TOOLING FOR PRODUCTION

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COMMANDER FAIRCHILD: Gentlemen, last week you saw a movie which showed the production of a section of a simple four-piece, three-inch projectile. You will recall that more than 250 machine tools were used, that these tools were of 57 different types, and that approximately 100 separate operations were involved. You saw that shop layout, tooling for production, scheduling, inspection, and many other factors were a necessary part of this operation.

If you keep all of these facts in mind and try in your imagination to compare the construction of this simple projectile to that of the complex modern automobile, I am sure that you marvel at the ability of the manufacturers to come out with a line of new models each year and, I might add, to produce such large quantities of the many styles of those models. When we stop to consider the magnitude of this task and all its involvements, it creates deep respect for the men whose abilities make this feat possible.

Our speaker today is one of those men. He is an outstanding engineer, and executive of the Studebaker Corporation, and, as you noted from his biographical sketch, has also had extensive experience in industries outside the automotive field. He was asked to discuss with us today one portion of the productive effort which is known as "Tooling for Production."

I take great pleasure in introducing to you Mr. Edward L. Usner, of the Studebaker Corporation, who is Assistant to the Vice President in Charge of Manufacturing.

MR. USNER: Thank you, Commander Fairchild.

"Tooling for Production," the subject which this lecture is to cover, has been a most interesting subject in its preparation and turned out to be a very broad subject, which, to be fully covered for all phases and types of manufacturing, would require a much longer period than is available. Consequently, this discussion will be confined in general to the mass-production industries, where a few end products in large volume are manufactured; the particular industry which is being covered this morning is the manufacture of automotive vehicles.

The problems of heavy equipment manufacturing are quite different from those encountered in mass production, particularly in regard to material handling, arrangement of equipment and plant layout, as mass production must be "progressive in-line" to the greatest possible extent, whereas in heavy industry, the variety of work produced does not usually permit, nor warrant, progressive production layouts.

Both of these types of manufacturing are most interesting. The mass-production industry is one that requires very meticulous planning to the utmost degree. Lead times must be determined so that the manufacturing program can be laid out properly. Purchased material receipts must be timed, and parts manufacturing must be timed. Where there is a variety of product going through the same channels, such as in the automotive industry where different models, with varying colors and trim materials, are put together on the same assembly conveyor, the line setting has to provide for bringing the various parts of the correct color through the subassembly operations up to the final line in the required sequence, and the lead time becomes a very important factor in the timing of internal plant operations.

"Progressive in-line" manufacture is where the tools and equipment required for an operation are physically brought to the place where the operation is to be performed in logical manufacturing sequence, this being accomplished by painstaking analysis and careful planning of the entire manufacturing processes. This planning, in all of its phases, will be discussed this morning.

In treating with today's subject, it became apparent that all phases of preparation for manufacture would necessarily be touched upon, as tools, machine tools, plant equipment, and plant layout complement one another into a complete manufacturing program, and their treatment cannot readily be subdivided. Therefore, this discussion carries through with the various steps in preparing for manufacture in the logical sequence in which they occur in actual practice.

During periods of great emergency, the steps to be taken still remain the same, although the time element in an emergency does not permit the careful, painstaking study of each small detail, particularly from the cost standpoint, which is so essential in the production of a purely commercial product. The problem in an emergency is to get a new project moving in all of its essentials, as rapidly as possible, with the refinements being made while the work is actually being done.

In order that this treatise may be fully comprehensive, the steps necessary to produce a completely new product have been used as a basis for the sequence of organizational operation. Let us start with the assumption that the product has been engineered from a type, a design, and a mechanical standpoint, and that pilot models have been built and tested. Let us also assume that production volume has been determined; as any such program, when the point arrives where the quantity of tools and equipment and floor space must be determined, must be planned around a certain definite maximum volume.

That is very important. The major plan must be reasonably complete before the detail of the internal planning is started. This does not mean that it is absolutely necessary to reach the maximum planned volume, but the internal planning should contemplate reaching that volume so that if it became necessary to do so a complete plant rearrangement would not be necessary.

During the process of product engineering, a preliminary check on the cost is made by the Engineering Division, working in conjunction with the Manufacturing Division, through a series of preliminary discussions as to the relative merits and cost of various ideas which could be incorporated in the product. Drawings, bills of materials, and parts lists are turned over by the Engineering Division to the Manufacturing Division. Models are also available, so that they can be torn down and the parts examined when the processes to be used in manufacture are discussed piece by piece. The effect of any changes which may be proposed in order to facilitate production, or to lower cost, can be best determined from models, in conjunction with the drawings, this being particularly true where sheet metal work is involved. Possibly a slight contour change can be made to facilitate forming and drawing a panel. Where parts are to be welded, the best location of the welding flanges can be better visualized when working from models.

In actual practice, so as to prevent a bottleneck in manufacturing analysis, this examination is carried on progressively during the period while the entire product is being engineered. Just as soon as a part, or a unit, has been designed, tested, and a determination made that it will be used in the end product, it is turned over to manufacturing for preliminary discussion, analysis, and development of Advance Operation Sheets, even though there is a great possibility that several, or many, changes may be made before actual production starts. In fact, the ability of a manufacturing organization to absorb engineering changes is essential in the automobile industry, as many changes to alter appearance or improve performance are made from the time of the inception of a new model to the time when the first cars roll off the production lines.

As an example of this, several years ago--this is hearsay with me--when Studebaker came out with one of the postwar models, it was buying sheet metal parts--which we still do, although we are now starting our own sheet metal stamping plant--and the sheet metal parts were to be made by a company which specialized in that particular work. When the engineering changes finally reached a total of 25 on one particular item, a member of the Studebaker organization told the stamping company how badly he felt that so many changes had occurred. The jobbing company said, "Think nothing of it. One of your competitors had 125 changes from the time when we first received prints up to the present time."

The manufacturing analysis, when made in detail, brings out changes which have been overlooked in the preliminary stages, and which may well be made in the interests of economy and ease of manufacturing, and possibly on equipment which is available. Each such proposed change then becomes a subject of discussion between manufacturing and engineering representatives to determine the best solution in the interest of design, quality, and cost of product.

Certain specialized parts in an automobile are frequently made by parts manufacturers who have specialized on these parts for a long period of time and, consequently, have developed special production equipment and methods, and have gained the necessary "know-how." This "know-how" and special equipment, combined with the fact that a parts manufacturer may produce a specialized part for several, or even many end-product manufacturers, thereby attaining large volume, frequently enables a price to be obtained from such parts manufacturer which is considerably lower than the cost at which the end-product manufacturer could produce the same part.

In other words, during the war period that was called subcontracting, which was necessarily carried out very extensively during that period, and in the event of any great emergency would again have to be carried on extensively.

The specifications of such parts, after being engineered into the end product as to general dimensions and requirements, and discussed with the specialized parts manufacturers, who can then determine how the new parts will affect their available equipment and production facilities. Frequently such a parts manufacturer is able to make suggestions on desirable changes which will decrease the cost and possibly improve the end product. The parts manufacturers, when these questions have finally been decided, must then arrange the necessary changes in their tooling and make alterations in their plant layout in order to meet their part in the production schedules.

That comes back again to lead time. Very few manufacturers are large enough, in a mass-production industry, to produce everything they require, so they must depend on subcontractors to a large extent, and that again requires the planning of the lead time, which is most essential.

Needless to say, the prices of such purchased specialized parts are constantly checked against the "out-of-pocket" costs which the end-product manufacturer could obtain by manufacturing the parts themselves. However, the parts manufacturers have managed to survive in a very competitive market and have become a most essential part of the automotive industry.

The independent automobile manufacturers purchased specialized parts from vendors to a greater extent than the very large integrated organizations, which have frequently found it advantageous on many of the specialized parts, due to the large volume involved, to establish their own separate divisions for making and distributing these parts to their various assembly divisions.

The planning procedures, which have been previously outlined in this discussion, have now reached the point where it is known what materials and parts are required to fill the program. The next step is to subdivide all of the detailed parts, subassemblies, and unit-assemblies into those which are to be purchased and those which are to be manufactured.

DETERMINATION OF WHAT TO MANUFACTURE AND WHAT TO PURCHASE

The parts lists, when turned over to the Manufacturing Division, indicate, based on company practice, whether a part is normally manufactured or purchased. This does not mean that such an indication is irrevocable, because, as brought out previously, the out-of-pocket cost and purchase price comparisons are constantly being made. A small saving on any item, when translated into terms of yearly production at high volume, really mounts up and might warrant the capital expenditure for space and equipment necessary to manufacture the item, instead of purchasing it.

We are concerned today with those parts which are to be manufactured and the procedures for determining the tooling, equipment, and plant layout requirements for those parts, subassemblies, and unit-assemblies which are to be processed. We are also concerned with the assembly equipment and the assembly layout required to assemble the manufactured and purchased parts into the completed end product.

To give a general idea of the magnitude that such a program can reach, the following is quoted from a booklet which is being prepared by the Automobile Manufacturers Association. The name of the particular automobile manufacturer is not given in the report, nor do I know to which company it refers:

"When one new post-war model was introduced, the company found it necessary to purchase and install 164 new machines, ranging in size from small special purpose units to a million-pound press. In addition, 979 machines and presses were moved to new locations; 1,650 new dies and 805 new fixtures were designed and built for the body plant; 2,615 new tools were made for the assembly plant, and 13½ miles of conveyor tracks were installed. This represented over two years of work on factory changeover at a cost of $16,000,000."

Cost is one thing that the mass-production industry must carefully determine, and enough time must be allotted to do this properly. In a great emergency, the situation is somewhat different. The cost factor does not enter to such a controlling extent, at least in the beginning. Cost reduction and improvements in processes can be made after the action is started. The main thing is to get the job moving.

ANALYZING THOSE PARTS WHICH ARE TO BE MANUFACTURED:

A complete analysis can be divided into several distinct steps, which must be carried on simultaneously in order to expedite the early completion of the task. These subdivisions are:

1. Determining what material shall be sent to the final end-product assembly lines as unit assemblies, as sub-assemblies, or as single parts.

The practice in mass-production industries is to sub-assemble and unit-assemble to the greatest practical extent, prior to the final assembly of this material into the end product. This is a logical development based upon conditions, some of which are:

a. Responsibility for output and quality become centralized in smaller manufacturing units if you subassemble and unit-assemble to a large extent.

b. The cost of transporting material to the final assembly lines in an assembled condition is much less than if individual parts were transported.

c. The production control problem is greatly simplified, as major control records under the subassembly and unit-assembly method deal with fewer items.

d. --and this is quite important also--the final assembly lines are conveyerized, so that, if a large number of individual parts were dealt with, the final assembly conveyer lines would be too long for practical purposes, and the number of men required to man the conveyerized final assembly lines would be very much greater, so that down-time losses would become prohibitive; as when trouble occurs at any point on a converyorized line, the entire line necessarily stops and all of the men become idle. Conveyerized assembly lines are an essential part of the mass-production industries but do place a burden of responsibility on the organization to keep them free of mechanical and material supply troubles, as stoppages are too costly. To illustrate, a line having five or six hundred assemblers has a down-time cost per hour that will knock a big hole in a thousand dollar bill, as the men must be paid, unless the failure of the line is so serious that work for that day is discontinued.

However, it takes a pretty serious delay to send men here and to lose that production.

2. Determining how each part shall be made and how subassembly and unit-assembly operations will be performed.

This is what may be termed as "Process or Methods Engineering" and is one of the main points to be covered in this discussion, as the information for determining the machine tools, machine equipment, and manufacturing methods is developed at this point.

Each part, subassembly, and unit-assembly is examined by the Process or Methods Engineer (or engineers), who specializes on the particular type of processing involved. These men work from drawings and models, when models are available, and preliminary determination is made as to the ideal sequence of operations and the type of tools and equipment that can be used to the best advantage on each of the necessary operations. This information is listed on Advance Operation Sheets which must be set up for each part, subassembly, and unit-assembly to be manufacturered. This advance information is usually put on a form which is of a different color than the Operation Sheets which cover the final decisions.

The Process Engineers are constantly in touch with any new developments in the fields in which they specialize, so that they can readily apply the most modern methods when making up the Advance Operation Sheets.

In the event that heat treating, or kindred operations, are required in the sequence of operation, the Metallurgical Department is contacted. This same practice applies when special welding or painting equipment is involved, as a large organization maintains staffs that specialize on such major operations.

When a part can be made in several different ways, optional Advance Operation Sheets should be made out to serve as a basis for discussion and final decision.

Operation times are estimated; or if similar to existing operations, the actual operating times are obtained from the Time Standards Department. Reasonable accuracy in predetermining the time standards is most essential, as it indicates the comparative labor costs between the proposed optional methods. Usually, a lowered labor cost for a particular operation means an increased investment in tools and equipment, and, therefore, the comparative operating times must be used during later conferences in forming decisions as to the methods which will be most advantageous to the manufacturer.

Notations must also be made on the Advance Operation Sheets, by operations, as to whether or not the machines and equipment specified are already in existence in the plant and are available; and if not available, the estimated cost of the required new machines and equipment must be shown.

These Advance Operation Sheets, after being checked and approved by the supervisor of the Process Engineering or Methods Department, become the basis for conferences and discussions between the Methods Department, the Master Mechanic, and the Divisional Superintendent affected. The General Superintendent is called upon for the final decision on the most important questions.

During these discussions the proposed methods are compared with existing procedures to determine, in general, the extent of rearrangement of tools and equipment that will be required; whether or not existing equipment can be used without undue cost penalty; whether or not operation costs could be lowered by new and improved equipment to such an extent that the expenditure should be recommended to the management; and whether or not the time element of production schedules would permit the procuring of the proposed new equipment. If the deliveries of new and improved equipment require such a long period that production schedule starting date requirements cannot be met, the decision must then be made as to whether or not to order such equipment and put it in the production lines when it does arrive. This determination is essential, so that the physical plant layouts, which are covered later in this discussion will provide room for the new equipment, in the event that it is not completely interchangeable with the existing equipment as far as sequence of operations and space requirements are concerned.

The development of the methods and tooling is a most interesting phase in the preparation for the manufacture of a new product. Mass-production volume, in many cases, permits the investment necessary for specialized machines for the operations on many of the parts; these specialized machines combining many individual operations which, with a smaller volume of production, would necessarily be performed on single-purpose machines. Many of these specialized machines are designed so that after the original setup is made work is automatically transferred from station to station until all of the operations combined in the machine have been completed. The many decisions necessary in the selection of those operations which can be combined into a special machine call for mature judgment, based on long experience as to just what will happen under certain circumstances.

Technological improvements have become progressively necessary in order to offset, or rather minimize, the full effect of the continually increasing hourly wage rates and the tendency of labor to continually insist that manual effort be eliminated to the greatest possible extent.

Specialized equipment for processing and work handling to an increased extent has been industry's answer to this problem, as the increasing use of such equipment enables a decrease in the labor hours required for a unit of product. This imposes a heavy burden of responsibility on a manufacturing organization in making well-considered decisions so as to accomplish the required results and still maintain expenditures for equipment at a commensurate level.

The cost of such specialized equipment, which is especially engineered and custom-built for each job, is very high, and a few of the questions that must be wisely answered by the manufacturing organization are:

1. How long a period will it take for the special equipment to amortize itself through reduced labor cost per unit of product, based upon the hourly rate of production which will be required by the schedules and which will be designed into the machine?

2. Will the part which is to be produced by the special equipment have a life span, before major changes in basic design render the part obsolete, of a sufficiently long period to permit the amortization, based upon the rate of amortization determined in the previous question?

3. In the event that a major change in product does occur before the end of the useful life of the machine, can it be converted at a reasonable cost and in a reasonable time period, or is the design completely inflexible?

4. Are the operations, which are being combined, of such a character that undue trouble in one or several of the operations will not be prevalent and thereby offset the handling cost advantages that are gained by combined operations? Delicate operations when tool breakage can be expected, or when tools must be replaced frequently in order to maintain the required accuracy, should not be combined with operations where tool life and upkeep is not a major problem. If they must be combined, extra allowances for down time must be made when the machine capacity is calculated, and provision must be made for the storage of suitable banks of material between the special machine and the point where the subsequent operation is performed.

A manufacturing organization, to be successful, must come up with a high proportion of correct answers to these questions, as an error in judgment, when once it has been put into physical effect, can be very costly. After production once starts, the failure of a machine to function properly may cause a very large financial loss through interrupted production of the end product and in the down time paid to workers who are dependent for their operations upon the proper performance of the machine; to say nothing of the cost of eventually replacing a machine which will not function satisfactorily.

The manufacturers of special machines and equipment are really abreast of the times and are continually working on new developments. They are constantly in touch with the product manufacturers and subcontractors and keep themselves fully informed as to the problems which are continually arising due to new product development or the necessity of cost reduction in existing products. They work very closely with the product manufacturers in keeping them informed as to any new developments which have been worked out successfully in practical applications and assist them in the solution of many of the special problems that arise. Those companies that have specialized on improvements in cutting-tool steels, and in the tungsten carbides, have also played a very important part on the team that has made us a great manufacturing nation. However, the end-product manufacturing organization carries the final responsibility of sorting out the wheat from the chaff and of fitting the factors together into a successful manufacturing operation.

When decisions have been made as to the processes and methods to be used, the Advance Operation Sheets are changed to reflect this latest information. The Time Standards Department must then analyze the operations as shown and make any necessary changes in estimates of production time, manpower requirements, and direct labor costs for each operation. These revised Advance Operation Sheets then become the basis for the further necessary steps in the planning of the complete program.

The foregoing decisions are tentative as, while they follow correct manufacturing practice, they have been based on general, rather than on specific, detailed information. No such decisions are absolutely final until the subsequent details covering the tools, jigs, processing fixtures, inspection fixtures, and inspection gauges have been worked out on paper, and until satisfactory machine and plant layouts have been made. If the detailed information indicates that a revision in any decision is advisable, the factors responsible for the original decision are reviewed.

We have now broken down the end product into what will be purchased and what will be manufactured, and have determined in general what processes will be used in making those parts, subassemblies, and unit-assemblies which are to be manufactured. The next steps, which are carried on simultaneously, are to translate the information on the Advance Operation Sheets into details and into terms of scheduled requirements. At this point the Tool Engineering Department, the Plant Layout Department, and the Plant Equipment Engineering Department come into the picture.

TOOL ENGINEERING

The Tool Engineering Department is one of the most important links in the chain that makes up a manufacturing organization. The ingenuity of the members of this department, backed by long experience whereby they know to a reasonable certainty what will happen under certain circumstances, has a very real effect on the cost of the product, the cost of tooling-up to make the product, and the resultant quality of the product.

There is definitely a sequence of operations of any detailed part that will enable the required accuracy and quality of finish at a minimum of cost. The problem of the Tool Engineer is to determine on each particular part the sequence which will give the desired results. In a large organization where a great variety of parts are manufactured the Tool Engineers usually specialize on certain types of operations, with a necessary general knowledge of the other types of operations which are required in a completely integrated manufacturing program. Even if the operations are not performed by the end-product manufacturer, but are purchased from outside sources, the Tool Engineering Department should have engineers who have an intimate knowledge of the processes involved. There are times when manufacturing troubles develop in the plants where purchased products are obtained, and the end-product manufacturer should be in a position so that definite assistance can be rendered to these outside plants. Also, economies of manufacture may possibly be made on a purchased part by an engineering change, and the Tool Engineering Department must be in position to either recommend or reject any such proposed changes in purchased parts, and if recommended, must clear the change with the Product Engineering Department.

In general, the Tool Engineering Department has specialists who cover certain manufacturing operations, some of which are: Castings--gray iron and malleable iron; forgings; machine work of all types, including automatic and semiautomatic operations; large sheet metal work, such as automobile body parts, hoods, fenders, front grilles, instrument boards, and bumpers, and the many small and medium sizes of stampings; assembly and welding of sheet metal work of all types; assembly of mechanical parts; inspection fixtures and gauges; quenching fixtures for heat treating and fixtures for copper brazing.

The drawings for those parts which are to be manufactured are sent to the supervisor of the Tool Engineering Department. He divides the drawings into classifications, depending upon how his engineering group is organized, and assigns a Tool Engineer to be in charge of each one of the classification groups.

The respective Tool Engineer then becomes responsible for the design and functioning of the particular tools involved and, in some organizations, is also responsible for following the progress of the tools during the period when they are being made, to make certain that they will be ready for operation in time for the master schedule requirements.

Each Tool Engineer, working in conjunction with the supervisor, makes recommendations, by operations, whether the tools, jigs, fixtures, or pieces of special equipment can best be procured on the outside from companies that specialize in the manufacture of such items, or whether they can best be made in the tool room which is operated by the end-product manufacturer. The extent of farming out the tooling program varies between companies, but, in general, it is not economic for a company to maintain a tool room large enough to provide all of the tools for an extensive tooling-up program. A rough guess on an industry-wide basis, a guess to which exception might be taken by individual companies, is that the end-product manufacturers procure from 80 to 85 percent of the total tool, jig, fixture, and special equipment requirements for new products from specialized outside sources. That is a guess on my part. I don't have any statistics on it, but I think it is reasonably close.

Machine tool manufacturers and welding machine manufactures usually maintain engineering staffs and tool rooms which produce special fixtures for customers, and it is customary, when procuring special machines from outside sources, to have the manufacturer of the special machines also make the fixtures, or at least assume responsibility for their performance. Die shops which specialize on dies for large sheet metal work maintain engineering staffs which work in connection with the members of the Tool Engineering Department of the end-product manufacturer in working up die designs that will fit into the press equipment of the manufacturer to the best advantage.

The usual procedure on those items of tooling which are to be procured from outside sources is for the engineers of both companies to get together and rough out their ideas as to how the tool, fixture, or special machine should function. When one of these ideas has been selected as having the best possibilities, the Engineering Department of the outside source makes rough layouts, indicating, in general, how the piece of equipment will function, how the piece on which the operation is to be performed is to be held in the fixture, and other essential details. If these preliminary ideas, when roughed out on paper, meet with the approval of the manufacturer's Tool Engineering Department, a tentative price is usually estimated so that a general idea of the cost of the equipment can be obtained. If it happens to be an item which is being thrown open to competition, several outside sources will be asked to submit their ideas and tentative estimates. A company usually has several approved sources for each of certain kinds of tools and fixtures, as tooling is not purchased entirely on a price basis, as a chief consideration is that the outside source is reliable as to quality of workmanship and also in the keeping of delivery promises.

When the preliminary designs and tentative costs have been agreed upon, the designing of the detailed parts becomes the responsibility of the outside source, even though it is necessary for them, in turn, to farm out the detail design work to companies who specialize on that type of work. Especially during the war period, the machine tool special equipment manufacturers were so loaded with work that they had to farm out the detail design to companies that had specialized on that particular kind of work, but it was supervised by the machine tool manufacturers.

These detailed designs when completed, and often during the processes of designing, are subject to the approval of the Tool Engineer of the end-product manufacturers, who keeps his supervisor fully advised of the progress being made. The approval of the supervisor must also be secured when any proposed departures from standard practice appear worthy of consideration.

When large dies for automobile bodies, fenders, hoods, or other large sheet metal work are to be made by an outside source, it is customary to send wooden models along with the drawings, so that these models can be used to better visualize the various contours of the product and also to serve as a guide in actually transferring the contours to the metal dies. In addition, handmade samples of sheet metal parts are usually available, and these sheet metal samples are sent to the outside sources who are to make the welding equipment. The type and the location of welding flanges on large sheet metal parts is very important, and the designer of the special welding equipment, by working for samples, finds them of great assistance in working out the positioning fixtures and in ascertaining that proper clearances will be available for the type of welding guns and tips that will be used.

I was recently in a jobbing plant where box type frames were being welded for an automobile manufacturer; it certainly was a very well worked out operation. The box type frame required spot welding along its entire length at intervals of approximately two inches. The original machine was built with a series of welding heads which were approximately two inches apart and extended along the entire length of the frame. This special machine was so built that all the welding heads would come down and do the welding in one operation. It did not work properly, as the welding heads, on account of being so close together, did not stand up in production service. They finally had to subdivide the operation into three separate machines, so that the first machine would weld six inches apart, and the work would then be automatically transferred to the second machine where welds six inches apart are again made, but which were spaced two inches from the original welds, and so on to the third machine. This illustrates that everything figured out by Tool Engineers does not always work successfully the first time it is tried, and designing tools of special nature is, to quite an extent, a game of cut and try.

The proper designing of fixtures for machine work requires experienced engineers, as all of the machine operations required on a part must be thoroughly thought through and analyzed before the actual designing of the work is started. The ideal condition in the machining of any part is where one locating point can be used as a basis for all of the machining operations, but on complicated work this usually cannot be worked out to advantage, and several locating points therefore become necessary. It then becomes very important that proper locating points be selected so that dimensional variations which creep into any operation through tolerances will not compound to the point where the over-all tolerances for the part are not maintained. In other words, if you add up a lot of allowable errors, you may come up with a total error that is just too much error. The establishment of locating points which are used in machine work corresponds to a great extent to the establishment of "bench marks" which surveyors use in making surveys; their importance cannot be stressed too highly.

The determination of the proper sequence of operations on a complicated part should be made by a Tool Engineer who has had both design and practical machining experience, in order to design fixtures that are capable of producing work accurately and economically, as changes which must be made on a fixture, after it has been put into operation in a production line, may be quite costly. Members of a Tool Engineering Department have the ability to make proper operation layouts and to successfully supervise the work of the Detail Design Draftsman; this is a most important factor in the results which are obtained in the original cost of the tools and the quality of the product which the tools will produce.

The operational line-up information, to follow the design which is built into the tools, must be conveyed to the machine operators who will actually produce the part. The usual practice is to describe each operation in detail on a Standard Practice Instruction Sheet. This has been the practice of most companies for many years and, in most cases, serves the purpose reasonably well. However, some organizations have found it advantageous, particularly when it is necessary to train employees in the production of new work, to supplement the Standard Practice Instruction Sheets by a series of drawings for each part, showing the detail of each operation and proper sequence in which the operations should be performed. To illustrate, if a part has six separate and distinct machining operations and each operation consists of the making of one or more cuts or grinding operations, etc., six separate drawings would be made, one for each operation, and these operational drawings numbered from one to six in the correct operational sequence as designed into the tools. This practice was of particular benefit during the war period when many manufacturing plants converted to products with which their employees were not familiar and is a practice which has proven itself well-worthy of consideration, providing the work is of such a complicated nature that the training of employees becomes a problem.

I believe that is a very good point and one which is worth remembering, as it certainly does help in training new employees on a particular job to be very explicit as to just how the work should be done. During a period of emergency when supervision is overburdened, the training of inexperienced employees becomes quite a problem, and the more detail that can be put into the instructions and into the drawings which are given to the operator certainly helps to a great extent. A satisfactory method for indicating the work which is to be performed on a particular operation is to indicate it on the operational drawing by using lines, while the balance of the part is shown in skeleton form with light lines. Some companies have even gone as far as to make isometric drawings. A good set of operational drawings are also of a great help to supervision because when you are building up for high production in an emergency many newly promoted supervisors have received sketchy training courses themselves.

Manufacturing companies which have well-organized tool programs have adopted standards for these detail items which are used in tools, fixtures, and dies, provided such items must be replaced from time to time due to war or breakage. These standard items, such as drill bushings, guide pins, bushings for dies, etc., can then be produced in quantities which are large enough to permit economy in making, or in some cases can be purchased from specialized outside sources which stock such items. The Tool Engineer should insist that the detail designing be built around standard parts to the greatest possible extent. Standardization on a national basis of such product items as bolts, nuts, screws, pipe fittings, and other items which are universally used, has been of incalculable benefit to the country as a whole, and the standardization of tool parts within a company is essential for its well-being, and really pays dividends in enabling lower inventories of these repair parts which must be carried in stock.

The Tool Engineers keep in active touch with the progress made by outside source by means of a weekly report which is made on each item; this report indicates the percentage of completion on an estimated basis. The engineers also actually make many personal and telephone contacts during the progress of the work, to be certain that difficulties, when encountered, are promptly ironed out, so that any unnecessary delays can be prevented. The tooling items which are being made in the manufacturer's own tool room are also followed up by the Tool Engineering Department in very much the same manner as for the outside sources. In tooling-up for a new product, there are a great many tools involved, and the failure of any of these tools to be ready in time to meet the schedule, or to function properly when put into operation, could have a detrimental effect on the entire project; this applying not only to tools, jigs, fixtures, but also to patterns, forging dies, press dies, special machines, and special equipment.

Successfully pulling together on scheduled time the many tooling details required for putting a mass-production program into effect is a gigantic program and requires an organization that is trained in cooperation and in the coordination of effort, and also one that is not afraid of hard work.

I cannot give a very close idea on the amount of lead time required; as it varies, dependent upon the product. The point I am trying to bring out is that there is a lot of lead time involved and that each item must be programmed so that everything comes together in time to perform the assembly operations.

We are now putting in a new Press Department. Studebaker has purchased practically all of its large sheet metal work. We do produce the small and medium size stampings in two existing press rooms, but the hoods, fenders, and body parts have been purchased. We are now tooling-up to make hoods and fenders for our passenger cars. A large number of dies are required for this work, which is a project started reasonably early in 1946. My opinion would be that any company which tried to tool-up for a large sheet-metal program in less than a year under normal conditions would stand a chance of being disappointed, although under great pressure in an emergency it could be shortened. I am again diverting from the subject at this point before taking up plant layout. At one time I was with the Marion Steam Shovel Company in the capacity of Works Manager. The operational cycle on a small revolving shovel was about 14 weeks from the time of inception of the order, when certain parts were started in the steel foundry, to the time that the shovel was ready for shipment. On the larger shovels it ran up as high as 26 weeks, and each step had to be programmed as to when different items of material would start in process and when they would be finished, the idea being to have everything finished in time, but not too far ahead of the required assembly date. In other words, some parts had to start 26 weeks ahead of the time when assembly was scheduled to start; other parts would not require starting more than a week ahead of the assembly scheduled date. Many companies miss the boat in getting out their product by sending bills of material, covering all parts, to the plant and saying, in effect, "Here it is and we want this made." And this is what happens under those circumstances. The easy parts are made first, and parts that require a long manufacturing cycle and which are hard to make are neglected. My first task while at Marion was to install corrective measures so that parts were not started until necessary to meet the assembly schedules, based on the operational cycle and lead time required for each part. The further effect of the faulty procedure previously outlined was that there would be a large inventory of finished parts which were not currently needed. So, for many reasons the programming of parts processing is very important. In a mass-production industry you have to program all the parts, or the whole procedure stops. It is just like a watch or a clock where everything must fit together; if one cog in the chain stops, the whole procedure stops.

PLANT LAYOUT

The Layout Department and the Plant Equipment Engineering Department are jointly responsible for the task of analyzing all of the problems connected with the rearrangement of the plant machinery and equipment required to meet the rate of production which will be necessary to fulfill the maximum scheduled output. The material handling equipment is also very important, and the planning of this is also the responsibility of these two departments. There are many factors to be taken into consideration, some of which are:

1. How many machines or pieces of special equipment will be necessary for each operation in order to produce the hourly production required to fulfill the maximum schedules? A rule of thumb is to use approximately 80 percent of the rated maximum productive capacity of a piece of equipment in making these calculations, but, as in all rules, there are exceptions where judgment is required, particularly in borderline cases where a slight change in this percentage would decrease or increase the number of pieces of equipment to be made available for a particular operation.

Some machines, such as presses and automatic screw machines, have a high hourly output and therefore may possibly be used for more than one operation on one part. In such cases, provision for die-changing and set-up time must be taken into consideration when determining the number of pieces of equipment required to meet the schedule.

It seems as though it might be possible, if you have one operation that is slightly short of equipment, to bank the material and run it on a third shift as an emergency, in order to pick up the difference between your schedules and machine capacity output. This is not always possible because the banking of some materials will clog things up to a very considerable extent.

We have at present a problem which has not been solved. The presses on the new sheet metal work, which we ourselves will start to make, are going to produce front fender stampings faster than the butt welding operation which is going to be made on the fender. We do not as yet know just what to do about it. The manufacturer of the welders tells us that the machines will not do the butt welding job as fast as we want it done in order to keep up with the presses. We do not want to take the manufacturer's word as final until we ourselves give it a whirl. Fenders are very bulky items, and we just cannot bank them ahead of the butt welding operation, as we do not have available space to store such a bank. Furthermore, storage of sheet metal presents another problem because it is liable to become scratched and dented in storage, and this then calls for metal finishing. You can really pour a lot of money into excess metal finishing work, as that is one of the costliest operations on an automobile. So, while we do not have that problem solved as yet, it must be solved, as otherwise the entire fender press line would have to be slowed down.

2. What banks of material must be carried ahead of the originating machine operations; between machine operations; between machine operations and sub-assembly operations; between subassembly and unit-assembly operations; and between the final operation on a part, a subassembly, or a unit-assembly, and the point where the final end-product assembly is performed?

3. What method will be used in bringing material up to the banks which are ahead of the originating operations; and what methods will be used in moving material between operations until the part is completed; also how will the part then be carried to the subassembly, unit-assembly, and final assembly lines?

4. Will banks of material between operations be carried in movable containers or on pallets; on gravity or on power-operated roller or belt conveyors; or on overhead conveyors?

The conclusions formed regarding the foregoing questions must take into consideration the types of parts which are involved. Some parts will be made at a production rate which approximates the usage rate in the product, and such parts should therefore flow directly to the point where they are to be used in a subassembly or in a final assembly.

To illustrate that, in our engine production lines--Studebaker makes its own engines--the rate of flow in the engine lines all through the machining and subassembly of parts of the engine, approximates the speed of the assembly of the engine on the final engine assembly conveyor. Small insurance banks of engines are always maintained so that if any delay happened in the engine assembly it would not be necessary to shut down the final car assembly line. The speed of the final engine assembly line, when considered over a 24-hour period, is approximately the same as the rate of usage in the car and truck final assembly lines, and the engines are carried on an overhead conveyor directly from the engine assembly line to the passenger car final assembly. The engines which are used in trucks are taken off the conveyor at a loading dock, where they are shipped by truck to the truck assembly plant, located some two miles south of the main plant. Engines for service are also taken off the conveyor at a loading dock, from which they are taken by truck to the Studebaker Plant No. 8, which is devoted exclusively to the storing and shipping of service parts.

The usual practice is to have a bank of such parts as insurance against delays due to breakdowns, but this insurance bank does not necessarily have to be adjacent to the production line. If the material in the bank must be rotated in order to prevent deterioration, it should be stored in a location which is reasonably accessible; but if the type of part is such that deterioration will not occur in storage, the accessible location of this bank is not of prime importance. Some parts which are necessarily produced much more rapidly than they are used in the end product, such as small stampings and screw machine parts, necessarily go into storage banks and are then fed out of the bank into the production lines as required.

The quantities of parts which will be carried in the afore-mentioned types of material banks must be determined so that the floor space required may be calculated, as providing floor space, or overhead conveyor space, for material banks are just as necessary as providing space for machine and assembly lines.

The usual layout procedure in most companies is for the Layout Department to make cardboard cutouts to scale, based on the floor space required for each machine and for each bank of material. These cutouts are then mounted on departmental layout boards with thumb tacks so that various arrangements of the cutouts can be made and discussed between the Plant Equipment Engineering Department, the Foremen of the operating departments involved, and the Divisional and General Superintendent. Conveyors, when required, are indicated by the use of colored tapes which are pasted on the layout table, various colors indicating the types of conveyors that are to be used. Conveyorized assembly lines have been widely publicized in connection with the automotive industry, and all of you are familiar with the general principles involved. There is some variation in practice between companies, due to the physical limitations of floor space, or due to difference in product which causes variations in the assembly methods which are used. A general rule for conveyorizing material for assembly is to arrange the conveyor so that the work is at the most convenient height for the operator, and in carrying out this principle, it is frequently necessary to vary the height of the conveyor for different operations. Customary practice, after the chassis assembly work has been completed and the tires mounted on the car, is to use floor level conveyors where the body and sheet metal work is added and the final connections and adjustments made. Pits are provided between the floor conveyor rails for those final operations that must be performed beneath the car.

Final assembly conveyors run continuously at a predetermined speed. Push-button stations are located along the path of the conveyor so that when trouble develops the conveyor can be stopped. When such a stoppage occurs, a system of lights is so arranged that the work area where the trouble has developed is indicated by them to assist supervision in promptly locating the work area where the difficulty has occurred. Exceptionally long assembly lines are frequently equipped with electric signs which are located at intervals above the conveyor and which indicate the work zone area where the stop button has been pushed.

Some assembly conveyor lines have a continuous length as high as 1,200 feet. Trouble in any one spot along that line may cause a necessary stoppage, so there are zone numbers assigned, which will run possibly from 1 to 10. If the stop button in zone No. 1 is pushed, thereby stopping the conveyor, No. 1 would show up on all of the electric signs posted at intervals above the conveyor, thus enabling the supervisors to concentrate at the proper point in order to apply corrective measures to whatever caused the trouble. Anything which will expedite the correction of trouble on a conveyor line is well worth while, as stopping a heavily manned conveyor line really is a costly procedure.

Conveyors which feed heavy parts, such as axles and motors, up to the main assembly line do not run continuously, but they may have an electric switch arrangement whereby the conveyor advances one station toward the main line after a subassembled part has been removed, thereby bringing up another part. These switches may be operated manually by the operator who removes the subassembly or, in some cases, the switches are operated automatically when a part is removed. The use of such a device keeps the work on the subassembly lines in exact timing with the usage of the parts in the main assembly. These refinements are worked out by the Layout Department and the Plant Equipment Engineering Department before the approved layout is finally released.

Possibly some statistics regarding the conveyorizing of an assembly plant will be of interest. Studebaker in the latter part of 1947 purchased from the Government the South Bend plant which Studebaker operated during the war period in making B-17 aviation engines. This plant now houses the Studebaker Truck Assembly and the Export Shipping Division.

Several optional layouts were made for the assembly of the truck before final agreement was reached. The aviation engine test cells occupy the entire north side of the building and, as these were not to be disturbed, the layout adopted for the final assembly was one in which the chassis was assembled on a side arm type conveyor, approximately 24" high, and the completed chassis, with wheels and tires mounted, was then picked up by a fork truck and delivered to the final assembly line, which runs parallel to the chassis assembly line, but this conveyor, which is of the flush floor plate type, moves in the opposite direction.

This has worked out satisfactorily from a material receiving standpoint and also for the storage of completed trucks, before driveaway, in a storage yard which is located south of the plant.

The layout was designed for approximately 20 trucks an hour, on a 16-hour day basis. Not only was this a new assembly plant, but the complete line of trucks was new. However, the layout was planned so carefully that only a few minor changes were necessary after production was started. The conveyor where front axles were subassembled had to be moved approximately 40 feet to the north, due to insufficient space having been provided on the main assembly conveyor for the assembly of the rear axles to the chassis. This adjustment was easily made over a week end.

Approximately two miles of conveyors of various types were required for the complete layout, 840 feet being used for the chassis and final assembly operations, the balance being used for handling material up to the assembly lines and into the banks, for painting cabs and truck body boxes, and for subassembly operations, such as cab and truck body box framing and welding, cab trimming, and adding front end sheet metal, radiators, and lamps to cab assemblies before the cab drop was made onto the chassis.

Plant layout is an interesting study and is a field where ingenuity on the part of the engineers really pays dividends by eliminating excess handling costs. The laying out of final assembly lines, with the subassemblies feeding directly into them, requires a thorough knowledge of the operations and of the space required for the men and material which make up the detail of each operation as it moves along the conveyor. When new products are being fitted into existing buildings, some really tough material handling problems arise, and these must be satisfactorily solved in order to permit a reasonable handling cost and enable a smooth production flow.

In preparing the material in this text, plant layout just could not be separated from tooling, as plant layout and tool engineering must work hand in hand in the development of a manufacturing program.

It has been necessary to touch on many of the points involved in rather a sketchy manner, but as the meeting is to be thrown open to questions, I sincerely trust that you will not hesitate to ask these questions regarding points which you feel have not been clarified or fully covered.

I thank you for the privilege of your having made it possible to present this subject matter to such a representative group of our Armed Forces.

QUESTION: At what point in your production do your spare parts come off, and do you have a set percent; when do you arrive at how many nuts, bolts per item per piece? Can you give us anything on that?

MR. USHER: That practice varies with companies. Speaking for Studebaker, we endeavor at the end of a run before a model change to make a reasonable quantity of spare parts. We then save the tools, dies, and fixtures in case additional quantities of spare parts are required at a later date. These parts are then either made--I mean if we have to make more than the original quantity provided--in our own plant, or they are sent out to a jobbing company. At the present time there is a company in Chicago to which we have shipped a large number of dies for service fenders and other sheet metal parts which are not currently in production. These sheet metal parts are necessarily made in small lot runs and for that reason are comparatively costly. We have made some service sheet metal parts in the new press room, to which previous reference has been made, but this cannot be continued after regular production starts. Our new Commander motor--the 1949 Commander--is a longer stroke motor than was in the 1948 Commander. However, the motors are basically interchangeable, so we can service a complete 1948 motor with one of the new motors, if an entire motor is necessary. Several adapting parts are required, but these are of a minor nature.

Now as to some other service parts, such as crank shafts and parts like that, we made those ourselves; and we have saved the tools to make such items when required. Some service parts have to go through separate equipment, which some plants maintain for that purpose, as it is sometimes difficult to get regular production parts far enough ahead so as to break in on your regular standard equipment in order to produce service parts. Service parts are really a major headache for the Manufacturing Division, particularly those that vary considerably from parts of a like nature being made in current production. It is, however, a very necessary part of the business.

QUESTION: Evidently tooling for a new model must take quite a bit of time, must be quite a job. I was wondering how long it takes to do that retooling and what do you do about minimizing it? The second question: In making these spare parts you say you operate 16 hours a day, would it be practicable to use a third shift to make those spare parts?

MR. USHER: No, it wouldn't, sir; because--I will answer your last question first--to tear down the equipment and set it up would take entirely too long. It can be done at times over a week end, but to produce spare parts on a third shift would be very hard to do, even though the equipment was open on the third shift. Trained men also would not be available for a spasmodic third shift operation, and overtime of trained employees would be required. We do have excess capacity in some of our machining lines, as it is essential--for instance, we are tooled up to make the crankshaft ourselves--it is essential that we make service crankshafts in our own plant. We do have excess capacity planned so we can run ahead on production crankshafts when necessary, and then change over the machining lines to service shafts. There are also companies which do specialize in making service crankshafts, camshafts, and similar parts in small quantities for automobile and truck manufacturers. Because of the small quantities involved, the obtaining of such parts is quite expensive.

QUESTION: How long does it take to shut down and change over?

MR. USHER: This new line of trucks recently brought out by Studebaker started around April 1948. The plant was not down for over three weeks before production was again moving in reasonable quantities. Pilot and educational models were produced in a considerably shorter period than three weeks. The new truck plant is about two miles from where the trucks were previously assembled, necessitating the moving of the equipment, which was the reason for the three weeks' loss. The entire line of trucks was new, the buildings were new so far as truck manufacturing was concerned, and much of the equipment was new. That was accomplished by using large crews of men contracted for on the outside, in fact, everybody was used that we could obtain. Every contractor who had available men was working on it. One of the chief factors in automobile production is the drying equipment for the paint, the washing and bonderizing equipment, and similar items. New drying equipment, using infrared instead of gas, was installed, so it was not necessary to move the old drying equipment, which would have been a considerable task. The washing and bonderizing equipment was moved. The overhead conveyors, being new, were also installed ahead of time. It was necessary to move the chassis and final line conveyors, as well as the conveying equipment for sheet metal assembly and cab trim lines.

We did not lose any time in changing over from the 1948 passenger car to the 1949 passenger car because the changes were relatively minor, although a large number of changes were involved in improvements and refinements. The major change was in the Commander motor, referred to previously which gave it more power.

However, from the start, or the inception of the idea for a new model, if you were going to bring out a completely new model, I think that the statistics, which I read, as given out by the Automobile Manufacturers Association indicate it took about two years from the time the job was started until the project was actually in production. I would say that any company which depended on getting sheet metal dies under less than nine months would very likely be disappointed.

QUESTION: In the case of the conveyor line which may be 1,200 feet long, how do you handle the problem of inspection and rejection along the way? Are there established stations along the line to remove work not up to standard, or does it continue through the line with a special identification to insure that it does not reach final assembly and inspection?

MR. USHER: Anything completely spoiled is removed from the line immediately. No further work is done. The inspectors are on the most important operations at various points along the machining line, such as on the engine block machining line, where many inspectors are stationed. If they find anything wrong, it comes off. The timing of the various operations is such that we can lose some pieces due to spoilage and still have enough parts banked on the conveyor to fill the gap. In case some machine does get a little behind, we can always work that particular machine overtime to refill a bank which has been depleted due to spoiled parts.

QUESTION: I was thinking of the main assembly line, not the subassembly

MR. USHER: Well, once in a while we do take one off the assembly line. We do not find many troubles on the main assembly lines that cannot be rectified on the spot without stopping the line. It is very seldom that a job has to be taken completely off the conveyor. The parts that go into the assembly are quite thoroughly inspected before they get there. It would be pretty hard to foul a job up so much on the final assembly line that a repairman stationed along the line couldn't do the mending and get it moving again. If a thread is stripped, or something along that nature occurs, they might have to tag it and then let it go through all of the other operations, so that the spoiled operation could have that part replaced in either the light or heavy repair service which, of course, is maintained at the end of the final assembly lines. Trucks are given a final inspection, and there are always some trucks taken over to the heavy repair. The same thing happens with passenger cars, which, after they leave the final assembly line, go into what we call the "doll-up" line. They are very thoroughly checked, and anything which cannot be repaired on the "doll-up" line, which is a conveyorized line, is pulled off and sent over to a passenger car heavy repair department.

Paint repair is also handled at the end of the assembly lines. If there are a few imperfections in the paint, it goes to a specialized paint line where it will be touched up.

COLONEL HOEFFER: Mr. Usner, we have used our alloted time. I thank you on behalf of the College and our guests for a very comprehensive talk on production.

(6 April 1949--750)S/mmg