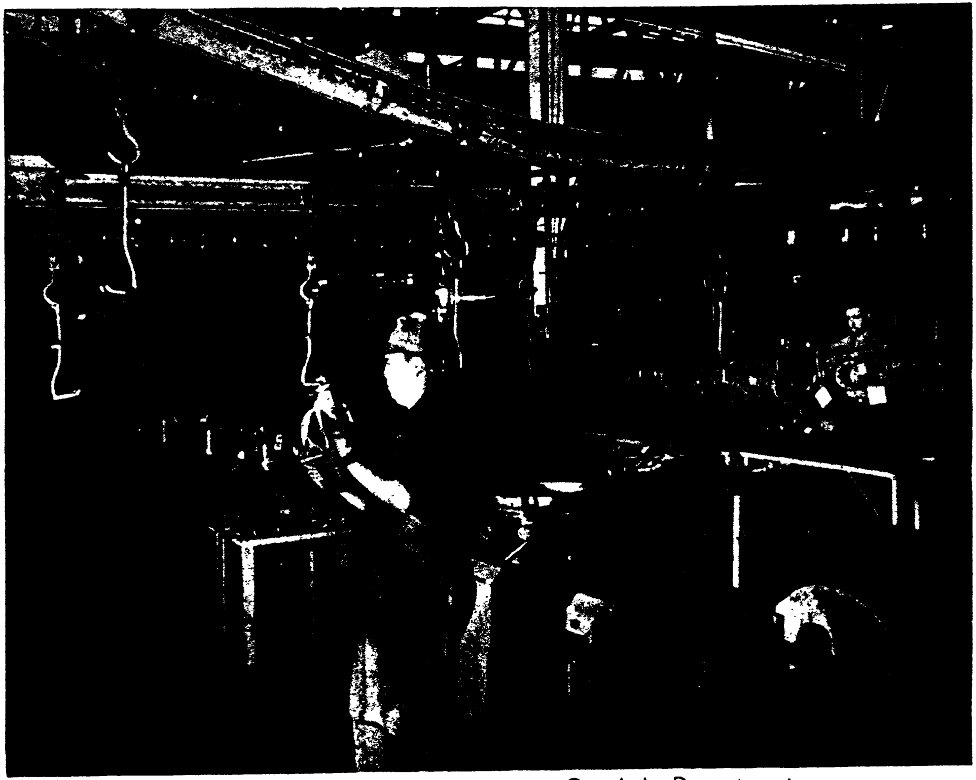

Figure 21. Overhead Conveyor in Car Axle Department

Designing engineers of a particular company began to sense the demands of the public for more efficient and more smooth engine operation. They realized that slight vibrating impulses were set up by the fact that the varying shapes of the cast iron combustion chambers caused varying impulses in each cylinder leading to slight crankshaft torsional vibration. It seemed, therefore, that the machining of the combustion chambers to exact shape and dimensions would bring about smoother operation.

Now, combustion chambers had rarely been machined before, and the planning or production department reasoned that this was an unnecessary cost because no competitor was doing it, and they could not see the advantage. Possibly the designing engineers were poor salesmen of their ideas, but at any rate they stuck to their point, and the planning department stuck to its points. It was an awkward job; they had no suitable machine; it would add cost, and so forth; until finally the general manager stepped in and settled the argument in favor of the designers.

What Manufactured? What Bought?—Policy problems come up strongly in deciding just what should be manufactured and what should be bought already manufactured. A striking instance of varying policies has shown itself in the automotive industry in recent years. At the beginning of the industry firms manufactured practically everything themselves. They had to do this for the industry was too young for anything else. Then arose a subsidiary industry supplying such main units as the engine, axles, and so forth. These subsidiary units became specialists and indeed advertised their wares in national magazines. Their policy of sales brought about a consumers' demand for so and so's engine or axle.

Certain companies, however, adhered to the policy of making everything under one roof and these companies were for a time so successful that their policy was thought to be responsible, and a change in sentiment took place to the disadvantage of the suppliers.

This condition brought about a lack of flexibility due to so much money being tied up in patterns, dies, tools, and fixtures, so that another swing of the pendulum had to take place, and now the largest companies buy freely on the outside in addition to manufacturing.

The governing policy is largely one of cost, where the purchased article is as cheap as, or cheaper than, the article of corresponding quality that can be made. Sometimes patents enter into the situation and it is necessary to go outside for the patented article. Sometimes the question of best use of capital is the governing factor, where capital can be better employed in sales than in manufacturing. Whatever the reasons, very close scrutiny should be given to this situation by conference all around with the purchasing, planning, and production departments.

Special consideration should be given to inventory, as sometimes a policy of purchasing outside leads to far too heavy inventories of fabricated material with accompanying capital tied up which could often be better expended in the direction of increased manufacturing facilities. Inventory is more liquid in the raw material stages than in the fabricated product, and can be controlled that much more easily.

How Completely Should One Manufacture?—Arising out of situations like those outlined above will come policy questions of just how far to go in manufacturing. Should a company making the parts for a main company decide to embark upon the main project?

To quote a specific instance: A company manufactured welded tubing for years supplying it to bedstead manufacturers. First of all, straight length tubing was sold, then a demand for bent shapes and varying sections arose, until the tube producer felt he was doing everything to the bed except

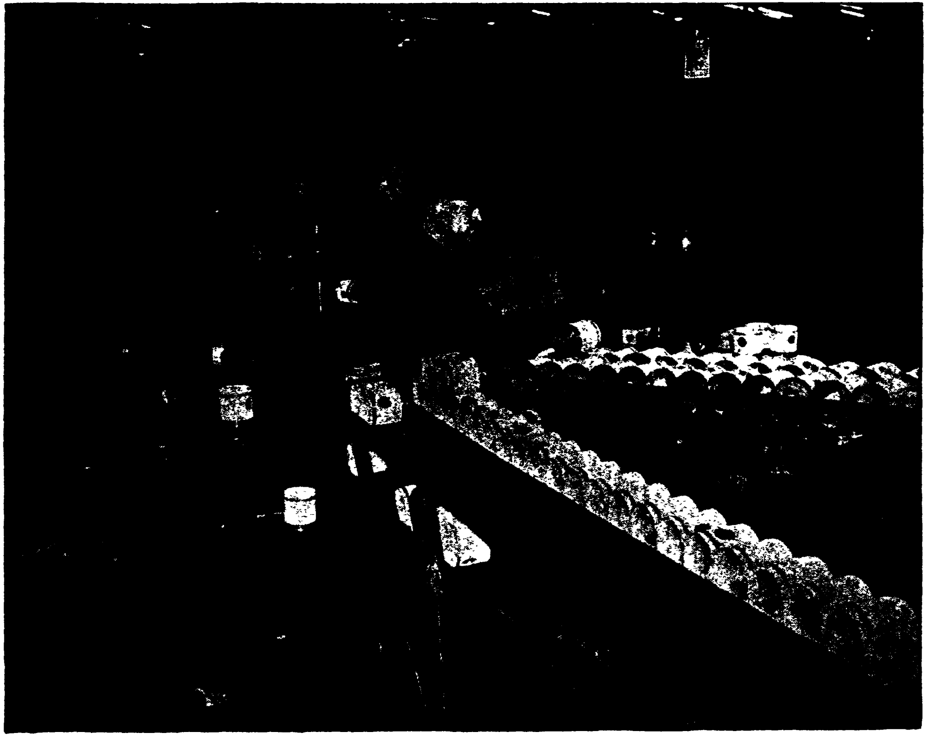

Figure 22. Gravity Conveyors Feed Iron Alloy Pistons to Final Inspectors

assemble it, and naturally the question arose as to whether or not he should enter the bed manufacturing business.

This problem is one primarily for sales and management, as the work of the planning department is simple. It is, therefore, sufficient to point out that a thorough study of the sales situation be made before starting out on what would be a simple manufacturing problem. In fact, there should always be a close cooperation with the sales department and the planning department.

Conversely, the sales department should not extend its lines too much to form an excessive burden on the staff of the planning department or to introduce a line of goods in which there is little or no benefit. A sales department often sees the grass greener in its competitor's yard and wants to sell something it has not yet produced. This tendency should be curbed by the planners, as the modern policy is to manufacture as few products as possible with as high a concentration on the products manufactured as can be obtained.

Current practice in the automotive industry is to manufacture as much of the product as is consistent with plant facilities. However, the producer relies upon responsible outside sources for many specialized parts such as electrical equipment, spark plugs, batteries, wiring, plastics, die castings, tires, instruments, etc., since these can be made most economically by the specialist. Moreover, in many instances, such specialized products are protected by special patents, license rights, etc.

In the case of smaller producers, more items are purchased from the outside since the specialist can make these products at the lowest possible cost owing to mass production methods. Usually such items as transmissions, overdrive units, brakes, clutches, and in the case of small motor truck manufacturers even the engines, are purchased from specialists.

The Ford Motor Company, of all motor car producers, doubtless has the most self-contained manufacturing plant—building its own bodies, producing its own glass, more recently making a good percentage of the tires. In addition, the Ford Motor Company operates its own iron and steel foundries and has one of the finest hot-roll and cold-roll sheet steel mills in the country.

Despite this intense centralization, the Ford Motor Company has a unique system of decentralized village industries. This operation consists of a group of 16 village plants located on water power sites on small streams in the small farming communities within a radius of 50 miles of the Ford River Rouge plant. The small plants manufacture a variety of non-bulky parts for use in Ford, Mercury, and Lincoln cars, give employment to people in rural communities, thus bridging the gap between the farm and the factory.

These plants make such parts as—horns, lamps, carburetors, locks and keys, cigar lighters, taps, drills, ignition coils, soy bean products, copper welding electrodes, etc.

Quoting again as to the underlying laws:[1]

1. "As the scope of an executive's responsibility is narrowed his efficiency increases."
2. "Concentration upon the manufacture of a single or a few types and sizes of products tends to improve the quality and lower the production cost."

Enlarging somewhat on this second law, we might find a seeming variation in some shops which manufacture a complex product. The Ford Motor Company is an example as it manufactures not only every part of its car but many by-products as well. A close analysis of this company reveals, however, that it is a gathering of a number of small shops each making its own specialty. Piston pins are made in a shop of their own quite distinct from the piston shop alongside. In modern mass production industries, specialization such as this is essential to economical smooth operation. Alford says:

"Specialization divides the work into various classes so as to have all of one kind of operation done in one place."

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[1] *Laws of Management Applied to Manufacturing*, pp. 82 and 83.

Problems

1. Discuss the advantage of making delivery promises that mean something. How is cooperation between sales and planning departments brought about?

2. How can the planning department help in maintaining quality standards?

3. How is cooperation brought about between planning and engineering departments?

4. A company owns large clay deposits and sells the clay to companies manufacturing porcelain ware. Discuss the analysis that must be made if they are considering making ware themselves.

CHAPTER 15

QUALITY CONTROL

Methods Used.—In recent years the demand for better quality has brought about a veritable revolution in quality control methods used in all industries. This is particularly true of mass production industries as exemplified by the automotive industry where the entire flow of process and assembly depends upon interchangeability of mating parts and where selective fits no longer are tolerated.

More recently, applied statistical methods in quality control have gained some prominence and merit the attention of everyone concerned with plant management and job routing. These methods are of particular value in highly repetitive operations where suitable sampling methods may be employed to reduce the amount of inspection without depreciating the level of quality. Such methods are, in fact, indispensable in the inspection of parts which may be tested only by destructive procedures.

One of the most useful and most economical applications of the statistical method is the use of the "control chart" which can be employed as an analysis of past performance, as a means of predicting the future course of quality, and, what is more important, may be used as a sensitive means of detecting variations from the standard in current production.

A study of the literature will make the engineer familiar with the "tools" that have been developed by the statistician. Some of the largest metal cutting establishments in the United States, for example, Western Electric Company and General Electric Company, have used statistical quality control for many years with signal success. When properly employed, the new method reduces the cost of inspection, reduces the time required for inspection, and exerts a marked influence upon the actual reduction in the cost of manufacture due to scientific methods of analysis.[1]

Practice of Quality Control in Automotive Industry.— A comprehensive survey of quality control practices in the automotive field was published in *Automotive Industries*, October 1, 1940. It directs attention to the close relationship between the actual operation of inspection controls and the nature of the process as well as the available inspection equipment. It is important to observe that in many cases the process itself is self-checking, as for example, the use of electronic controls on welding machines, applications of the Superfinish processes, balancing of pistons and connecting rods, sampling of foundry metal, electroplating, modern heat treating equipment, etc.

It is of interest to examine some of the case studies reported in this survey. Borg & Beck, one of the largest producers of clutches, follows the generally accepted practice of receiving inspection of all purchased material, floor inspection of parts in process, a sampling check of finished parts, and 100 per cent inspection of finished assemblies. Floor inspection serves more as an information bureau on the process than as a production check, since the actual responsibility for quality is vested in the production department and its supervisory staff.

Analysis of the reports reveals the fact that in many plants, the operator of the machine is supplied with suitable gages and is responsible for the quality of his own operation. In fact, in

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[1] The most recent working literature on the subject is as follows:

An Engineer's Manual of Statistical Methods, by Leslie E. Simon, Major, U. S. Army, John Wiley & Sons, Inc. (1941).

A.S.T.M. Manual on the Presentation of Data (1940).

Guide for Quality Control (a), *Control Chart Method of Analyzing Data* (b), American Defense Emergency Standards, issued by the American Standards Association (1941).

Statistical Method from the Viewpoint of Quality Control, by Walter A. Shewhart. The Graduate School, The Department of Agriculture, Washington (1939).

Economic Control of Quality of Manufactured Product, by Walter A. Shewhart, D. Van Nostrand Co. (1931).

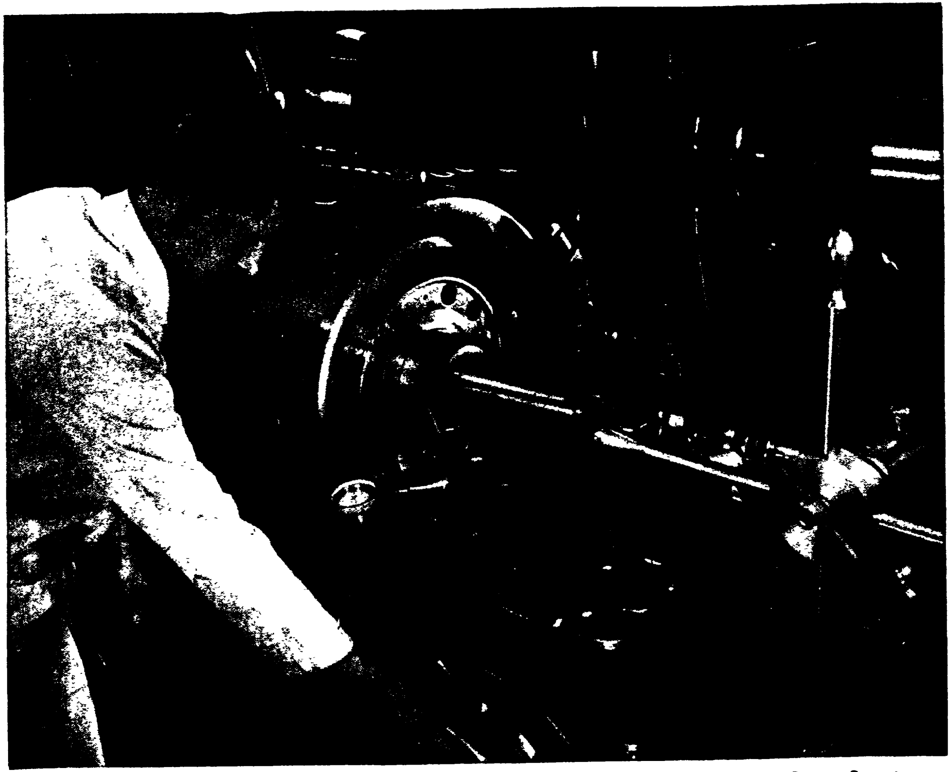


Figure 23. Using Bryant Grinder, Cylinder Bore Is Ground to Minute Specifications

some cases the operator is paid an extra rate for inspection, thus making him a part of the general quality control scheme.

At Buick the inspection department, under the direction of a superintendent, parallels the organization scheme of the production departments in every respect, and works closely with production executives in each department. Basic criterion at Buick is the acceptance of the finished product whether it be a machined part or a complete assembly.

At Chevrolet there is a unique feature—each inspection foreman has a free-lance "check-up" man whose duty is to double-check on the work of the regular inspectors. He is provided with a kit of special gages and instruments, used only by himself, making it possible to check on the condition of the inspection devices used by the inspectors in his department. Another group of free-lance inspectors have a roving commission to make unannounced excursions into the plant and to double-check on the work that has been passed by the regular inspectors.

One of the outstanding developments in the Ford organization is the use of Johansson gage blocks as a production tool in the hands of machine operators. For this purpose, Ford has 235 sets of Joblocks and 491 Johansson internal indicator gages. A recent check shows that Ford has over 38,000 precision gages of every description with at least 6,350 gage applications per car.

Federal-Mogul, one of the principal manufacturers of engine bearings, employs 100 per cent inspection for all finished products, has a floor inspector for each bank of about 30 machines.

In aircraft engine plants, such as Pratt & Whitney, for example, it is current practice to have one inspector for each group of about 10 productive workers. Currently the inspection force consists of about 1,400 men.

Thoroughness of Quality Control.—Generally speaking, quality control is a vital part of the production process and

Figure 24. Inspection and Testing

deserves an important place in all production planning. Quality control goes far beyond the usually accepted notion of passing or rejecting work in process. Quality control starts with the acceptance of all raw materials; provides a check on the initial set-up of every operation. In actual application in the plant, quality control can be employed to expedite work progress, to prevent a breakdown at any point, to reduce rejects to the very minimum.

Proper inspection procedure, unique to each type of production process, is as important as the process itself and can exert an even greater influence upon cost economy. Best current practice shows that inspection must be tied in with the production process at every step, wherever possible making it the responsibility of the production foreman and the machine operator.

This means that job routing may take into account the overall picture of quality control and must accommodate the gages as well as the time for inspection right in the factory routing for each piece.

Statistical control, when properly used, offers an economical means of unifying the entire production process.

CHAPTER 16

SIMULTATION

Definitions.—To E. P. Blanchard, of the Bullard Company of Bridgeport, Conn., goes the credit of having coined the word "simultation" which expresses so much use of the important factors in modern mass production. It is sometimes defined thus: "Performing two or more operations simultaneously and in harmony on one machine with the same amount of labor as for one operation, and thereby leading to greater efficiency is called "simultation."

L. P. Alford, in his *Laws of Management,* states the law as follows: "The minimum overall production time for a group of operations is obtained by the maximum overlapping or simultaneous performance of the several work units."

These definitions are well illustrated by a story about a worker at one of our large automobile shops. This worker was taking nuts from a tote box and securing them down on a lever, doing all this work with his right arm. He was very busy and we would say unhesitatingly that the man was a hard worker. But his boss thought otherwise when he asked the man what he was doing with his left hand. And so an extra tote box was furnished and an extra vise and soon the man was working right hand, left hand, simultaneously and in harmony and practically doubling his output.

Along comes the boss for the second time and asks what he is doing about his feet, whereupon a treadle device leading to a finger arm carrying the nuts to the lever was rigged up and the man now went right foot, right hand, left foot, left hand, working very fast and almost quadrupling his first

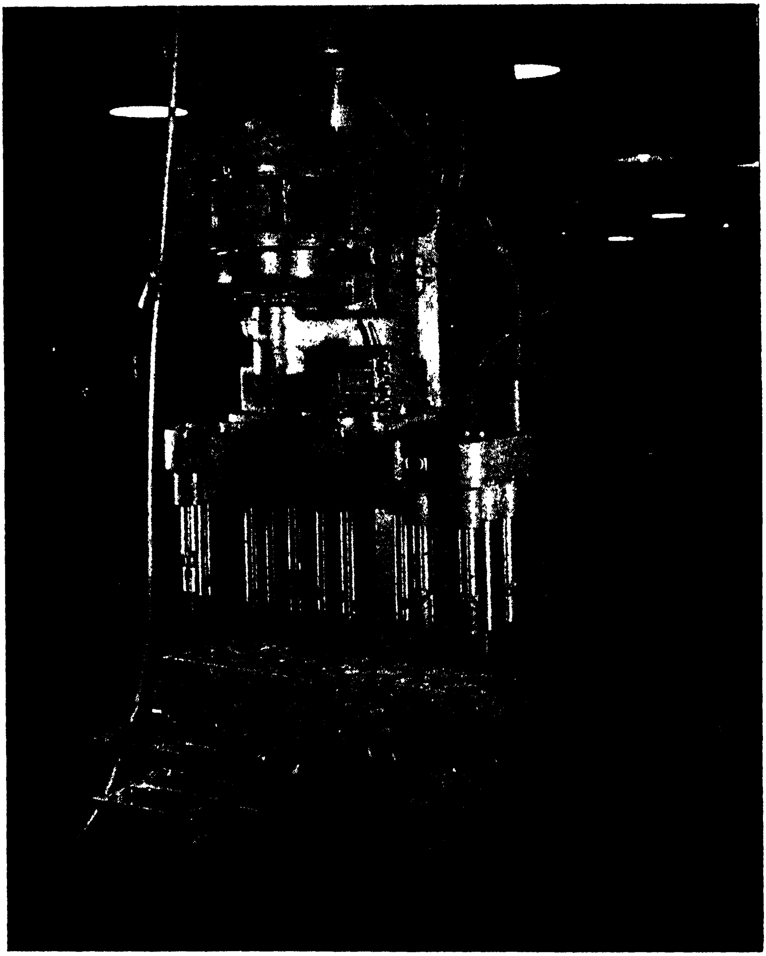


Figure 25. Multi-Spindle Drill

output. The story which is true up to this point serves excellently to illustrate the principle of simultation.

The Principle of Simultation.—Take the case of the simple flange. If we intend to make only one or two of such flanges, we mark out the position of the holes, centerpunch them, and proceed to drill. During the marking out operation the machine is idle, during the drilling operation the man is idle. In other words, we have not the principle of simultation satisfied; to get full satisfaction we should have man and machine working simultaneously.

If we have more flanges to make, we proceed to make a fixture to hold them and as a rule we make one fixture and consider we have satisfied the claims of interchangeability and accuracy and quality by that means. We have, but we have not satisfied the principle of simultation and do not until we have two fixtures. These two fixtures should be arranged on a drill plate and indexed so that when one fixture is being unloaded and loaded the second fixture is being machined. In this way we have man working and machine working simultaneously and in harmony, thereby leading to greater efficiency. Far too many shops stop with one fixture and do not go on to the more efficient use of the two.

Or take the history of the lathe. It started out as a simple piece of machinery in which one tool only was used for the work. During the cutting operations the man is more or less idle, the machine is working. When the man is chucking or centering his work, the man is working and the machine is idle. The first step was to introduce the idea of a second tool at the rear of the saddle and this contributed to greater efficiency—greater output.

Then followed the development of the turret lathe, and finally the invention of the full automatic lathe in which the machine works and the man acts as a feeder to the machine, constantly placing in bars of material, and operating four to

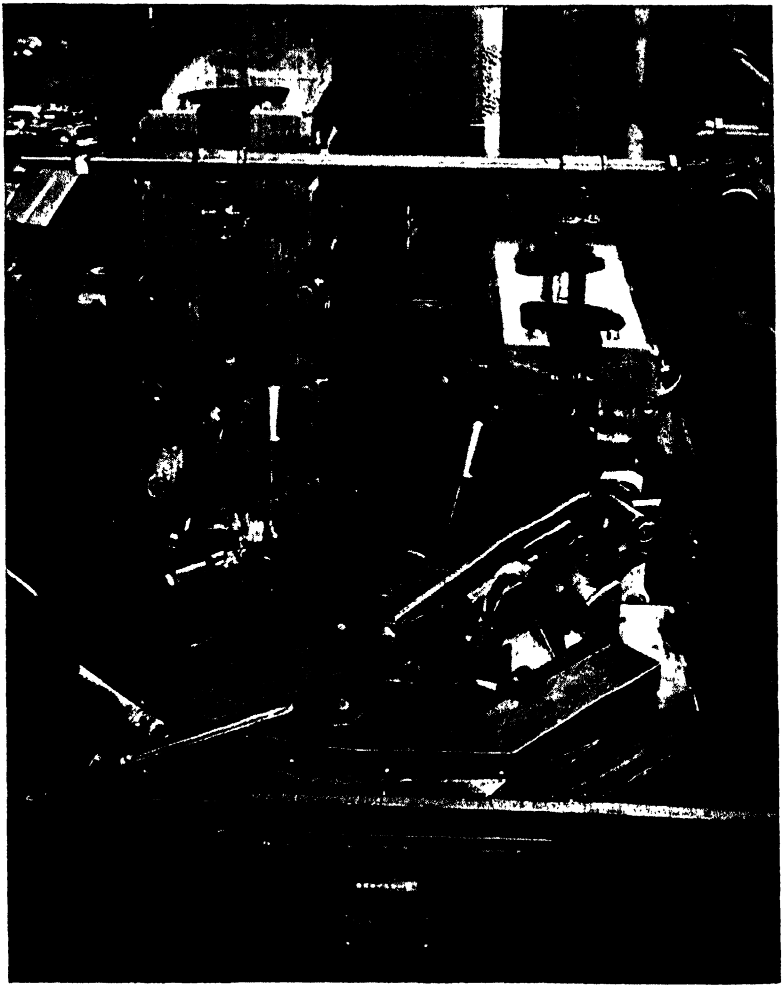
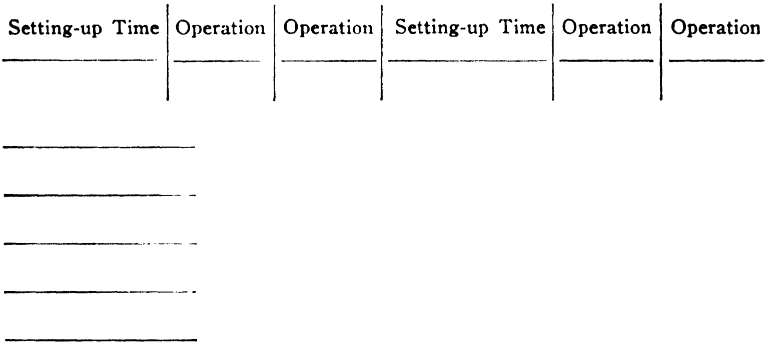


Figure 26. Surface Broaching

six machines at a time. In this case man and machine work simultaneously, thereby contributing to greater efficiency that we are all aware of. Probably the maximum use of the idea of simultation is made in the machine tool that Mr. Blanchard sponsors, "The Bullard Mult-Au-Matic." Here a man stands at a loading station constantly loading and unloading the work; meanwhile the machine revolves to various appointed stations, several in number, and machines the work to its proper dimensions. All this work is done simultaneously and in harmony and great efficiency results.

The idea may be expressed as follows:



In one instance that comes to the writer's attention a particular piece took 118 minutes, comprised of lengthy setting-up process and lengthy machine processes. The whole job was eventually done on a Bullard with an overall time of one minute.

Simultation Principle Applied to Assembly Work.—In assembly work the former idea was to build one product at a time and finish each subassembly addition in sequence, completing each before starting the other. Today in our conveyor systems the aim is to have a number of products worked on simultaneously, with every operation going on also in simultation. Possibly the working of a conveyor system can be understood in its simplest form by considering a rotating table which carries bottles from one operation to another. Operator number 1 loads bottles on the table; operator 2 fills them; operator 3 puts labels on them; operator 4 seals them; and operator 5 takes them from the table and loads them into their delivery crates. Each operation is going on simultaneously with all the others at any given moment and with the pace set by the speed of the table and the number of bottles initially placed upon it.

It will be noted that a good average speed is demanded from each worker; no worker is allowed to go faster than the conveyor dictates. So powerful is this pace-compelling mechanism of the conveyor that the Ford Motor Company long ago abandoned money as an incentive for increased work. Its men are paid a flat day rate of sufficient amount to compensate for the increased energy demanded by the speed of the conveyor.

Compare this process with the older idea of one machine tool working on one product doing the operation in sequence and it will be realized what an enormous economy is effected. Complete use is made of every function of man and machine.

This law, applied within economic limits, governs the design of production and assembly control boards and the scheduling of work on the one hand, and the design of machines which perform simultaneous operations on the other.

Mr. Blanchard states: "A bar of given diameter to be turned in a lathe by the single tool process would mean that one tool must travel the entire length, the production time being T. With a tool slide design that would mount these tools equally spaced along the length of cut, and all operating at the same time, the total accumulated tool time would be the same but the production time would be represented by $\frac{T}{3}$. In this simple case, 3 is the factor of simultation."

In one instance noted by the author, the use of a man and machine unit designed according to the simultation principle was 116 times faster than the older method. Six-spindle lathes operated by one man for each six machines have a produc-

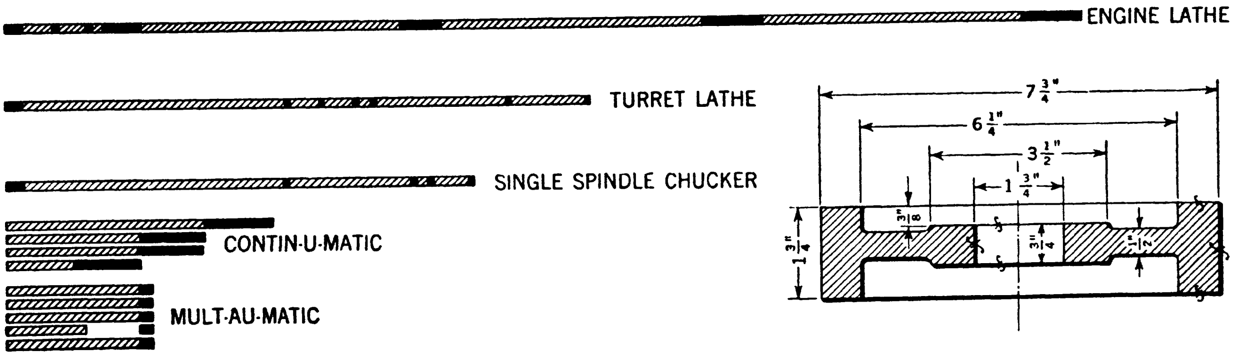


Figure 27. A Comparative Study of Machining Time of a Gear Blank on Various Types of Tools

Figure 28. Bullard Mult-Au-Matic

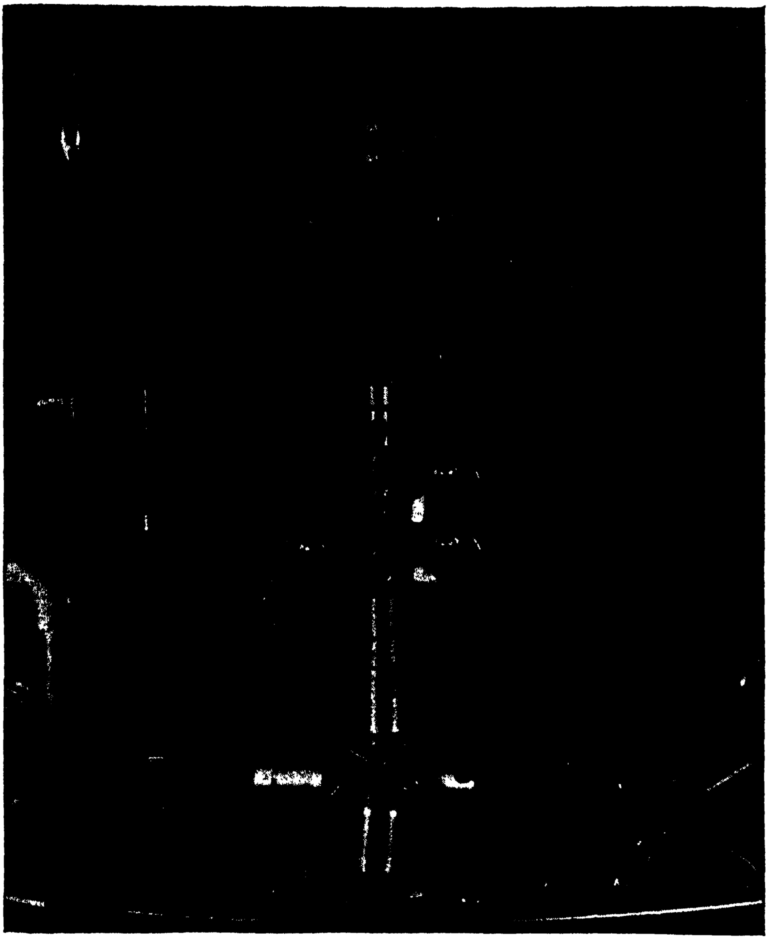


Figure 29. Close-up of Bullard Mult-Au-Matic

tivity or simultation factor of about 36 to 1 when compared with the single-unit lathe operated by one man.

Problems

1. Discuss your understanding of the principle of simultation. Give illustrations from your own experience.

2. With the viewpoint of simultation, compare the operations in two types of foundries. One where one man cuts the sand, fills the flask, withdraws the pattern, and finishes the mold, then closes the flask. The second foundry works on the progressive system wherein one man cuts the sand by machine, a second fills the flask, a third takes out the pattern and finishes the mold, while a fourth closes the flask and prepares it for pouring.

3. Discuss the economies effected by "simultation."

CHAPTER 17

TOOLS, JIGS, AND FIXTURES

Economy of Tools.—The planning and routing departments are vitally interested in the economic factors that enter into tools, jigs, and fixtures. They are, of course, interested in the design but not necessarily in the technical details. Their function is to see that they get the proper outfit of tools and fixtures to do the work economically and speedily.

Generally speaking, a small run of product will allow of only a small amount of money to be spent on fixtures. A medium run will allow of a larger amount being spent. A large run will allow of a very complete "tooling-up" and will warrant the extensive study of the use of fixtures and a large sum being spent on them.

Fixtures may have money spent on them,

(a) To provide interchangeability
(b) To provide lower cost of operation
(c) To give permanency of tenure for product maintenance
(d) To give greater accuracy

Small runs will often warrant a slight expenditure to provide interchangeability and greater accuracy. If the runs tend to repeat themselves during a year or so, then it might be wise to consider a more extended use of fixtures than would normally be the case. Sometimes maintenance standards are a prime consideration, where the part replaced must absolutely fit. In such cases fixtures are distinctly indicated. But the great use of fixtures is to reduce cost, and their economic study will repay the efforts put into it. Broadly speaking, there is a tendency today away from specialized machine tools capable of

Figure 30. Fixtures in Autobody Manufacturing

doing only one job, and toward a more extended use of flexible standardized machines with highly specialized fixtures.

These fixtures should be very carefully thought out and designed.

Number of Fixtures.—As we saw in our study of simultation, there has been in the past too little attention given to the number of fixtures to be provided. A manufacturer was content to provide one fixture and thought he had done all in his power to promote interchangeability and a certain amount of lower cost.

Today several fixtures are often provided, so that, as one fixture is in service on the machine, a second fixture is being unloaded, and cleaned, and reloaded, while the third fixture is "on the standby" in case of breakdown or injury to one of the first two.

Sometimes, instead of the fixtures being separate, they are combined into one mechanism and thus operate as multi-station fixtures. This feature is splendidly worked out in some of our modern tools, where a series of similar fixtures holds the job in position while various tools are presented to the work.

The Human Element.—Fixtures should have a maximum resistance to handling and wear so as to ensure a longer life with lower maintenance cost. Workmen are not delicate in their handling of tools and will often use hammers to lock and unlock.

One fixture that the author remembers had ⅜″ bolts and nuts, and unfortunately for them, the operator used a long-handled wrench instead of the proper ⅜″ wrench. The result was that the threads were stripped and the fixture rendered useless. After this experience nothing less than ⅝″ nuts were accepted on fixtures. Theoretically, correct design should always be given an additional factor of safety to compensate for the human element. Fixtures are thrown around roughly and this abuse should be compensated for.

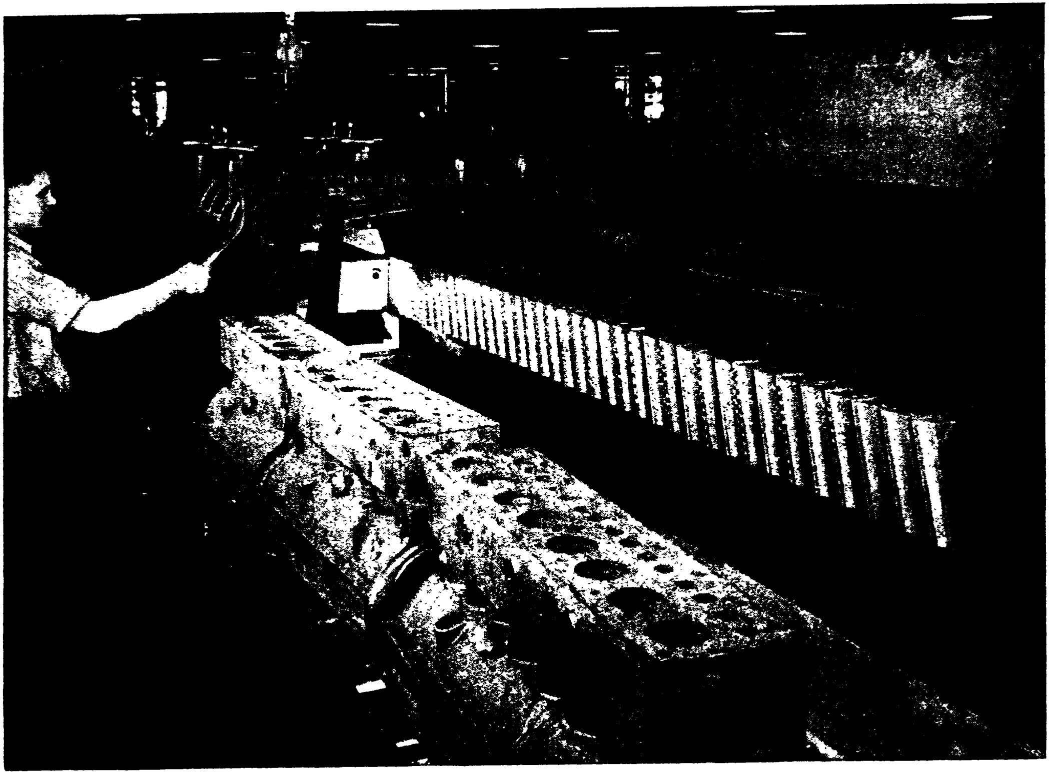


Figure 31. Cincinnati Machine for Surface Broaching Motor Block

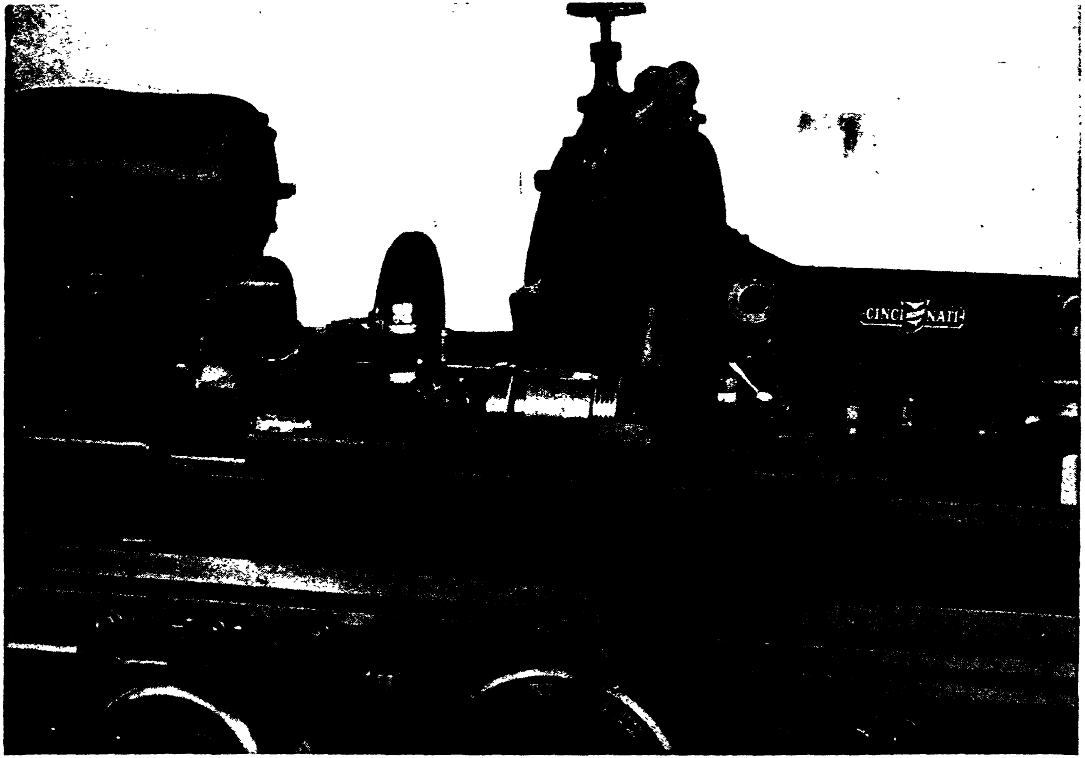


Figure 32. Cincinnati Grinder for Grinding Elliptical Skirts on Aluminum Pistons

Another point to be watched is that the fixtures are often lifted and placed by man power. They should, therefore, be as light as is possible, consistent with the other factors. This feature has led to the use in some places of aluminum fixtures, steel faced.

There should be a measure of standardization in fixtures. One detail that has been worked out well is a standardized system of interchangeable bushings now in commercial use. Other details not in such general practice involve the similar functioning of all levers, bolts, or clamps.

Tool designers are, as a rule, individualistic in their designs. One man, for instance, will tend toward an extended use of eccentric levers for clamping down pieces. All of his work will show this feature and the men in his shop will become accustomed to it and will rapidly learn the operation of successive devices. Another designer, however, will lean toward the use of hinged bolts with wing nuts for clamping down. All his fixtures will be so designed, and the men will become accustomed to them. The mistake should not be made of having differing types of fixtures in one shop as the men will become confused and will lose time in going from one to another.

The tool designer should, of course, be familiar with all these points but it is advisable for the planning engineer to watch out for them too, as they affect the resultant economy of the product.

Similarly, a fixture may be strong enough to do its work but not of sufficient mass to absorb the vibration set up by the working tool, thus making it impossible to take any but the lightest cuts.

It will often pay to design a combination of fixture and conveyor system for care and accuracy in handling. Such a system is often found where the piece is locked up in a cradle fixture and the fixture is mounted on a truck so that it can be moved in sequence past each one of a row of drilling or other

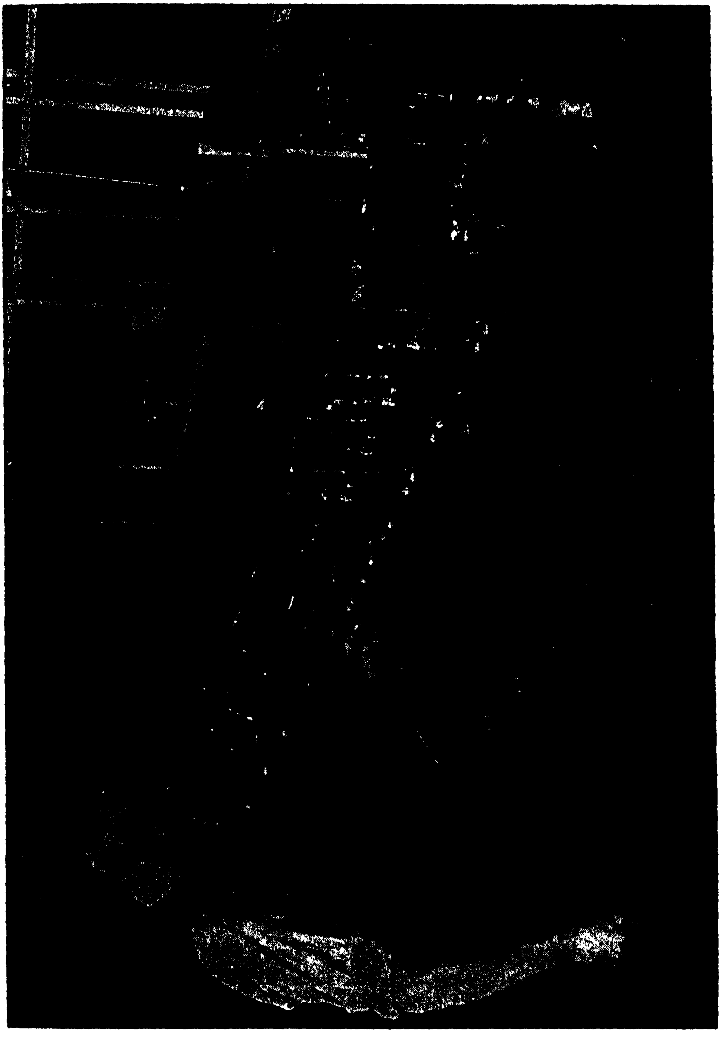


Figure 33. Push Rod Testing Machine (Ford)

machine tools. The truck in this case insures ease of handling and accuracy of placement.

Money to be Appropriated.—As regards the money that can be appropriated for expenditure on tools and fixtures, for any kind of run a careful estimate should be made showing the cost of doing the job without fixtures and the cost of doing it with. The difference will represent the maximum amount of money that can be spent for this purpose.

Taking a specific example, suppose the price at which the job is taken amounts to $10,000. The factory cost of doing the job without fixtures is $8,000. The factory cost of doing the job with fixtures is $6,000. Then it will pay to spend up to something less than $2,000 on fixtures. Sometimes two or more estimates can be made showing how much different methods of tooling-up will amount to so that a comparison can be made. It will be noted that the cooperation of planning department and cost department will be demanded for the making up of such estimates.

Another way that one can regard the problem is to take the simple equation:

$$y = mx + c$$

where y = Total cost
m = Labor cost per piece
x = Number of pieces
c = Cost of fixture

Suppose with a very simple fixture or perhaps without a fixture we get a labor cost per piece of 50 cents, a number of pieces 10,000, and a cost of fixture zero. Also suppose with a fixture cost $300 we get a labor cost of 35 cents per piece and still a number of pieces 10,000.

Taking our equation we get:

y, the cost, equal to $.50 \times 10{,}000 +$ zero
or the cost equal to $5,000

Also we have:

$$y \text{ equal to } .35 \times 10{,}000 + \$300$$
$$\text{equal to } \$3{,}800$$

thus showing that we will get a clear saving of $1,200 by the use of the fixture.

F. E. Darling has contributed a great deal of thought to the problem in his article.[1] He first points out that we have graduated various types of fixtures. For example, we start with the very simplest, which may be a templet. Then we go to the next step, which would be a simple welded steel or cast iron structure. Then we graduate by steps to the final structure of cast aluminum with steel facings. Each of these steps will represent an increase of cost of the fixtures, so that we may express this as a curve (Figure 34). But we make these graduations in order to save labor cost. Our most inexpensive fixtures will have the greatest labor cost, while the most expensive ones will have the least labor cost; thus we get a curve of labor as shown in Figure 35. Combining these two curves we then get the final curve of total costs, which indicates at its

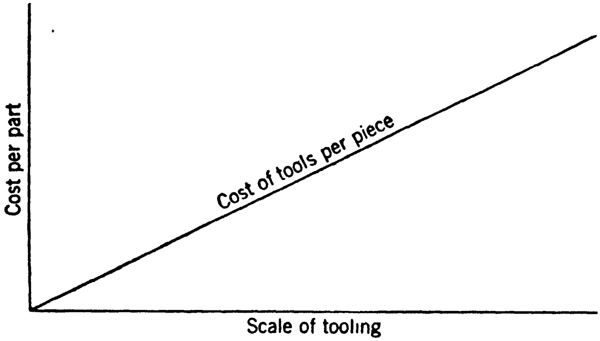


Figure 34. Cost Curve of Tools and Fixtures

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[1] *Transactions of the A. S. T. E.*, March, 1940.

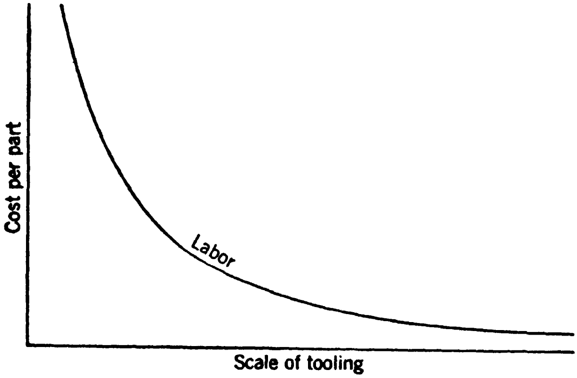

Figure 35. Labor Cost Curve of Tools

lowest point the most economical point to give lowest total costs, as in Figure 36.

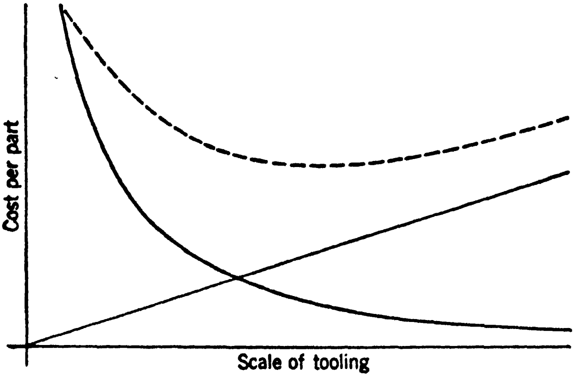

Figure 36. Total Cost Curve of Tools

It may generally be said that for large quantities it pays to have good and fairly expensive fixtures.

Current Machine Tool Practice.—The past ten years have witnessed an amazing evolution of principles governing the design and utilization of production equipment, leading to important changes in machine shop management and job routing.

All of these developments have combined to effect profound improvement in quality, in productivity, and in lower cost levels.

In the first place, it is possible to group machine tools into three broad categories:

1. The universal or general-purpose equipment, generally used in toolrooms, in job lot manufacturing, and in small shops where the volume of production is moderate.
2. The unit type equipment—most widely used in mass production and even in moderate production in the tractor industry, motor truck industry, commercial engine building, and parts production.
3. Special equipment, designed specifically for a unique mass production application.

The universal type is the most familiar since it is found in practically every establishment concerned with metal cutting. With modern design this type of machinery accounts for much of the production of articles of every kind where the quantities of product do not warrant the investment in mass production machinery.

The unit type is characteristic of the machinery now employed in the automotive industry. The particular feature that makes these machines so outstanding in metal working operations is that of flexibility. In general, the machinery in this classification is so designed as to be composed of an assembly of component units such as a standard base, a column, a table, and any number of independently mounted and individually driven heads. This type of machine when fitted with suitable work-holding fixtures, and suitably tooled becomes, in effect, a highly specialized single-purpose machine. But unlike the single-purpose machine it lends itself readily to minor changes in the product or to application for the machining of an entirely different kind of part.

This changeover usually is accomplished by changing the heads, by altering the disposition of heads on the base, etc.;

and by the use of new fixtures and small tools. The important point to note is that in the process of changeover only certain replaceable elements of the machine must be changed so that the major part of the initial investment in the machine can be salvaged. Usually only about 25 per cent of the original cost of the machine is thus affected, although at times, the changeover may affect up to 50 per cent of the cost.

Nevertheless, this degree of flexibility has marked a profound change in mass production industries. For one thing, it justifies a reasonably large initial investment in machine tools since at the outset the machine is in every respect of single-purpose character and, consequently, capable of high productivity at extremely low cost levels. Usually it will pay for itself to a large extent on the first job for which it is tooled. Thereafter, only a relatively small additional investment is required in the same machine to adapt it for an entirely different job.

Another important feature of unit type equipment in mass production is the fact that it expedites progressiveness in product design since the designers no longer fear product changes even during the course of a given model run. Minor changes in the design of the work can be readily accommodated at reasonable cost without having to discard an expensive piece of equipment.

Single-purpose equipment dates back to the beginnings of mass production when there was no other method for handling a large volume of output by an automatic process. Such machines were amply justified by virtue of the tremendous savings in cost that were effected through their use. However, single-purpose machinery has the drawback of inflexibility, making it difficult if not impossible to effect product changes at will.

Nevertheless, the advent of unit type machinery did not entirely supplant the single-purpose machine. The latter still has its economic place in manufacturing and is widely used. Latest developments indicate that much of the early inflexibility of such machines has been overcome by the adoption of methods employed in the design of unit type machines, so that certain single-purpose equipment may be logically classed as being of unit type.

Perhaps one of the most significant accomplishments of machine tool designers has been the development of unit type machinery of high flexibility which lends itself to job-lot production. The latest practice is to select a family of similar parts or of similar kinds of operations on different parts and to route them over the same machine. The variety of product can be handled either by universal types of work-holding fixtures or by quickly interchangeable fixtures, and by the use of quickly interchangeable tooling.

One of the best examples of the procedure is found in the case of surface broaching machines. Generally the surface broaching equipment for mass production is considered to be single purpose in character during a model season due to the expensive tooling and work-holding means. However, the broaching machine designers have developed the so-called utility broach of single-ram type which lends itself to a wide variety of operations simply by suitable changes in broaching tools and work-holding fixtures. This offers unusual economy as compared with conventional methods of milling, grinding, boring, etc., and compares favorably with the costs on a single-purpose broach.

The same principles may be applied to the utilization of drilling machines where it is possible to use a basic heavy-duty single-column drill press fitted with a large variety of interchangeable multiple-spindle heads for drilling, tapping, etc. The same is true of precision-boring machines and many other types of equipment.

In summary, it may be said that the planning department now has at its disposal a variety of types of manufacturing equipment suitable for any given problem. The industrial engineer must familiarize himself with the available products of the machine tool industry and acquire the judgment necessary for the proper selection of those types particularly suited to the problem at hand.

Judgment values comprehend such considerations as—desired productivity, rapidity with which product changes are anticipated, nature of the process, funds available for the purchase of new tools, and amortization practice. It is obvious, for example, that if only a relatively few pieces of a given part are required, it is far more economical to use a general-purpose machine, manned by a skilled operator, than it is to schedule the part over a specialized machine which can probably turn out an entire year's requirements in a matter of hours or days. On the other hand, there are plenty of instances where a specialized machine may be economically utilized even under these circumstances due to the need for a unique means of accomplishing the desired result.

Tool Engineering Department.—With the transfer of emphasis from the product to the process, the tool designing and control departments have become among the most important in the plant. At the beginning of fabrication, when material is at hand and machine tools and men are ready, the fixtures must be ready. Taking an analogy from the first law of material control, the law of routing is as follows: "The highest efficiency in work routing is obtained by providing the required quantity of requisite material together with the proper fixtures and necessary personnel at the required time and place."

The truth of this law is obvious, but study will show that there must be just as much planning to get fixtures on time and at the requisite place as there is for getting the material. In fact, the situation is often more difficult, as the time available for the design of fixtures is usually only that left after the product design has been released and before the material is received. Time, therefore, is an exceedingly important element in planning a tooling-up job.

Planning charts of the Gantt type are, therefore, necessary to carry the work forward step by step, from the drafting room through the toolroom, to the tool crib. This plan though often made up by the proper authority in the toolroom should be outlined in conference with the central planning department to insure proper timing and routing. In this connection it is often advisable to consider tool drafting and toolmaking as one unit department, and many firms recognize this situation by putting one head over both.

If the work is heavy in tool designing, then it will be found advisable to specialize in the work. Cutting tools can be segregated into one group, fixtures for one unit into another, fixtures for a second unit into the third, and so on. In other words, there must be as much specialization in the toolroom as there is in the plant. Above all, there should be kept a unity and standardization of design.

Maintenance of Fixtures.—Some of the work of a tool department lies in the maintenance of fixtures and the bringing of them up to date. There must, therefore, be a system for returning all fixtures at the completion of a run, or of so much time, say a week, for rechecking, revising, or repair. This work means constant reference to drawings or blueprints. For this reason, it is good practice in mass production shops to have tool drawings as completely finished, recorded, and blueprinted as part drawings for production. Some firms even go to the trouble of estimating the expense of each fixture during its working life.

Factory instruction sheets should bear the fixture number and list the cutting tools required. The tool itself or fixture should be numbered legibly to correspond. A fixture must not be regarded as completely equipped unless it has its necessary holding-down clamps or bolts and cutting tools with it. Delay in shops is often occasioned by having the fixture seemingly complete, but requiring the man to search for his own wrench, holding-down bolts, or cutting tools.

The place where the fixtures and tools are located in the plant is commonly called the tool crib. Careful attention should be paid to its, or their, strategical location. One tool crib is usually sufficient for a small or moderately sized shop, but more are necessary as the shop grows and the departments become more complex.

Location of Tool Crib.—In planning out the location of machine tools, the tool crib should be considered as one of the tools and a proper degree of space allotted to it in such a situation that backtracking is eliminated and short distances and central location assured. Tool cribs located disadvantageously will lead to delays and lack of economy in operation.

The system used for checking out the tools should be simple, one that the workmen can understand. It should be such that the location of every tool, jig, fixture, or other tool device, such as gage, will be known immediately. The amount of tools in any one workman's possession should also be known so that if the man quits for any reason his equipment can be checked instantly.

The cribs can be under the charge of the tool head but the planning department can check on the service being given. Sometimes arrangements are made to have all micrometer gages, and all very accurate tools, jigs, and fixtures returned in the evening for checking purposes. Provision must then be made that these devices are ready and available for work at its start in the morning.

Problems

1. Discuss the law of simultation and its application to tools, jigs, and fixtures.
2. How does the human element affect the design of jigs?
3. How does it affect their economical operation?
4. Work out a mathematical formula for the amount to be allowed in "tooling-up" a job.

5. A production design is released and fixtures are started through design and construction. At what points would you trace up the progress of a typical fixture to insure its completion on time?

6. Why should there be one head over the tool department? Discuss this from its value to the central planning department.

7. Discuss the law of work routing and planning.

8. Discuss the value of having tool cribs centrally located and at strategic points.

CHAPTER 18

PLANNING FROM THE SALES CURVE

The Sales Curve.—Sales curves are intensely interesting to the planning department. They visualize the production of the past and estimate that of the future. They are the basis for future planning to meet the results that the sales department wants, which will cause profit for the company.

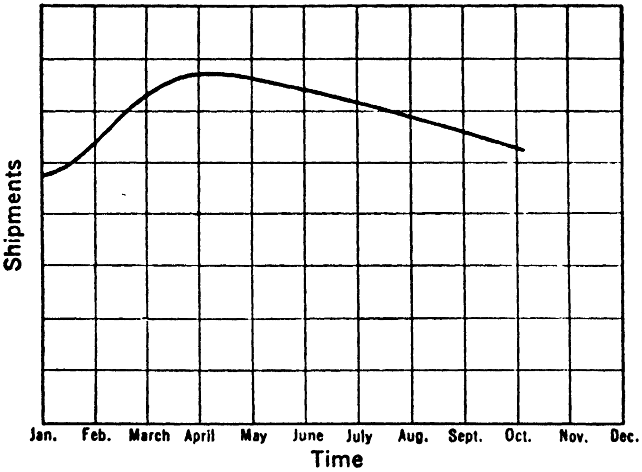

Figure 37. A Sales Curve

Glancing at a sales curve such as shown in Figure 37, it is difficult at first to realize that the smooth, vertical ordinates are really an integration or summation of small individual orders which total up to the length of the ordinate. If as an illustration we could place a typical ordinate under an analytical business microscope, we would find it something like Figure 38. If we used a higher power microscope, we would find that each of the state divisions would be broken up into small individual orders.

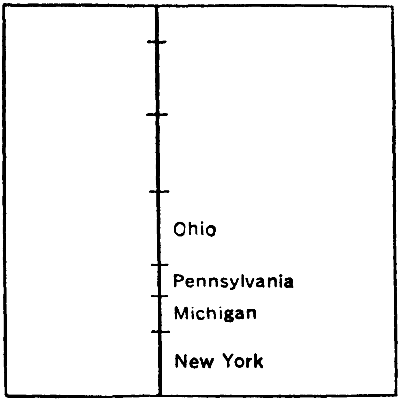

Figure 38. Analysis of an Ordinate of a Sales Curve

Building Up the Sales Curve.—This suggests how the sales curve is built up for the future, a knowledge that is necessary for the planning engineer. The first sales curve is a summation, month by month, of the orders on hand, as shown in Figure 39.

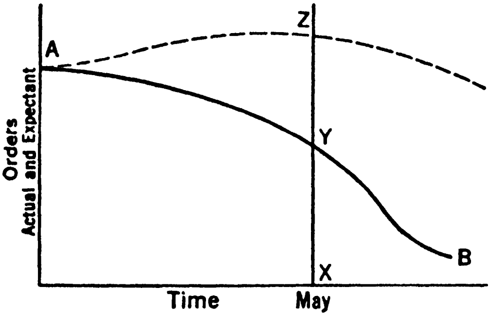

Figure 39. Monthly Sales Curve

The full line *AB* represents orders. The ordinate *XY* of this curve represents the actual orders received for forward delivery in May. The line *YZ* is built up from estimates received from distributors, jobbers, or other agents of the distribution channels, of orders that can be expected during the month of May. The full ordinate XZ is, therefore, the representation of the expected business to be done in May. This ordinate XZ can then be weighted (i.e., lengthened or shortened) to conform to business trends that may be studied, or to take advantage of the results of a proposed advertising or selling campaign, or some other factor that will affect orders.

Such curves can be built up six months or more ahead, depending on the nature of the business and the length of time it takes to make the product from the initial purchase of the raw material.

Some firms in making up these curves go into elaborate detail, receiving reports from their distributors and dealers, estimating the effects of business, estimating the effects of campaigns, or estimating the effect of local conditions as affecting a specific quota.

The first question that arises in studying the sales curve is one of policy. Shall manufacture be directly to the sales line, or shall it be on a norm or average straight line through the sales curve?

Seasonal Sales.—If the sales curve is highly seasonal, the problem is difficult to solve, because in lesser volume months, if manufacture is in accordance with sales volume, the equipment will be operating to a much smaller degree than when working to the peak of the curve. Fortunately, time of working hours is somewhat flexible, and it is possible to work one workday shift when slack and two workday shifts when busy with a certain amount of overtime in the other portion of the curve. By doing this, shop facilities can remain unchanged, the only change being in the number of employees. This plan also keeps inventory of finished goods at a minimum, which is highly desirable.

The only danger point to be considered in following this policy is labor turnover expenses. Men rarely like to work in plants which are constantly varying the size of their working forces by laying off and firing.

The other policy, of manufacturing to the norm, brings about a smoother manufacturing condition where an even number of men are employed. The machines are kept running at constant capacity, planning troubles are lessened greatly, but inventory of stored completed products (which are to be called for during peak times) is heavy during slack periods.

Sometimes a compromise policy is worked when a limited number of articles are manufactured to stock and some overtime or double shift resorted to during peak seasons to take care of the load.

It is difficult, if not impossible, to lay down a plan for a general set of circumstances. Only a consideration of a specific case will yield a solution of the problem. Some plants may not have the labor supply available to draw from in peak times, and hence must work their material into stock. Again, local sentiment in some places is against overtime or night-shift work and these facilities can only be resorted to as a last effort. The labor variables are too great to allow of general mathematical analysis.

Reasoning Back.—Let us return to the sales curve and consider one of the future ordinates, and, with the cooperation of the time study engineer, work back the events which lead up to the anticipated sales ordinate.

Consider a specific single product which has to meet a certain shipment demand at some future date, say September. The time study man estimates that it will take three weeks to assemble this part, five weeks to fabricate it, and seven weeks between the purchase order being placed and the raw material received.

Plot this time back in a sort of reversed Gantt chart arrangement and it will be found that, in order to meet the demands of sales, purchasing must be initiated fifteen weeks ahead of the beginning of shipments, fabrication eight weeks ahead, and assembly three weeks ahead. Such a chart then becomes the basis of planning (see Figure 40).

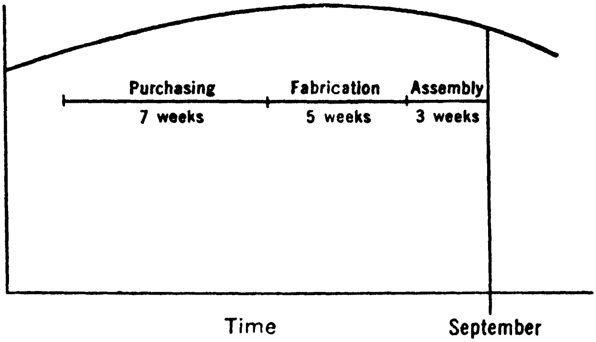

Figure 40. Time Estimates Preceding Shipment

This horizontal ordinate can be split up as much as desired and in accordance with the detailed data on hand. For example, the fabrication section can be split up into the actual details machine by machine, and assembly can be split up into the various bench operations, or conveyor stations. This chart becomes, therefore, of valuable aid to the stock or material chaser and will work in splendidly with the Gantt progress chart.

Purchasing from the Sales Curve.—Purchasing can be arranged for definitely to meet demands. Fabrication and assembly can be started at exactly the right moments. Inventory can be kept low. All of these steps will bring resultant economies in the total manufacturing operation.

There remains one question: Suppose something unforeseen happens. Perhaps business conditions will fall off, causing reduced consumer demand. Perhaps an error has crept in on the first estimate. The point is that the sales curve must not be regarded as something fixed and immutable to be made up in December for the following year. Instead, it must be constantly checked and corrected every two or four weeks to conform to changing conditions. The arcs of many curves, showing by differing colors changing conditions with the actual sales curve in heavy black, will be a valuable guide to the planning engineers who use this as their chart. The process of keeping the chart changed and corrected is analogous to that involved in making changes in blueprints to keep them up to date.

Stock Chasing.—After having had these plans and charts completed, the next step will be to put them to use in the hands of the stock-chasing department. Armed with a "tickler file" in which various items are docketed under their proper date, the stock chaser goes his rounds. He sees under date of July 7, for instance, that the purchasing order should be in the hands of the foundry people and that the order should be ready to start. He checks up on this to see if the foundry is "on time." At the expiration of the foundry time he again checks up to insure the work being done on time and if the work has been delayed he insists on overtime or night-shift work to bring it back to schedule. So he goes from department to department constantly checking, constantly seeking to have the work kept "on time."

He knows that if there be any delay in work, this will be reflected in the inability to proceed on schedule. Such work is of great value in maintaining shipping dates and in keeping orderly material movements throughout the plant.

Problems

1. Plot an anticipated sales curve from the following data:

Orders on hand in units of product:

	January	February	March	April	May
Ohio	200	180	150	80	30
New York	300	200	140	70	40
Pennsylvania	250	190	100	65	20
Other States	1,000	850	600	450	200

Additional orders expected by distributors in these territories:

Ohio	15	95	100	200	220
New York	35	60	150	210	280
Pennsylvania	40	85	130	190	230
Other States	150	480	580	875	1,100

2. Taking the May ordinate on this curve and assuming assembly takes one week, fabrication takes three weeks, and obtaining material takes seven weeks, for one specific product, find the date when the purchasing agent must initiate the purchase of raw material.

3. Discuss the value of the horizontal ordinate in 2 as a means of controlling inventory, keeping promises, and obtaining maximum production.

4. Detail how the sales curve is changed to show changing conditions and also sketch out a series of curves (arbitrary) showing:

Last year's sales
The business trend
Orders on hand at a specific date
Additional orders expected
Corrected sales curve made three weeks after inception

Use different-colored inks if possible.

CHAPTER 19

MATERIAL HANDLING

There are several laws giving mathematical equations and formulas for providing for economy in labor-saving, material-handling equipment. These laws were developed for and adopted by the Materials Handling Division of the American Society of Mechanical Engineers. They are fully detailed by Alford in *Laws of Management.*[1]

One law that should be restated here is as follows: "Quickening material turnover reduces the expense of material control." No agency is better fitted to increase material turnover than some kind of mechanical material-handling device. Formerly, the time of a job in between machines was of little importance. Today it is vital and our mass production industries have installed the most elaborate mechanisms particularly of the pace-compelling type for handling material between processing operations. These devices pay, and the planning engineer should have an intimate knowledge of their workings and possibilities.

Progressing Material.—Alford states another law on the subject which should also be studied. "The greatest economy in progressing materials through a manufacturing plant is secured when the materials move a minimum distance in passing from operation to operation."

Perhaps this law would have been better expressed if it had read, "Move in minimum time," because distance in handling is of little importance in machine handling provided the work be done expeditiously.

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[1] *Laws of Management Applied to Manufacturing,* p. 232.

Dexter S. Kimball in discussing this law[2] under the heading, "Plant Planning Flow," states: "It will be obvious that greatest economy in transporting the material through the plant will result when the several departments and buildings are so managed with reference to each other that the material shall be moved along with a minimum amount of handling and traveling, and so that the factory shall work smoothly as a whole." Straight-line production is usually the most economical, by which it is meant that production does not backtrack but moves forward from operation to operation in a direct minimum length conducive to a thin, rapidly flowing stream.

The Conveyor as Pace Setter.—In the above statements emphasis is placed on minimum distance and straightness of flow but the author believes that the time element is of most importance and should be more seriously considered. Some elaborately conveyorized plants have many curves in their tracks and long distances to traverse, but the point is that the handling is done in minimum time possible and also with a pace-compelling motive.

The ideal situation is where the man completing the operation lays the piece down in immediate position for the next operation. This ideal is often found in isolated cases but rarely complete in a plant.

Savings resulting from decreased handling and increased inventory turnover are remarkable and have a marked effect on the cost of the product. In one plant manufacturing automobile rims, the plating was completed in several tanks. One tank pickled the rims slightly, a second was an alkaline wash, a third a water wash, and then the plating was proceeded with. Rims were carried through the plating bath on an elaborate conveyor which was timed to give the depth of plating and quality desired. A finish wash was given the rims by this conveyor and the rims taken off the conveyor by man power. Men stood

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[2] *Ibid.*

at the preliminary tanks performing the proper operations but the use of the conveyor in the plating bath was looked upon as the last word. The cost of this process was at the time the lowest ever reached.

Unfortunately for this firm, however, a competitor improved on the process and conveyorized all the tanks with the consequence that one man stood at the beginning of the conveyor hanging the rims on the conveyor hooks. At the end of the process the rims rolled themselves off the hooks and by chutes into the freight car. Only one man controlled a vast production with a further lowering of cost.

Henry Ford, in his *Today and Tomorrow,* writing of his pressroom says: "Eight trimming presses are used. Most of these presses straddle a belt conveyor so that the flashings that are trimmed from the forgings are carried away immediately. Small forgings are allowed to fall into the conveyor. Near where the conveyor makes its exit from the building these forgings are removed and routed into boxes. The conveyor discharges the flashings into a car on the switch outside."

Conveyors Possible in Many Industries.—There is scarcely an industry but what has its own type of conveyors. Foundries for a long time resisted the innovation but now many such are completely equipped with mechanical handling. Even the metal is poured into the flasks as they are moving slowly past the ladle. Old sand is carried on conveyors to be tempered and cut, and the molds are slicked as the conveyor moves them along. It is significant in this work to note that the day of the old molder, who performed all of the operations from cutting the sand to pouring the flask, is going rapidly. By means of the conveyor, one of the laws of management is being realized in this particular industry. This law is: "Subdividing work so that one or a very few manual or mental operations can be assigned to a worker improves the quality and increases the quantity of output."

In the forge shop similar trends are visible. Material is conveyed through the furnaces on special conveyors and thence to the hammers. The forgings in their turn are carried on conveyors to the freight car or storeroom, the flashings are conveyed to the scrap disposal unit.

In non-metal working industries the conveyor is also coming in rapidly as an efficient handler of materials and as a pace setter. In the soap industry, for example, cakes or flakes of soap are carried to automatic packaging machines and to the shipment department. The ceramic industry, one of our most conservative industries, is beginning to feel out where conveyors can be used, and the most progressive plants have adopted them for tunnel kilns and for the conveying of finished ware.

Types of Conveyors.—There are many types of conveyors varying from the simple tote box, which must be regarded as a conveyor, to the most elaborate complex mechanisms. There are main conveyors and subconveyors. Too often conveyors are visualized as the complete, complex type used in the assembly of automobiles. Just as much serious study should be given to the use of subconveyors, as their extended use will yield many savings.

Conveyors may be operated by manual power, by gravity, or by electric power. They may take the forms of belts, chains, buckets, hooks, or motor trucks. In some furnace work reciprocating bars are used as conveyors. In others pusher rods operated by cylinder, piston, and ram, push the work through. There is endless variety of types.

The simplest, of course, is the tote box. This type may take several forms from the simple box containers to the elaborate, specially designed tote box for delicate articles. Any kind may be carried by hand, by skid, or by truck, or may be pushed along a roller structure. Or the tote box may be suspended from hooks and carried along in this way.

As a means to assist transportation, the roller type of conveyor is the simplest. Rollers are mounted on a structure and revolve easily either on plain, roller, or ball bearings. Not only tote boxes but the actual material itself may be propelled manually along these rollers.

Conveyors may move horizontally, inclined, or vertically, or by a combination of all three directions. In the case of the plating installation mentioned above, the hooks on the conveyor lift the object from one tank to another vertically and then travel horizontally. A similar path is followed by the conveyor used in dipping objects to be enameled from one tank to another and thence by incline through the drying ovens. Such conveyors represent complex types.

The conveyor should be designed for the project. Detailed time studies should be made of each operation to determine the speed at which it should travel to secure maximum economy. Gangs or individuals should have their work so laid out that each is taking an average share of work in minimum time.

For example, if it takes one gang 4 minutes to assemble a unit, another gang 5 minutes on another unit, and a third gang 10 minutes on a unit, the space allotted to each gang must be in proportion to the time taken so as to get efficient results without loss of time to the conveyor. At times, operations can be combined to speed up the work, or at other times a further subdivision of work is indicated.

Speeding Up Conveyors.—One important fact must be remembered in connection with the changing of the speed of conveyors in a complex installation. When the Ford Motor Company shortened its assembly line of automobiles and speeded it up, they found they had to speed up correspondingly every contributing line in the whole plant. To enable more engines to be assembled for more chassis, then the engine line had to be speeded up. To enable the engine line to be speeded, then its contributing lines, such as the connecting rod line, had to be speeded. To get the rod line speeded meant more forgings and a speeding up of the forge shop on that particular item.

Problems

1. State and discuss the law of quickening material turnover. Explain how the use of conveyors designed on a time element basis assists in increasing material turnover.

2. Consider the law of economy in progressing materials and discuss the relative effect of straight-line flow, minimum distance between stations, and the time element. Why the importance of the time element?

3. Discuss the use of conveyor and subconveyor in a foundry. Detail the conveyors you would install in a foundry.

4. A conveyor line completes a product every 2 minutes. It moves at a speed of 9 feet per minute. One gang assembles a unit in 3 minutes, another in 4¾ minutes, and a third, the third unit, in 7 minutes. What length of conveyor line should be allotted to each gang, if no overlapping is permissible?

CHAPTER 20

PRODUCTION PERSONNEL

Previous chapters have shown how important it is to have materials, fixtures, tools, and men available in their proper amounts and qualities to promote smooth operation. The question of providing men is one that has many problems, and is one that should be planned for as seriously as for any other factor in the work.

It is true that an idle man is a source of loss. It is just as true that having too few men is also a source of loss, as this situation brings about idleness of equipment. Men must, therefore, be planned for and cooperation is necessary between planning and employment or personnel department to provide the requisite quantity of men—no more and no less.

Generally speaking, the curve of employment will parallel the curve of production, unless rapid changes are being made in equipment to displace men, when the curve of employment will trend down relatively to the curve of production.

Employment and Production.—The employment office should be kept in touch with the rise and fall of the production curve so that those in charge may make their plans accordingly. It is exceedingly difficult to obtain men at a moment's notice and ample time should be given so that scouts may have the men available when and as wanted.

If the production curve is differentiated into departments, then the employment office can take steps to transfer men from a slack department to one that is busy. This procedure is much better than laying off men in one part of the plant and hiring new men for another.

It can be seen, therefore, that good planning can play a direct part in promoting the morale of the plant, and indeed, in many other respects, good planning gives the men a wholesome respect for the plant which goes a long way toward setting up a good morale.

One of the problems that bother the planning department is that of the delays caused by tardiness, unforeseen absences, and accidents. All such delays on the part of the men mean delays on the part of the equipment, and it would appear as if it would pay to install a system wherein these delays are minimized to the fullest extent.

Flying Squadron.—To the Goodyear Tire & Rubber Company goes the credit of establishing what is known as the Flying Squadron System. This squadron is made up of versatile, thoroughly trained mechanics who are able to take over any of the work of the plant. Naturally, the squadron is not 100 per cent versatile but is separated into groups of men each group being thoroughly familiar with the work of one or more departments. These men are paid more than the average and normally work on some stock job apart from the main production jobs. Incidentally, many of these men are young college men gaining experience to qualify them for advancement. Foremen, for example, are often recruited from the ranks of the Flying Squadron.

At starting time in the morning or afternoon, the foreman of each production department checks up his men. If one is missing he is allowed 15 minutes to report. If he fails to show up after this time, a report is sent to the Flying Squadron and a man is immediately sent down from the proper group to take the place of the absentee.

By this means every production machine or bench is kept busy at nearly 100 per cent capacity, the squadron acting as a reservoir to draw from to fill production places in case of absences or accidents.

The company has found this a profitable system and one of great advantage to the planning department. It is in effect a sort of insurance system to make sure that the plans of the production department will not be upset by human delinquency.

Summing up, then, the squadron has two major functions: First, it assists planning by providing a reservoir of men to step in in case of human delays, and second, it acts as a training ground for shop executives.

In discussing this human phase of planning a word or two on the advisability of taking foremen into confidence on the plans is advisable. Too often in our mass production industries, the foreman sees himself as a single unit unrelated to the other units and his interest is correspondingly lowered. By means of conferences the foremen should see how the plan ties in their work with the work of the plant, and how important each one is to the success of the enterprise.

A watch gearing analogy is apt, for the intermeshing of the work in an industrial establishment. The foremen are the gears in the plant. Take one gear away, and unless you replace it, the mechanism stops. The work of each gear, or foreman, contributes to the general plan and an understanding of this fact will promote a higher morale in the shop.

Problems

1. Draw out a production curve based on the following intended shipments:

January	1,500 units
February	1,800 "
March	2,000 "
April	2,200 "
May	2,600 "
June	3,000 "

Assume a force of two men per month turns out 10 units. Draw out the corresponding employment curve assuming no overtime and no major machine tool changes.

2. Draw out the employment curve,

Assuming straight time is worked in January
Assuming 10 per cent overtime in February
Assuming 15 per cent overtime in March
Assuming 20 per cent overtime in April
Assuming 25 per cent overtime in May
Assuming 25 per cent overtime in June

3. Discuss how the sales predictions tie up with the employment curve.

4. Discuss the value of the Flying Squadron System in a plant subject to many labor variations.

5. A plant employs 500 men. About 3 per cent of these men are constantly absent from unforeseen causes. What would be the approximate number of men required in the Flying Squadron?

CHAPTER 21

PLANNING THE NEW BUILDING

We remarked previously that all effort should be taken to use existing buildings where possible. However, there are occasions where the demand for space is such that a new building is absolutely necessary. Such a building should not be guessed at but should be planned for intelligently.. It should be remembered that it is the machines and equipment that make the building profitable and that, therefore, these machines should be considered first and the building becomes a secondary, though of course, an important consideration. In other words, design first for the machines and, secondly, place the building around the machines.

Use of Models or Dolls.—First of all, the machines should be represented by models cut (to scale) from paper and using the exact dimension of the floor plan of the machine. This plan should include such things as the length of traverse of the table or bed such as, for example, when a planing machine has its reciprocating bed extended its fullest extent. It should not include space for aisles or material storage. These will be added later. Just simply the floor plan.

These models, or dolls as they are often called, should then be arranged on a large sheet of drawing paper, with due emphasis given to their sequence of operations as desired in the project, and with proper regard for the flow of material from one machine to another. Proper space should be given for material storage between the machines and working space and there should also be proper aisle space allowed for handling of material. The little dolls can be held down with thumbtacks so that their positions can be maintained or if necessary changed.

The study of this board with its models of machines and its flow of material will show exactly what will transpire in the new building. Some planners take colored threads and wrap them around the thumbtacks and lead the threads from machine to machine to insure a clear path of manufacture.

At any rate, as stated, the board should be analyzed and the dolls shifted around until the best sequence of operation is found and the best system of material handling. The suggestion of crane handling can be given by taking a strip of stiff paper representing the truss of the crane and carrying it on two washers so as to clear the models.

The next step is to make the necessary allowances for non-productive space. The space for inspectors' functioning should be calculated. The spaces for the other necessary offices and the lavatories should be calculated, and space allotted to these should be placed on the board.

We are now able to draw in the outline of the building around these dolls and spaces, and of course at this point the service of an architect should be called in and the final building arranged for. Throughout all this work the whole consideration is one of plan and the final result will be one in which everything will function as planned.

Naturally consideration of each factor must be taken into account but these can be planned for equally well. Some firms are not content with doing this work alone, but plan on a more ambitious scale. One firm, for example, makes out a very elaborate model in three dimensions and actually makes a model of the building. The scale used is about ¼" to the foot and the result shows how the building fits in with existing buildings. Another model had the dolls replaced by plasticine, or modeling clay, replicas of the actual machine tools, with the building made up of matchwood and plyboard. The result was distinctly good and showed the building exactly as it would

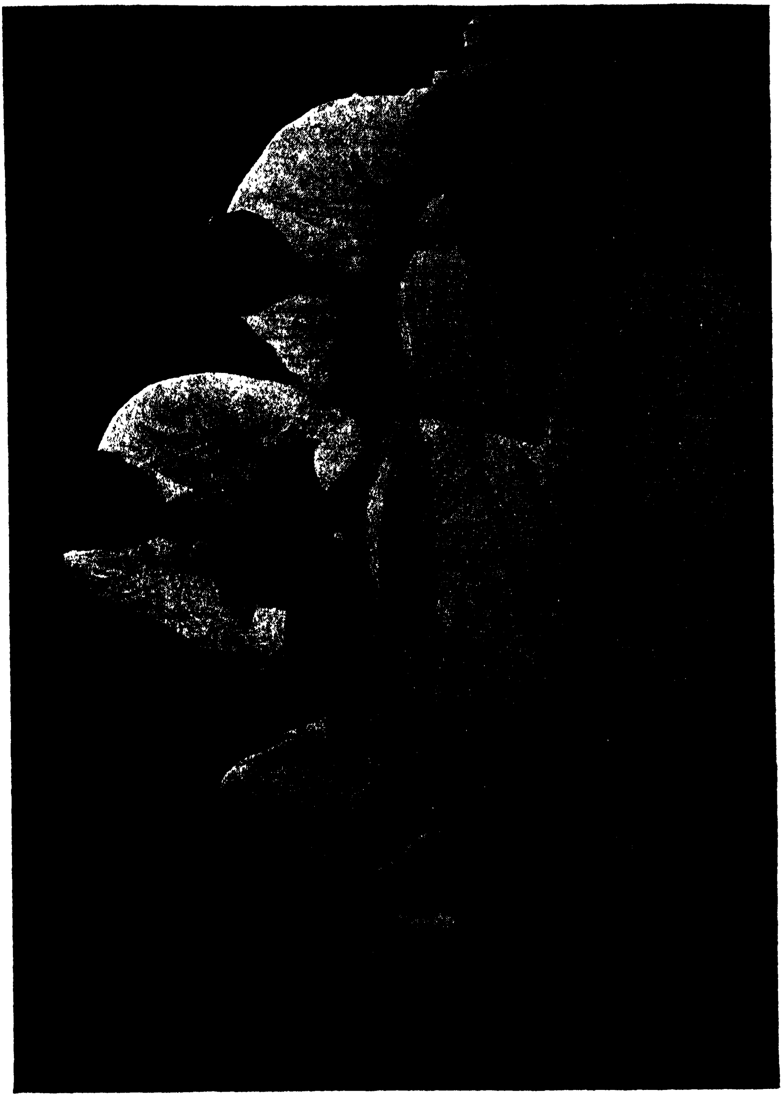

Figure 41. Use of Models in Layout of Plant (From Iron Age)

look when finished. These models should be kept and filed away for future reference and comparison.

Regarded as the first application of model templets to assembly procedure, the assembly line layout (Figure 41) was used at the Cadillac plant, Detroit, as it prepared to begin production of new models. The system includes use of a draft of the assembly department floor plan, with obstructions noted at a scale of one-eighth inch to a foot. String is used to simulate conveyor systems. Templets of the equipment, cut to floor area scale, are mounted on the board in proper position. From these layouts and time study, it is possible to post the theoretically perfect distribution of man-power. This is done by listing badge numbers of workmen and mounting the cards at stations along the assembly line, as shown in this photograph. Regular assembly men are listed on white cards, utility men on yellow cards, and inspectors on blue cards.

CHAPTER 22

PLANNING FOR ACCELERATING OR FREEZING PRODUCTION

At a time like the present, many firms are considering expansion of their facilities, and the question arises as to how best this can be done. Land area is of first importance and it may be necessary to expand the lot or perhaps purchase a new location. In this latter event due consideration should be given to labor facilities, power availability, and similar factors that enter into the picture. Then the building should be planned for as stated elsewhere.

However, the question arises, "By how much shall we expand?" Some firms want 50 to 100 per cent expansion of existing products, others expand with a totally different product but this latter we shall not consider. The significant thing is that such expansion if continued usually results in a hyperbolic curve rather than a straight-line curve and production increases at an ever-increasing rate. This fact is one which has surprised some of us recently—as production facilities increased, the productivity increased much more rapidly.

Thus, a 50 per cent expansion today increased productivity by 50 per cent but another 50 per cent expansion on top of that increased productivity nearly 125 per cent over the original. In other words, productivity goes up by geometrical progression rather than by arithmetical. Naturally the law of diminishing returns enters into the picture but not so much at the early stages of expansion.

Planning for recession is, however, on a different footing. You cannot always tear down buildings and sacrifice equipment; you have to vary your productivity by other means.

You naturally want to preserve the efficiency of your plant and hence you want to preserve the existing speed of your assembly and production lines.

During the recent depression this factor was taken care of, first of all, by shortening the hours of work. The eight-hour day, 5½ days a week became the 6-hour day, 5 days a week. When that did not help, then the 5 days a week became 4 days and 3 days and even 2 days a week. Some firms had to resort to a change in speed in their production lines where one operator, instead of doing one simple repetitive job, now became a versatile operator doing more than one job along the line. This practice is not good and should be resorted to only in times of dire necessity.

Depression times are sometimes a blessing in disguise. This is the time when there is opportunity to overhaul all the existing practices and find out how they can be improved. Inefficient machine tools can be eliminated and attention focused on the good machines. Inefficient practices in general should be revised and overhauled and new practices installed. Naturally this procedure is difficult in a state of rush and rapid expansion where an inefficient machine is tolerated for the time being simply because it is some kind of a producer and adds its quota to the necessary amount.

Times of depression are times of stress but they should not be taken lying down. It pays to maintain efficiency in all directions even though profits are desired. Naturally in times of expansion we should still consider efficiency but sometimes it may be sacrified to getting productivity. As stated elsewhere, delivery dates are of prime importance at this time and often a poorer machine is accepted where a better machine is not available in time. This, however, is only a temporary consideration and we should constantly be looking ahead toward improvement of the plant.

CHAPTER 23

RHYTHM IN MANUFACTURING

Movements That Obey Laws.—An interesting analogy can be drawn between the movements of the planets and the movement of material in a modern shop. The sun obeying certain mathematical laws moves in its path. The planets obeying similar laws move in their orbits around the sun, and finally the belts of Saturn and our own moon move with fixed precision around each respective planet.

Or to quote a further analogy, we have the gearing of a watch in which the gears revolve in their paths obeying the mathematical construction of the watch.

You cannot deviate one planet from its path without the system being upset. You cannot make one gear in a watch move faster than the others without stripping some of the other gears.

Laws of Material Flow.—Material flowing in a mass production shop is also governed by its laws, and it is the authors' impression that eventually with further study mathematical expressions of the laws may be found. For instance, let us consider such material flow in a modern automobile manufacturing plant. The wheels of the conveyor chain travel round and set a pace for the completed chassis to develop into being. Chassis units flow in at exactly a definite pace from the various lines. The chassis line delivers one car each 60 seconds. Correspondingly, the engine line delivers exactly one engine each 60 seconds—no more, no less. The connecting rod line delivers four or six rods, as the case may be, every 60 seconds. The forging line in the ideal state would deliver exactly four or six forgings to the rod line. And finally, the steel mill would deliver its precise half-dozen billets to the forge every 60 seconds.

The whole flow of material is accurately geared up under the ideal conditions to a definite regular pace, just as definitely geared up as a sun and planet motion or a watch movement.

It is worth noting that the tremendous advances in scientific management are rapidly bringing about a realization of the ideal. In some shops, the desire for this ideal has manifested itself by an installation of signalling devices which go into action when a change takes place in the rhythm of the line. Instantly foremen and millwrights cluster around the portion of the line that is giving trouble, with a strong intention of setting it in even pace again.

Planning of a High Order.—Elaborate planning of a high order is necessary to carry out a system of this kind, but some engineers have not been satisfied with their achievements in this respect. Not content with the running of a conveyor line with standardized products, and only such leaving the line, they have sought for and succeeded in introducing subordinate rhythms in the line itself. Reverting back to our solar system analogy, they have introduced the thought of moons revolving round the planets.

Perhaps this may seem rather far-fetched but when one sees conveyor lines assembling cars first with coupé bodies, then with sedan bodies or with blue bodies followed by green bodies then by yellow, or again with blue wheels followed by green wheels then by red wheels, one appreciates the fact that flexibility can be introduced into a conveyor line. One conveyor, in fact, has a number of passenger cars come down the line followed by a truck and then again more cars.

The Rhythm Cycle.—This procedure brings up an interesting policy. Suppose for simplicity's sake that we imagine a plant with orders for blue wheel equipment and also for red wheel equipment. One procedure would be to build all the blue wheel equipped cars in the morning and all the red wheeled ones in the afternoon. However, by doing this a dealer who had ordered a mixed carload would have to wait until the evening to get his car filled. Automobiles would be standing about awaiting their box cars and prompt shipment would become difficult.

Suppose, instead, that the manufacturer found that of every ten cars shipped six had blue wheels and four had red, then he could plan his assembly line so that six of the first type could travel down the line followed by four of the second type and so on in rhythm, thus effecting prompt shipment and minimum storage space.

To work according to this method demands, of course very carefully executed plans. The wheel department must work in similar rhythm, producing six sets of blue wheels and four sets of red wheels in a ten-car cycle of time. Then, of course, they roll down the six sets of blues followed by the four sets of reds and so on in rhythm or routine throughout the day.

Virtually what we have done is to introduce a second department in the original wheel department and then arrange for proper output from each of the two during the proper assembling cycle.

This plan can be amplified, as for instance, when a manufacturer builds green cars, blue cars, and yellow ones at a pace of three greens, four blues, and three yellows for every ten cars. Three divisions are made in the body painting department and during the time cycle of the ten cars, three greens, four blues, and three yellows will be produced or painted and shipped in rhythm to flow into the conveyor.

Another Application.—A similar idea is worked out with sending a truck down an assembly line preceded and followed by cars.

If five cars are required for every one truck and 60 seconds is the time cycle for each unit, then once every 6 minutes at a definite point in the period, the truck lines are tapped into the assembly lines. Thus one truck engine will enter the line, one set of truck springs, and so on.

In developing the rhythm of assembly line operations, the motor car industry has achieved the greatest degree of co-ordination by locating "banks" or stock-piles of component parts directly at the points of usage. The more bulky parts such as engines, transmissions, sheet metal, etc., are transported to the assembly line on overhead monorail conveyors which keep a steady stream of component parts in circulation.

This sheds further light on the function of the materials handling conveyor as a pace maker. In essence, the chief function of the feeder conveyor is to synchronize the delivery of component parts with the movement of the work on the conveyor, the timing of both the assembly line and feeder lines being so arranged that the proper unit, of the right color, appears on the scene at the precise moment that it is required.

In recent years, a further extension of the principle of expediting the smooth operation of assembly lines has been achieved by locating minor and major subassembly stations at points of usage directly along the path of the assembly conveyor. Thus, for example, the assembly of the front end sheet metal unit may be in the form of a compact merry-go-round assembly conveyor, right off the main assembly line. The same principle is extended to the assembly operations on an engine or a transmission or a body.

The complete synchronization of all assembly functions is coordinated with the timing of machine shop operations, body assembly, and the paint shops through a comprehensive system of scheduling. The teletype is typical of the equipment used for this purpose, with teletype stations in a number of key locations in the plant, all communicating with the central station which is directed by the dispatcher. Depending upon the nature of the operation, instructions are issued hourly or twice daily or once a day, but always beginning with the first moment of operation and scheduled from shipping instructions issued by the sales department.

In this type of organization, each hook on a monorail conveyor has a definite function at any given time, since it is scheduled to carry, say, a hood or a fender of a special color to match a numbered chassis which is proceeding along the assembly line. The speed of the conveyors is so synchronized that this hood or fender or body will meet its own chassis at a given point so as to effect a harmonious unit in adhering to the customer's specifications.

Although the scheduling process is extremely complex and difficult to visualize in the area of a teeming plant, the foregoing generalization gives the essence of the process and indicates how synchronization may be achieved regardless of the volume of product. Needless to say, the mechanical facilities such as variable-speed conveyor lines, dispatching equipment, and the like are essential elements vital to the orderly progress of mass production manufacture.

Motion Study.—Possibly one of the most valuable of the management devices developed in recent years has been the principle of "motion study" in which a scientific analysis is made of highly repetitive operations, particularly of small assemblies. This principle has been employed in the assembly of sparkplugs, instruments for motor car instrument panels, and for other small assemblies where a number of fine parts must be taken from containers and suitably fitted in fixtures.

It has been found that the speed of the operation could be increased many fold with a consequent decrease in manufacturing cost by controlling such factors as—

1. The layout of the work table
2. Proper location of component parts storage with respect to the reach of the operator

3. Correct positioning of the assembly fixture and tools
4. Location of all elements in such fashion as to facilitate the use of both hands simultaneously

Each job is carefully studied by means of the micromotion technique developed by Gilbreth,[1] using a trained operator in the investigation, analyzing the motions by means of a motion picture camera. The procedure is continued until the layout has been satisfactorily developed so as to do the job most economically. An interesting byproduct of such studies is the revelation that motion study relieves much of the operator fatigue usually associated with highly repetitive operations, leading to better feeling and improved cooperation on the part of the workers.

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[1] The Gilbreth technique is explained in *Wage Incentive Methods,* by C. W. Lytle, The Ronald Press Co.

SUNDRY PROBLEMS

Not only the student but the executive responsible for production should constantly ask himself questions. Just as the good designer has a set of questions before him that he passes on, or checks, before completion of his design, so should the production man have his own series of questions as a check on his work. A few of such questions follow. They can be amplified or modified in accordance with the considerations of the business.

1. Is full advantage being taken of the possibilities of semi-automatic and automatic machines on forgings and castings?
2. Would special purpose automatic chucks effect a saving in time or labor?
3. Would automatic counters on the production machine save time now wasted in manual counting?
4. Is full use being made of the savings possible through the use of multiple-spindle drills or multiple drill heads?
5. Are the limits of accuracy carefully chosen to allow as much tolerance as possible?
6. Is the machinery guarded against accidents with full appreciation of the savings in both lost time and in insurance premiums?
7. Is the illumination such as to provide uniform light of the correct intensity for the work being done?
8. Would modern automatic or continuous milling machines reduce costs on certain operations?
9. Would machine molding, with its large labor savings, be applicable in the foundry?
10. Are lubricating and cutting oils supplied to the machine without involving a waste of time on the part of the machine operator?
11. Are operating speeds checked up to make sure of maximum efficiency on cutting operations?

12. Is time being wasted in counting parts which could be weighed?

13. Are cuts and feeds being checked up to assure maximum production from expensive machine tools?

14. Are lathe tools and other cutting tools kept in condition at all times, to avoid production time losses?

15. Are single cuts being taken on work where multiple cuts would more than pay for the necessary equipment?

16. Are metal parts being washed by hand? Is the quantity such that washing machines might show a worthwhile saving?

17. Are the hardening and tempering furnaces of a type to keep pace with production requirements?

18. Are grinding machines being used on work that requires accuracy?

19. Are cutting speeds checked up, to see that the work is giving the best possible efficiency with the particular tool and operation?

20. Are the jigs and fixtures adequate to the work?

21. Would modern welding equipment afford a means to cut production costs?

22. Would the oxyacetylene torch perform certain operations more cheaply than doing them by machine?

23. Is there a "bad traffic hold-up" somewhere in the chain of production processes; if so, would rearrangement or additional equipment solve the trouble and pay dividends?

24. Are the cutting tools getting efficient cooling and lubrication at the cutting edge, independent of the variable human factor?

25. Are the gages supplied to operators so designed as to minimize time lost due to their use?

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