HOW TO GET THE MOST OUT OF YOUR TURRET LATHE

a guide to
better
turret lathe
practice

THE WARNER & SWASEY COMPANY · CLEVELAND, OHIO

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OUT OF YOUR

TURRET LATHE

A GUIDE TO MODERN PRACTICE
IN WORK PLANNING, TOOLING, AND PRODUCTION

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CONTENTS

PREFACE

This book consists of a series of articles which presents the best in up-to-date practice in the **management** of the turret lathe.

Thus it supplements the well-known Warner & Swasey Operator's Manual, which offers a detailed study of the handling — or actual physical operation — of the turret lathe.

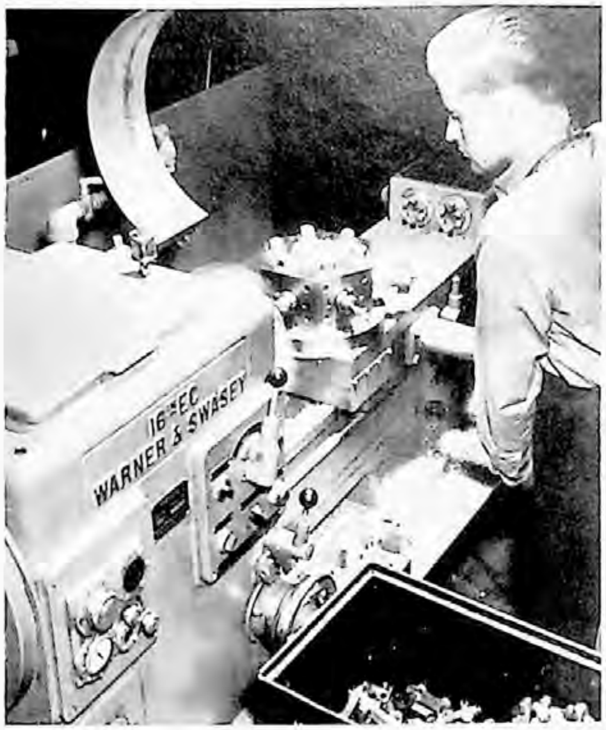
The articles are essays and actual case histories which collectively show the way to a very vital goal, that of getting maximum production at least cost—and with minimum effort.

Much of the ground covered lies in the area where great gains can be made — that of organizing the work prior to actual metal-cutting. Work planning, establishing the sequence of jobs to be run, selection of tooling and minimizing setup requirements are among the subjects covered.

As a result, the tool engineer, methods man, equipment engineer, supervisor and the owner himself stand to gain as much as the advanced operator from a careful study of the principles presented.

THE WARNER & SWASEY CO.

HOW TO GET THE MOST OUT OF TURRET LATHES



Automatic control panel takes over many manual operator functions on this chucking turret lathe. Because of its fatigue-reducing characteristics, machines of this type are well suited to jobs with large proportion of handling to cutting time in the over-all machine cycle

Turret-lathe efficiency depends not only on the machine itself but also on teamwork between shop and office personnel. This means preplanning, for without preplanning, the flexibility of the machine may tempt its user into cutting practices that sap its profit-producing potential. Here are eight fundamentals of turret-lathe practice which the user must observe so the machine can produce effectively

1. Match the Job and the Machine

Jobs may be too simple or too stringent for the turrent lathe. Such jobs dissipate profits rapidly. Jobs involving simple drilling and facing may be handled well enough on a drillpress with a smaller overhead rate. On the other hand, grinders, tapping machines, thread millers, and precision boring and turning equipment hold limits of tolerance and finish beyond the capacity of the turret lathe for work required in production lots. Tolerances to 0.0005-in. and finishes to about 60 micro inches rms may be handled by the well-conditioned horizontal turret lathe. Limits beyond these exceed the normal capacity of the machine to produce large quantities efficiently.

What effect has the size and type of job on the size and type of turret lathe selected? The modern concept of machine selection considers metal-removing ability and maneuverability as true gages of job placement. Yet, collect capacity or swing over the bedways may mislead the user into scheduling jobs according to dimensional capacity.

For instance, is it true that a 2-in. bar which must be reduced to $\frac{3}{4}$-in. diameter in one pass belongs on a turret lathe with a 2-in. collet chuck? The turret-lathe user may readily agree that a machine with a $2\frac{1}{2}$- or 3-in. collect chuck and greater metal-removing capacity will produce the work at less cost than the smaller turret lathe. This is true if there are enough savings in production to overcome the higher cost of the larger machine. Calculations usually are necessary to evaluate this relationship.

Another consideration is the ratio of handling time to cutting time for different jobs made from different materials. For example, the average production cycle of small-to-medium-size brass castings may contain 80% handling time and 20% cutting time. And certain cast-iron and steel jobs may have 30 to 40% handling time against 70 or 60% cutting time. Consequently, machines are available with semi-automatic control features that transfer certain functions of manual handling to the automatic control panel. Production increases of 25% for iron and steel jobs and 300% for brass jobs have been possible through the application of this type of machine control to suitable work requirements.

In any event, matching of job to machine is of vital importance in establishing the basis for all other factors in good turret-lathe practice.

2. Keep the Machine in Condition

A machine cannot operate at low cost if it is not in condition. The need for major overhauls and reconditioning is recognizable and ordinarily satisfied without delay. The advantages of routine maintenance are not so readily appreciated. For example, accuracy in turret-lathe production is a direct function of machine alignment. Maintenance of alignment is fundamental to turret-lathe practice and, properly attended to, reduces undue wear in toolslides and minimizes taper boring and turning.

Headstock and feed clutches must be in proper adjustment if available power is to be transferred to the cutter and wear on clutch plates minimized. Turret binder clamps are adjustable and must be kept in adjustment to preserve accuracy and the ability to withstand heavy cuts.

Square and hexagon turrets should be checked periodically for index accuracy. If required, the lock bolts may be replaced to restore original machine performance.

Toolslides ordinarily are equipped with gibs which must be in adjustment so slides progress under feed in a uniform manner. As with turret binder clamps, this helps maintain accuracy and promotes metal-removing capacity.

V-belts between the main drive motor and drive shaft must be in condition and properly adjusted to transfer power to the headstock effectively.

Spindle bearings must be in proper adjustment if chatter and poor finish are to be controlled. Adjustment normally is not complicated, although users may request assistance from turret-lathe manufacturers when required.

Cleanliness on and around the turret lathe is of prime importance. The turret-ram slide and cross-slide of the machine should be removed and cleaned periodically. Workholding devices also should be disassembled, cleaned, and lubricated regularly if accuracy is to be maintained.

It is of course axiomatic that a planned schedule of routine lubrication for the entire machine should be maintained according to the turret-lathe manufacturer's recommendations.

3. Eliminate Production Delays

As with other machine tools, the turret lathe produces profits only when it is running. In some cases, down-time is excusable, but in most cases the various influences on machine performance which establish its net operating day should be inspected closely.

For example, the job always should be at hand near the machine before the job currently on the machine runs out. Frequently a "utility man" in the department may be charged with this responsibility. When the foreman assigns the next job to a given machine, the utility man has advance notice that bar stock is to be ordered or castings moved to the machine prior to the operator's need for the material.

In like manner, tools for the next job should be available in advance. Many turret-lathe departments have a "tool selector," who may be a former setup man, check the advance schedule board and make sure that all cutters, fixtures, and tools are next to the machine along with the raw material. This prevents delay between tearing down the current setup and beginning the next job. Depending on the tool selector's qualifications, such a man may be invaluable in helping the foreman advise operators on speeds, feeds, arrangements of tools where setup cards are not available, and similar problems.

Some delay in machine operation may arise from disputes between inspection and the shop concerning the nature of work specified on the blueprint. If tolerances, finishes, and concentricities are not specified exactly, then there is no common ground for cooperation between inspection and production. This may lead to endless discussion concerning the acceptability of the work, during which time the machine may not be in production.

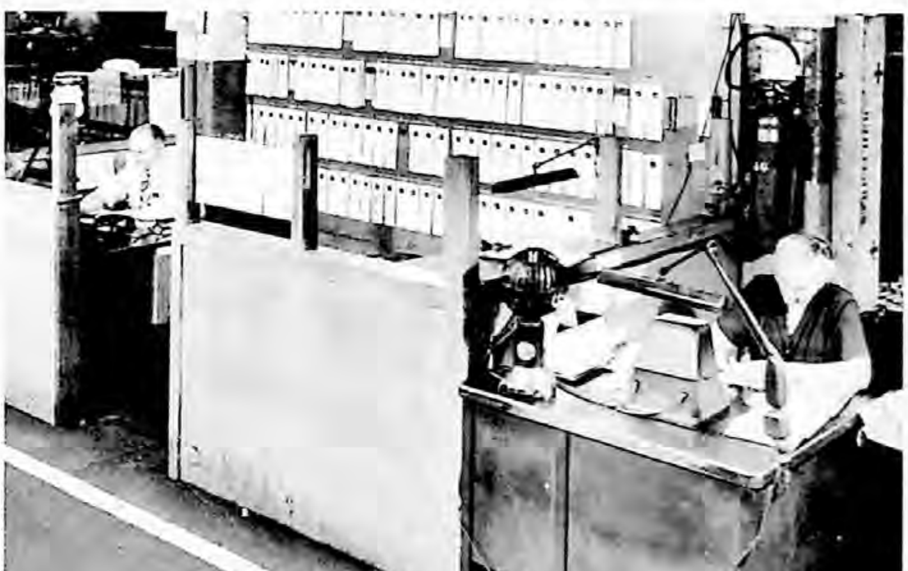
When possible, such routine processes as chip disposal, lubrication, and minor adjustments should be scheduled for lunch hour, second shift, or other slack production periods.

When all details are under full control, the foreman can devote more of his day to supervision and job scheduling. This is essential to full production.

4. Select and Maintain Cutting Tools Properly

Despite the prevalent use of carbide cutting tools on horizontal turret lathes, opportunities arise which justify the selection of high-speed steel and cast alloys. Turret-lathe setups should be analyzed to determine the cutting material most likely to "lay more pieces on the floor" at the end of a given production period. The application of that material then should be developed fully. In many cases, a combination of two or more cutting materials may be most effective.

An important source of increased productivity is centralized responsibility for the performance and grinding of cutting tools. The importance of this system of control is proportionate to the number of turret lathes in a shop department or plant, and may in some cases represent the difference between low- and high-cost production. A centralized responsibility can accumulate the broad experience necessary for intelligent application of cutters of all sorts. It



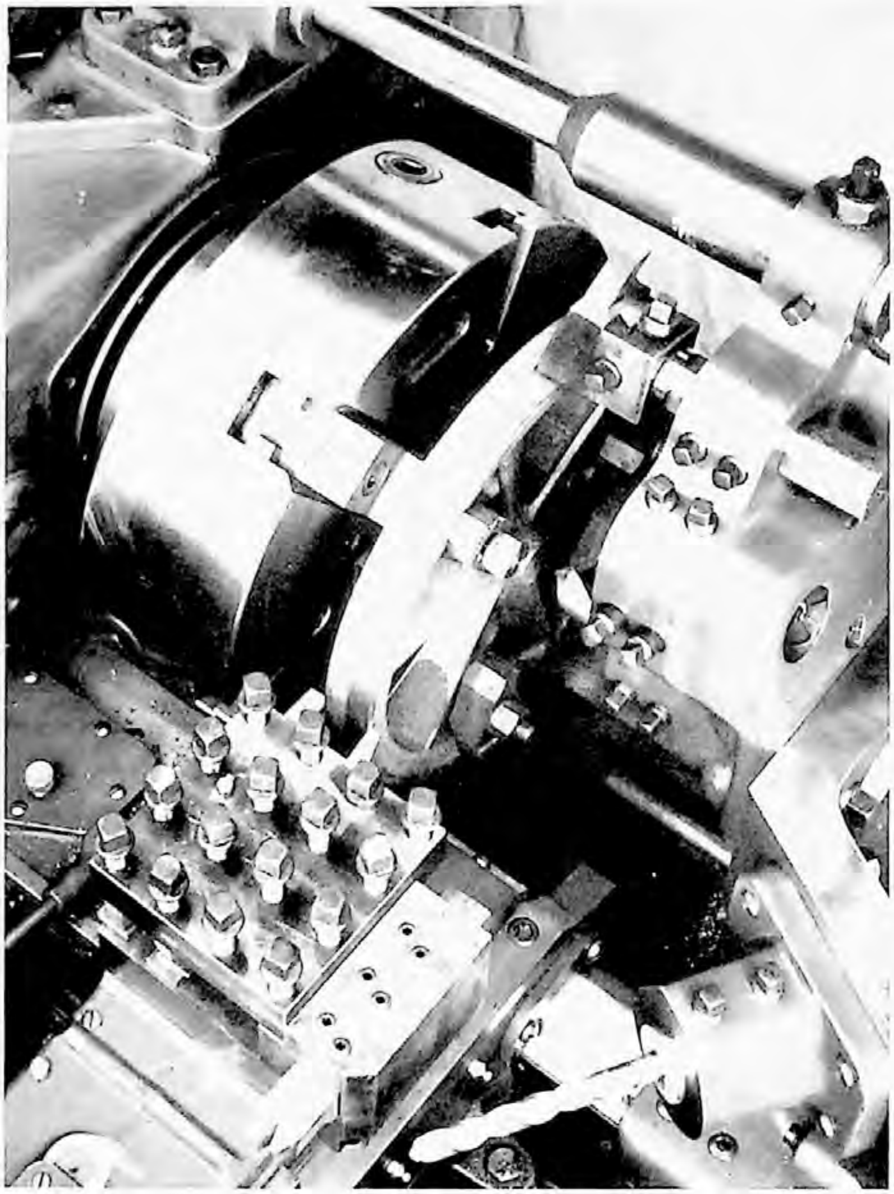
Eliminate production delays—Foreman's booth in Warner & Swasey turret lathe department is control center for some 60 turret lathes. Job cards in rack schedule work to various machine centers in department. Board is part of system that provides tools, bar stock, and castings to each machine in advance of setup also can minimize the number of shapes of tools required and, in the case of carbide, the number of grades necessary. Advantages of this function are similar to those of centralized grinding, which permits cutter sharpening on machines rather than at the turret lathe—more than likely done by hand at that source. As mentioned previously, a secondary advantage of centralized tool control lies in maintaining an adequate supply of sharp cutters on hand in advance of machine needs.

5. Use the Turret Lathe As a Turret Lathe

The horizontal turret lathe originally was designed for mounting tools in an indexing turret so numerous cuts could be taken in rapid succession. The second important design change in turret lathes, made about 35 years ago, introduced a cross-slide which could be fed under power simultaneously with the power-feeding hex turret. The principle of tooling practice behind this design is still as important today as it was 35 years ago. Much of the ability of the turret lathe to produce at low cost lies in its ability to combine cuts from the cross-slide simultaneously with cuts from the hexagon turret. Whenever this principle is not applied, the turret lathe is not producing at maximum efficiency, and steps should be taken either to retool the job or to transfer it to another machine if it is so simple that combined cuts are not feasible.

It should be understood that multiple cuts — that is, cutters arranged to operate simultaneously from an individual cutting station—save time and fatigue, as well as promote accuracy, by eliminating the need for operator attention to machine stops.

There is a prevalent tendency among turret-lathe users to perform an excessive amount of turning, chamfering, and like operations from the cross-slide of the machine, at the same time limiting the hexagon turret to centerline work such as drilling, boring, and reaming. It can not be emphasized too strongly that the primary function of the cross-slide of a turret lathe is to combine cuts with the hexagon turret lathe or to perform cutting operations **that cannot possibly be arranged on the hexagon turret.**



Use the turret lathe as a turret lathe—Note combined and mutiple cuts. Overhead turning is done in multiple with start-drilling operation from hex turret. Cutters in square turret straddle-face rim of cast-iron fan pulley. Tools in both turrets cut in combination with each other—a basic principle of turret-lathe practice

For example, a turning cut should not be taken from the square turret while the hexagon turret is idle. A better arrangement is to turn from the hex turret with a cutter preset to size in combination with a facing or chamfering cut from the cross-slide. When cuts are set up on the hexagon turret, it is possible to set positive machine stops for those cuts. This not only speeds up the job and reduces operator fatigue, but also maintains fixed cutter-settings such as are not possible with cutters on the cross-slide.

6. Select the Right Durable Tools

In a turret-lathe setup, tools may work satisfactorily to all visible intents, yet obscure changes frequently are possible which further reduce production costs. For example, relatively inexpensive chuck jaws built specially to hold a given casting may permit greater feeds and speeds through more rigid holding.

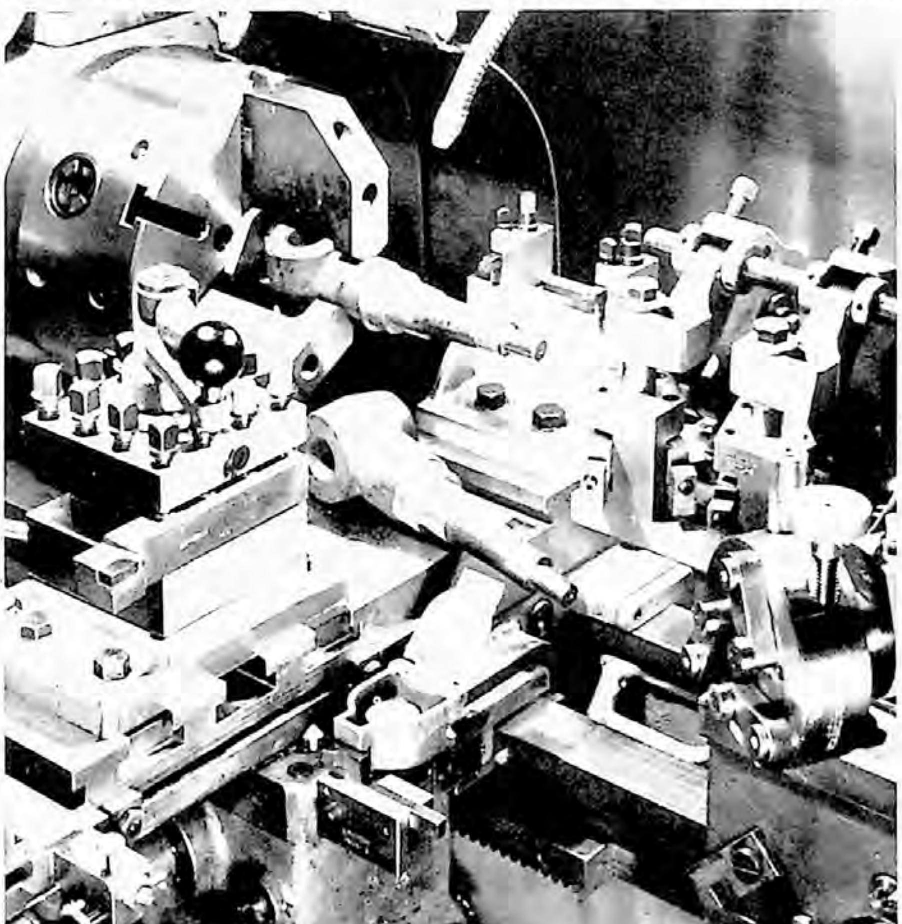
Most manufacturers of turret lathes offer complete lines of universal standard tooling which can be arranged in a permanent manner on the hexagon turret. Setup or changeover time can be minimized, thereby extending the turret-lathe principle into smaller job lots. By the same token, many turret-lathe setups can benefit from the judicious application of special boring bars, work-holding fixtures, cutter blocks, and so on. The rather sensitive relationship between standard and special tooling ordinarily is not judged offhand but requires balancing the costs of production with special tooling against the quantity of pieces to be made to determine whether such tooling is justified or not.

7. Pick Right Size and Type Motor

An underpowered machine cannot remove metal at rates consistent with good turret-lathe practice, provided such metal-cutting capacity is required of the lathe, nor can an overpowered machine entirely justify itself if the nature of the work does not require such powering.

Generally speaking, if the turret-lathe user has a large variety of work in small-to-medium quantities which must be machined from a variety of soft and hard materials, it is advisable to equip his turret lathe with a main drive motor which matches the capacity of the headstock. Although some jobs may not require the power available, there can be times when the maximum capacity of the machine is necessary to do the work satisfactorily.

By the same token, if the turret-lathe user is able to define his work flow over given machines, then the nature of the work may be related more specifically to the size of motor required for the lathe. Frequently it is an advantage to match job power requirements with the motor so the motor will work oftenest in its highest range of efficiency and power factor.



Select the right durable tools—Standard and special tools are properly combined to produce cast-steel part at low cost. Special jaws grip piece with sufficient tightness to permit heavy cutting feeds. Dial indicator on carriage measures adjustment of cross-slide for close forming

Many shops have penalty clauses in their contracts with utility companies. These require that the shop power factor be kept at or above a stated minimum. A general condition of over-motoring in a shop has an injurious effect on the shop power factor and may therefore increase the cost of power.

Turret-lathe headstocks are available in a variety of types —all-geared, direct motor-drive, or automatically controlled. All-geared headstocks, however, which change speeds either by shifting gears or by clutches, may, in many cases, be improved in operation by a two-speed motor. For instance, a 2-in. ram-type bar turret lathe may be equipped with a 15/7½-hp, 1800/900-rpm motor. Ordinarily this machine has twelve headstock speeds obtained by shifting gears. With the two-speed motor, an additional range of twelve speeds is obtained by a push-button shift in the starter box on the head of the machine. This extends the range of speeds conveniently available to the operator and invariably aids production.

8. Gage the Fitness of the Machine for Further Service

When is a turret lathe unfit for further service? Generally speaking, high maintenance costs, loss in accuracy, and excessive down-time are considered the important measures of a turret lathe's profit-producing potential. All of these factors relate to deterioration; none of them include the less-frequently discussed factor of obsolescence. Yet, a six-months old machine tool in good condition may be unfit for further service because is is obsolete and thus is not able to compete production-wise with an improved model. When profit margins are thin, as in a competitive economy, the factor of obsolescence as a deterrent to low-cost production is just as important as deterioration. Therefore, a better yardstick by which to gage a turret lathe's ability to produce efficiently is any recognized system of comparing total yearly costs of operations between present equipment and equipment which is available for the job.

For example, a machine in service may be examined for its cost of operation based on maintenance, down-time, scrap or salvage, power consumption, property taxes, insurance, direct and indirect labor costs, and so on. Another machine available for the same service but not present in the user's shop may likewise be examined for its comparative ability based on the factors cited. Should an excess cost of operation appear chargeable to the equipment in use, then it is an economic advisability to make the replacement with the available new machine.

The important point is that inaccuracy, excessive maintenance, and so on, are quite evident and may be spotted without difficulty in equipment in present use. Far less obvious are the lost savings or the excess cost of operations because of another machine which could produce the work at less cost if it were placed in service. A realistic policy should be adopted to keep a machine in use only until such time as it can no longer hold its own against a lower-cost producer.

A secondary advantage of machine replacement lies in work downgrading which takes effect when a new machine is placed in service. Normally, if ten machines in a turret-lathe department are examined and one new machine added, the tenth machine is displaced and much of the more accurate and critical work gravitates naturally to the new machine. In effect, the remaining nine machines then are assigned work on a scale lower than that previously produced. This means that profits may be multiplied throughout the department by virtue of a single machine replacement. All work, in effect, is performed on better machines.

The virtues of these eight fundamentals have been proved in practice. They are an important reservoir of profits and the user of turret lathes is urged to examine his turret-lathe practice continually to make sure he is getting the profits implied by the equipment at hand.

CLASSIFICATION of TURRET LATHES

General description of the horizontal turret lathe; the various types available; and standard attachments.

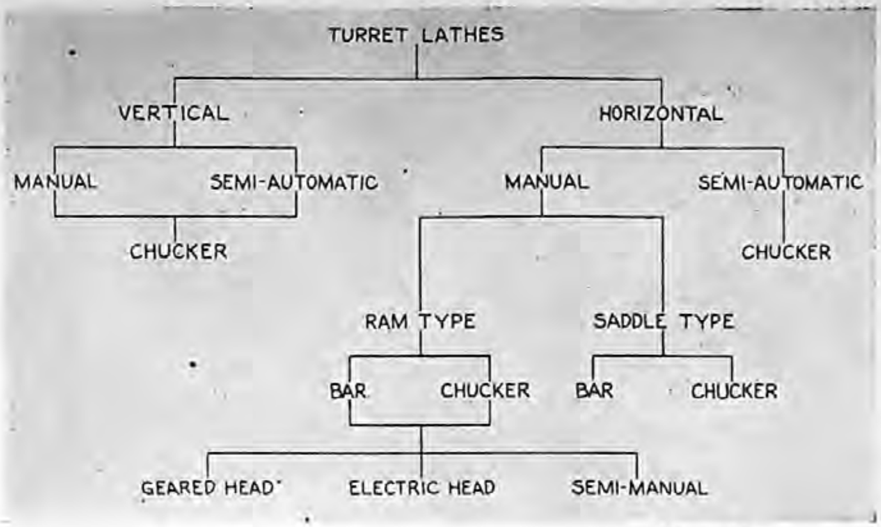


Figure 1

The horizontal hand-operated turret lathe of today is a vast improvement over that built only 35 years ago; perhaps no other type of machine tool has experienced such pronounced changes in design in such a short span as the turret lathe.

The reasons for this are significant. Since the earliest days of interchangeable parts manufacturing, the cost of producing work has affected the shape of human affairs, and the law of survival has constantly forced the search for better ways of doing things.

During this period, cost and quality unfortunately have never been respectful of quantity, and the same standards of good work at low cost have applied, and still apply, alike to the need for one piece or for thousands of pieces. In this lies the reason behind the development of the horizontal turret lathe and the reason for its importance in today's production scheme.

The turret lathe first assumed its place in industry by enabling cuts on a work piece to be taken in quick succession through a system of indexing turret tool holders. The cutters were grouped in multiples on a tool station, and combined in the cutting cycle with one or more cutters on another tool station. This is important. It is one of the basic theories of turret lathe practice—one which primarily justifies the existence of the standard turret lathe, and yet is a practical cost-reducing theory that is violated more consistently than any other in turret lathe practice.

The continuous demand for better work in less time has created in the turret lathe of today a machine tool for producing an infinite variety of work in job lots of one to thousands. The modern turret lathe fills the requirements for rapid metal removal, strict standards of surface finish and size control, and maximum relief from operator fatigue.

One of the first requisites of good turret lathe practice is the proper selection of the type machine for the job. In this respect, there are several types of turret lathes available as shown in the chart, Figure 1.

Turret lathes may be broadly put in two classes—horizontal or vertical, each type being available as a hand or semi-automatically controlled machine.

The vertical turret lathe is equipped with a horizontal work table. Advantages for this type of turret lathe are immediately apparent for large, heavy work, or work with pendant arms requiring a large swing out of proportion to smaller cutting diameters, and overhanging work with lengthy distances between chucking and cutting areas. The vertical turret lathe can be equipped with automatic control units, which make it particularly suitable for high production runs. Standard semi-automatic horizontal turret lathes can best be used where the advantages of automatic job cycling are useful to reduce costs on the longer run jobs.

However, neither the vertical machine nor the semi-automatic turret lathe possesses all of the special advantages of the hand-operated horizontal turret lathe that are required to handle an infinite range of jobs in all sizes of job lots.

The horizontal hand-operated turret lathe, known simply as the turret lathe, obtains its advantage on work of a relatively compact nature. Many sizes and types are built with overlapping capacities, thus permitting a most efficient correlation of work range to machine size.

This machine being equipped with a horizontal spindle, permits free interchange between bar and chucking work on the same machine through the use of proper tooling. Turret lathes may therefore be further classed as bar or chucking machines, the basic machine being equipped with suitable tooling and work-holding devices for either or both types of work. The horizontal bar or chucking machine may in addition be classified as ram or saddle type.

THE RAM TYPE TURRET LATHE

This lathe is so named because the indexing hexagon turret is mounted on a ram slide which is guided by a saddle which, though adjustable on the bed, is clamped in one position for any particular job. The indexing stroke of the hexagon turret head is hand operated through a turnstile, rack and pinion. Power feed for the turret is obtained by clutch engagement to the power feed rod. Due to the ram construction, the principal limitation of the ram type machine is in the length of the working stroke, which varies with the size machine from about 4″ to 15″. Ram type turret lathes are built with bar capacities up to 2½″ diameter and chucking swings up to approximately 20″ and may be powered with drive motors ranging from 3 to 15 h.p.

Figure 2 illustrates a hand-operated horizontal ram type turret lathe with capacity through the spindle collet tube for 1½″ round bar stock and with a chucking capacity over the bedways of 15⅝″. Note that the term "hand operated" refers to the manual feeding of the bar stock through the collet chuck for successive work pieces and to the fact that the cross slide unit and hexagon turret units are positioned adjacent to the cutting areas by hand before the power feeds are engaged for actual metal removal.

From a description of the component parts and functions of a typical ram type turret lathe, as in Figure 2, it can be noted how the design of the various components permits the machine to be used on duplicate or repetitive work.

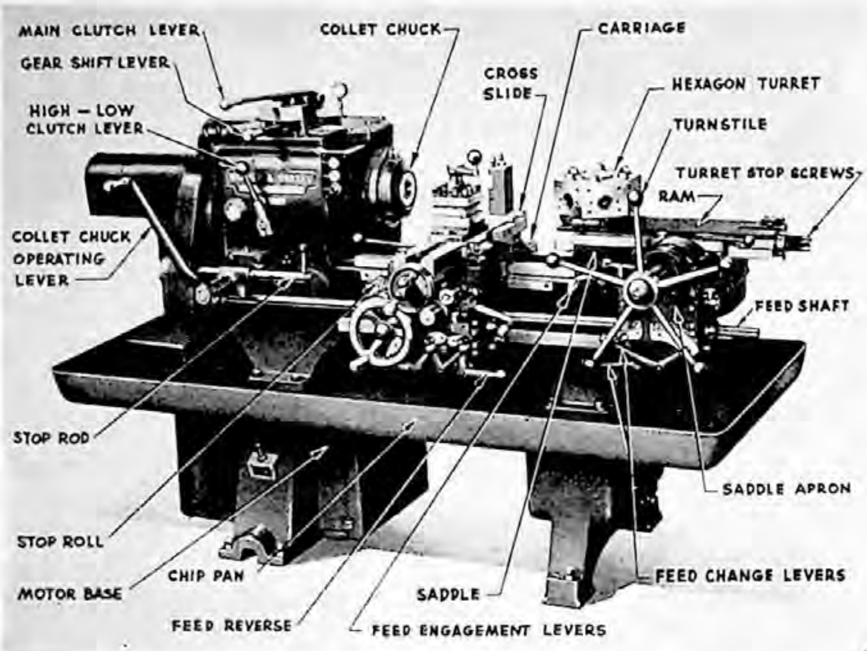


Fig. 2. The basic elements of a standard hand-operated ram type turret lathe.

The headstock and bed are cast in one piece for rigidity, and the bedways are machined integral with the bed casting for the purpose of guiding the cross slide unit. This machine has an all-geared headstock with three basic speeds obtainable by changing the spindle speed gear shift selector lever. These three speeds are increased to six by a high-low lever mounted on the front of the headstock. The available spindle speeds of the machine can be further increased to twelve by means of a two-speed electric drive motor mounted in the pedestal base. Thus four speeds may be obtained without changing the gear setting by simply shifting the high-low clutch lever and by actuating the high-low pushbutton in the electrical control station. The machine spindle is mounted in anti-friction bearings, and the nose end of the spindle conforms to American Standard specifications for interchange of work-holding devices. The machine shown in Figure 2 is equipped with a collet chuck for holding round, square, or hexagon bar stock, and the collet chuck is opened and closed by means of the collet closing and bar feed lever.

The advancement of the bar stock through the collet is obtained by pulling this lever toward the operator, and the collet is closed by advancing the same lever toward the rear of the machine.

Two cutting units, the cross slide unit and the indexing hexagon turret unit, are mounted to the bedway in such a manner that power cuts may be taken on the work piece either individually or simultaneously. The cross slide unit consists of a carriage which slides on the bedways and a gear apron which is fitted beneath the carriage. The cross slide traverses at right angles to the bedways on the carriage. Mounted to this cross slide are the four-way indexing tool posts and non-indexing rear tool post.

THE SADDLE TYPE TURRET LATHE

This type machine is designed with the indexing hex turret mounted directly to the saddle, without the use of an intermediate ram. The saddle, in turn, slides directly on the bedway. This, in effect, greatly increases the length of the work stroke and rigidity compared to the ram machine, the only limitation being in the given length of the bed. Saddle machines are available with bar chuck capacities up to 6″ round and chucking swings up to approximately 30″ in diameter. Machines of this type are generally powered by drive motors from 15 to 50 h.p.

Figure 3 illustrates a typical saddle type turret lathe. The machine is a 2A turret lathe and is shown with a three-jaw scroll chuck and ranges up to 20″ swing for chucking and 3½″ round for bar work. This machine is also built with a one-piece headstock and bed which is mounted on support legs with an intermediary cutting fluid and chip pan. The spindle is mounted in anti-friction bearings, and the spindle nose built to conform to the standard flanged nose specifications. Shown fitted to the top of the headstock is the preselector head with a single clutch lever for forward and reverse operations of the spindle and the speed selector handwheel. This unit permits the preselection of the next spindle speed in the cycle of operations for any given job while one cut is in progress. At the end of the cut, the machine operator may shift the preselected spindle speed into gear by simply pulling down on the clutch lever. The saddle type machine, as well as the ram type machine, is equipped with both the four-position indexing turret on the cross slide and the six-position hexagon turret on the saddle. These units may be fed under power together or separately, thus permitting the effective use of combined and multiple cuts for savings in cutting and handling time. Since the saddle type machine is built in the larger capacities, a rapid traverse shaft is normally included from which power take-off can be provided to the carriage and saddle aprons. Note how the saddle of the machine, shown in Figure 3, fits directly to the bedways and how the hexagon turret is mounted on this saddle. As mentioned previously, this means that the entire unit has no fixed position on the bed for any one job and may be advanced to or from the work as the cutting requirements demand. This, in effect, provides a constant overhang of all cutting tools from the hexagon turret, regardless of the progress of the cut or length of cut, and also allows exceptionally long turning, drilling or boring jobs to be performed from the hexagon turret with less limitations than that of the ram type machine where the ram itself moves within the stop limitations of the saddle.

TURRET LATHE ATTACHMENTS

The flexibility of turret lathes is greatly broadened with a variety of attachments. Discounting the wide variety of standard work-holding devices and standard tool holders, which in themselves make the turret lathe a versatile producing unit, there are also several types of threading and taper attachments available.

SCREW CUTTING. Threads in production may be cut from the hexagon turret by taps and dies in one pass or they may be generated by single point tools with suitable lead control from the cross slide carriage on ram type machines and from the hexagon turret of a saddle type machine, provided the latter is equipped with a cross sliding hexagon turret. There are four types of threading attachments: 1. leading-on attachments. 2. leader and follower attachments. 3. change gear full length lead screws, and 4. full length lead screw with quick change gear box. Changes in pitch for different threads are obtained in the first two instances by changing leaders and half nuts in the threading attachment. Separate replaceable change gears in the head end gear box are used to establish pitch for the third and different pitches are obtained for the fourth through changing the position of the tumbler lever in the quick change gear box.

TAPER ATTACHMENTS. Straight tapered surfaces may be produced on turret lathes with the cross slide unit by using taper attachments or compounds. Simple contours may be produced with the taper attachment by substituting a profile guide plate for the straight plate or by the use of special contouring devices.

STEADY RESTS. Fixed-position steady rests may be used on turret lathes for supporting overhanging work. They are usually built to special specifications and may be the closed type, where the carriage may work on either but not both sides of the rest, or the open type, which permits free travel of the carriage on either side of the steady rest where cuts must be taken on both ends of the work piece during the course of one chucking.

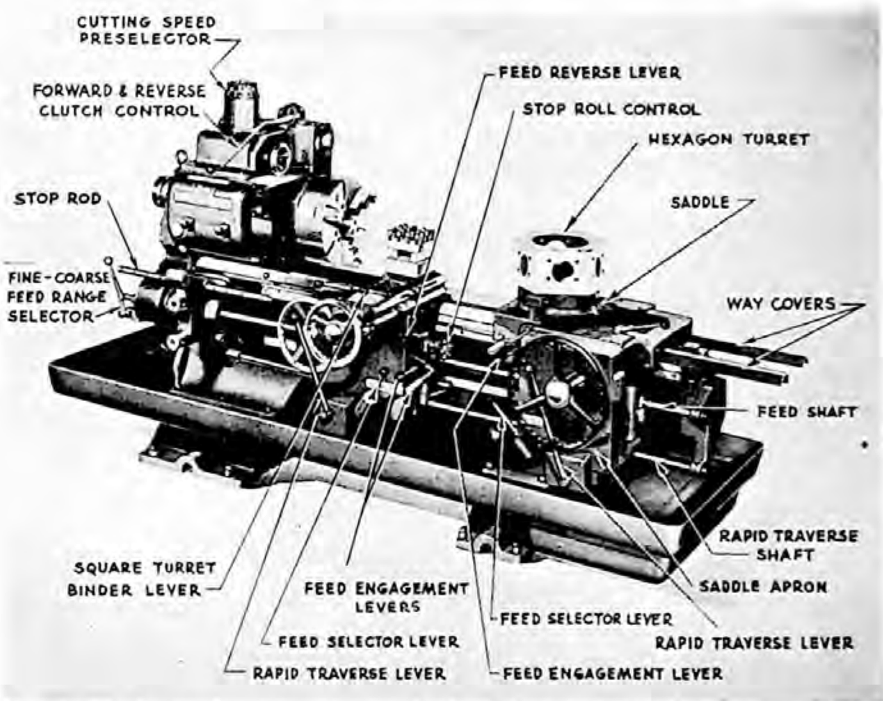


Fig. 3. The basic elements of a standard saddle type turret lathe arranged as a chucking machine. Note the rapid traverse control levers which reduce to some extent the manual effort required to position the two cutting units.

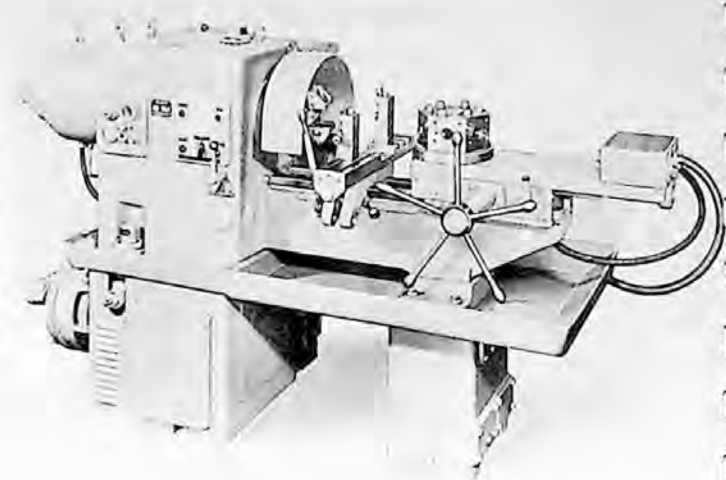


Fig. 4. A manually-operated high speed turret lathe for machining non-ferrous materials. Full control of spindle functions may be obtained by setting buttons on the drum.

Within very recent years, a new type of turret lathe has been built which combines many of the advantages of both the hand and semi-automatic machines. This lathe allows the machine operator to retain the "feel" so essential to many jobs, and yet transfers control of spindle functions such as speed shifting, direction of rotation, etc., to automatic devices. A lathe of this type is illustrated in Figure 4.

This machine is designed especially for high speed production on non-ferrous materials, where handling time on a full-manual type turret lathe normally takes a substantial percentage of the total time per piece.

The spindle of the 16″ Electro-Cycle Machine in Figure 4 has a direct "vee" belt drive from the motor and may be equipped with either a bar collet chuck or a two or three jaw chuck. Any of these holding devices are opened and closed with an air cylinder which is stationary and does not rotate with the spindle. In effect, this minimizes the rotatable weight on the spindle and thus facilitates quick starting, stopping, reversing and "end of cycle" positioning of the spindle.

A control drum mounted on the turret cam contains four sets of six buttons which are adjusted to control desired functions of the spindle for any particular working face of the hexagon turret. See Figures 5A and 5B. As the turret is indexed through the cycle of the work piece, the spindle performs the function preset on the control drum.

This relieves the machine operator of all manual operations except the loading and unloading of the work piece, the moving of the hex turret ram through its stroke by the turnstile handle, and the operation of the plain cross slide.

A similar machine for ferrous bar or chucking jobs is shown in Figure 6. The basic theory of operation is precisely the same, except that the control drum may also engage a set of back gears in the headstock to provide the torque required to cut cast iron or steel. Standard equipment for the No. 3 Electro-Cycle Machine is the universal cross slide offering power feed in all directions.

Note that the design of these two types of turret lathes still satisfies the original need in turret lathe design for a faster way of producing work in job lots of a few to several thousands. This is secured by providing automatic control to the spindle to produce large work lots economically, and yet minimizing set-up time by simplification of controls and elimination of cams.

Another type turret lathe, different in design and application from any lathes previously discussed, is that shown in Figure 7. This is a high speed lathe built in two sizes to handle up to ⅝″ and 1″ bars respectively. Being high speed, it is primarily a machine for non-ferrous work and can also be adapted to chucking work as well as bar work.

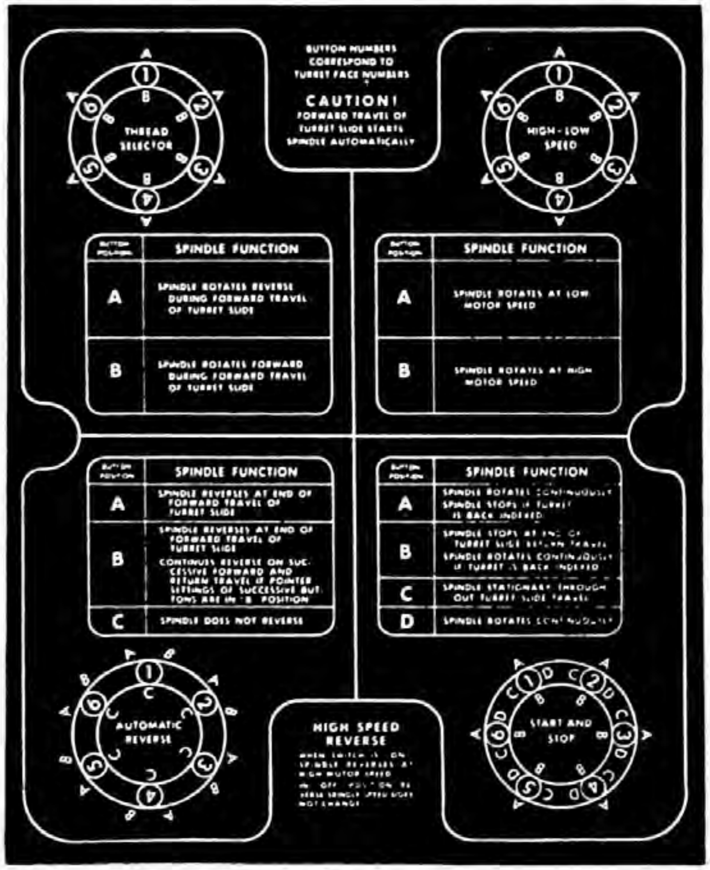
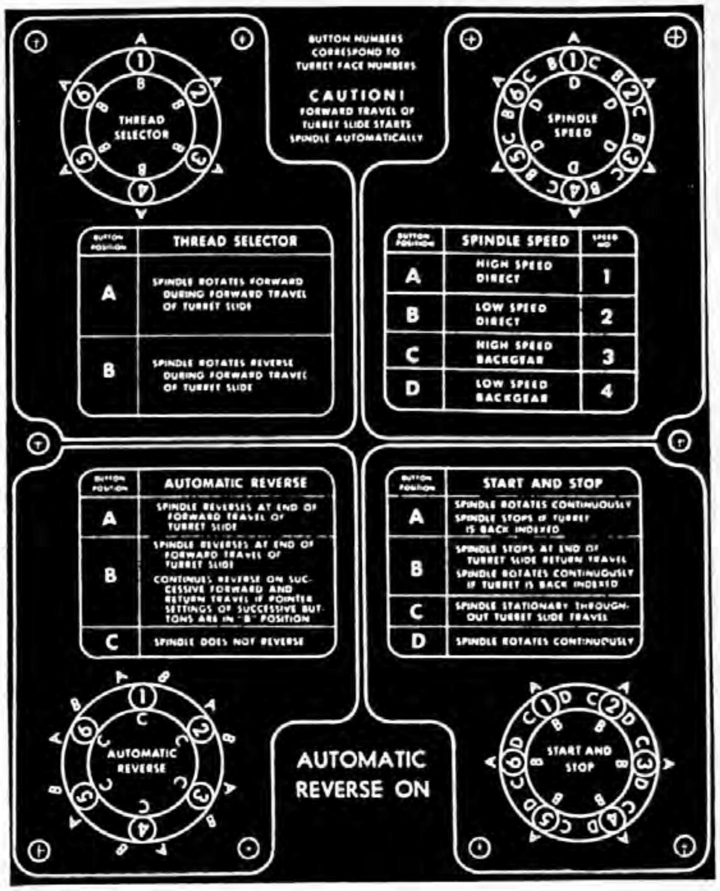


Fig. 5A. Close-up of instruction plate on control drum of 16″ electro cycle machine.

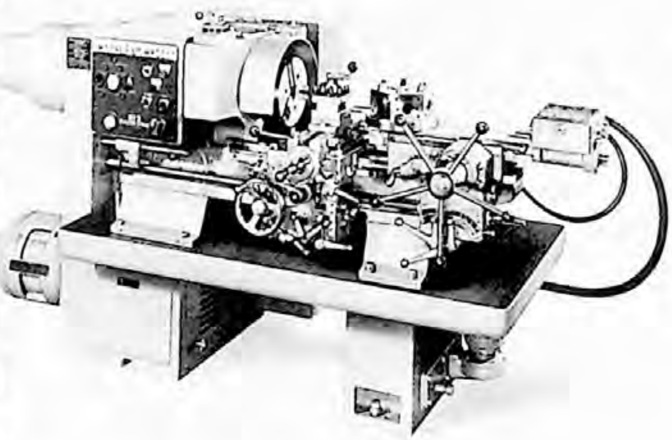
The rotor of the drive motor is integral with the spindle, which permits continuous, vibrationless speeds up to 3600 r.p.m. An electrically operated collet chuck and bar feed mechanism feeds and grips the bar stock at the touch of a lever by the machine operator.

This machine is particularly efficient on small brass studs, nuts, shafts, washers, etc. Diamond or cemented carbide tipped cutters may also be used for precision finishing on abrasive materials such as hard rubber, plastics, etc., due to the speed and vibrationless operation of the spindle.

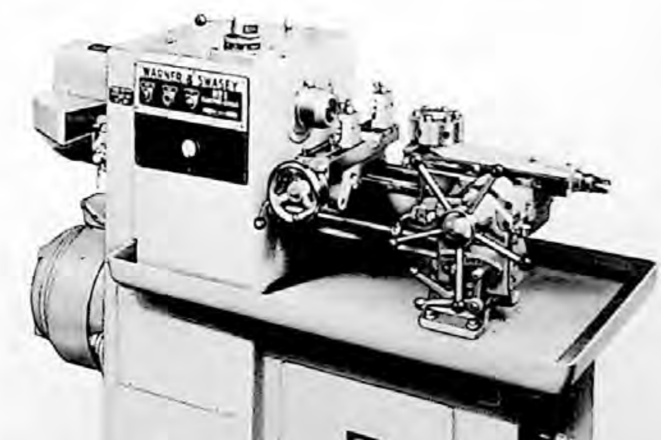
Editor's Note: From the author's description of the many types of hand-operated horizontal turret lathes and the numerous attachments available to expedite production, it may be seen that economy of operation depends largely on a clear understanding of the fundamentals of turret lathe practice and tooling principles. These subjects, together with examples, will be discussed in a succeeding article.



Right, Fig. 5B. Close-up of instruction plate on control drum of No. 3 electro cycle machine.



Left, Fig. 6. A high speed manually controlled turret lathe for cutting operations on both ferrous and non-ferrous materials. Complete control of spindle functions is obtained by setting buttons on the drum as with the lathe in Fig. 4.



Right, Fig. 7. A small high speed manually controlled turret lathe for ferrous and non-ferrous bar jobs. Clutch engaged back-gears provide lower speeds and required torque for cutting iron and steel.

TURRET LATHE CONSTRUCTION

Detailed description of ram and saddle type turret lathes and the purpose of the various elements of the machines

THE HAND-OPERATED horizontal turret lathe is a metal turning machine, usually floor-type, equipped with two independently operated tool slides. The end working tool slide is furnished with a six-position indexing tool turret. Feeds, speeds, tool positioning, and work positioning are manually controlled in a turret lathe by the machine operator. (*See Figures 1 and 2*).

As a consequence of its design, the turret lathe fits a definite field in shop production in several respects.

Almost any kind of job can be done on the machine because the operator has full control of all feeds, speeds and tool positions and thus retains the "feel" of the job.

Basic cutting operations include turning, boring, facing, forming, reaming, tapping, threading and cutting off.

The large number of cuts possible in one setup permits concentricity and squareness in the part, plus the possible elimination of second handlings on another type machine tool otherwise needed to finish up the part.

The arrangement of cutters in

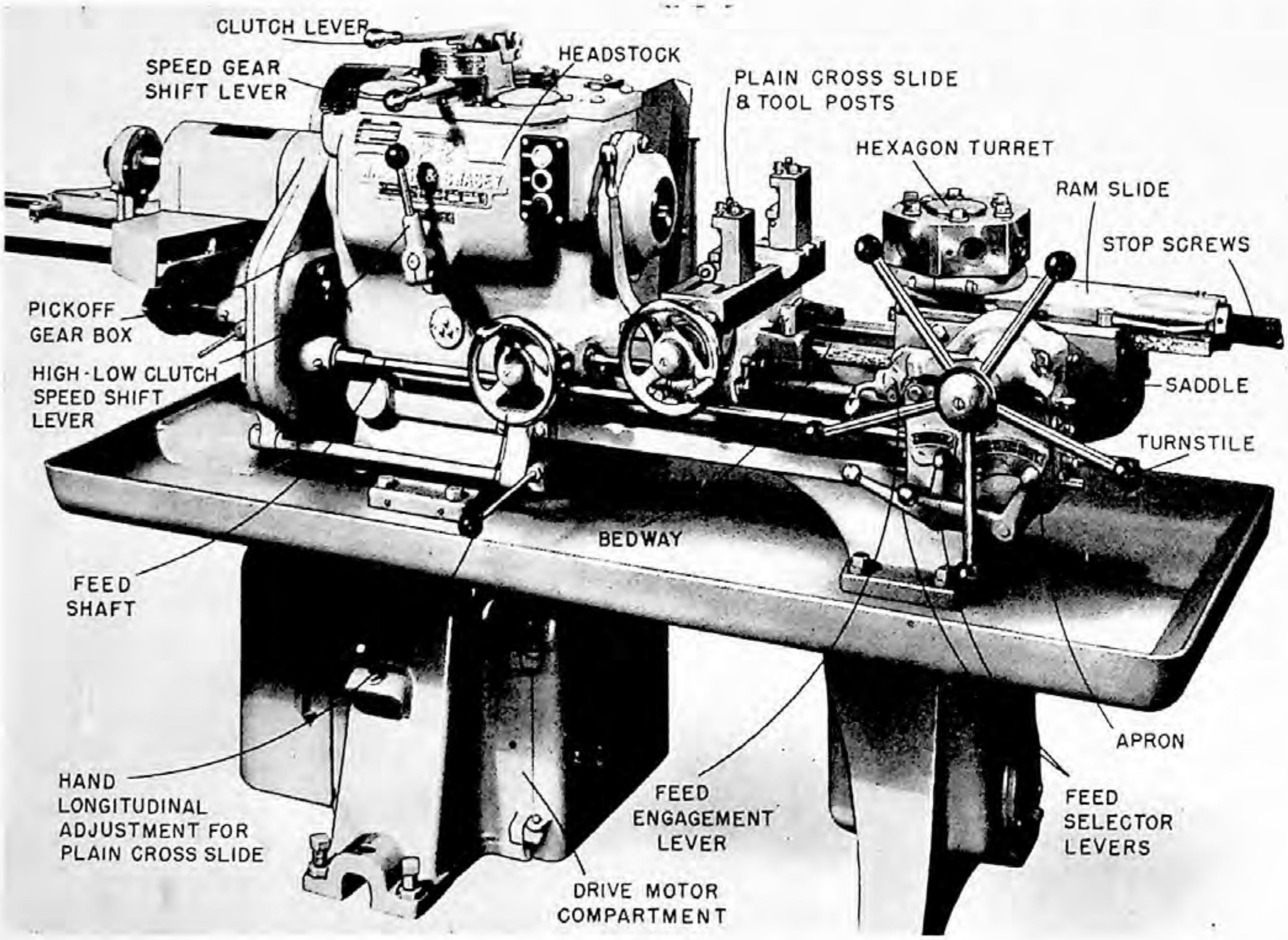


FIGURE 1

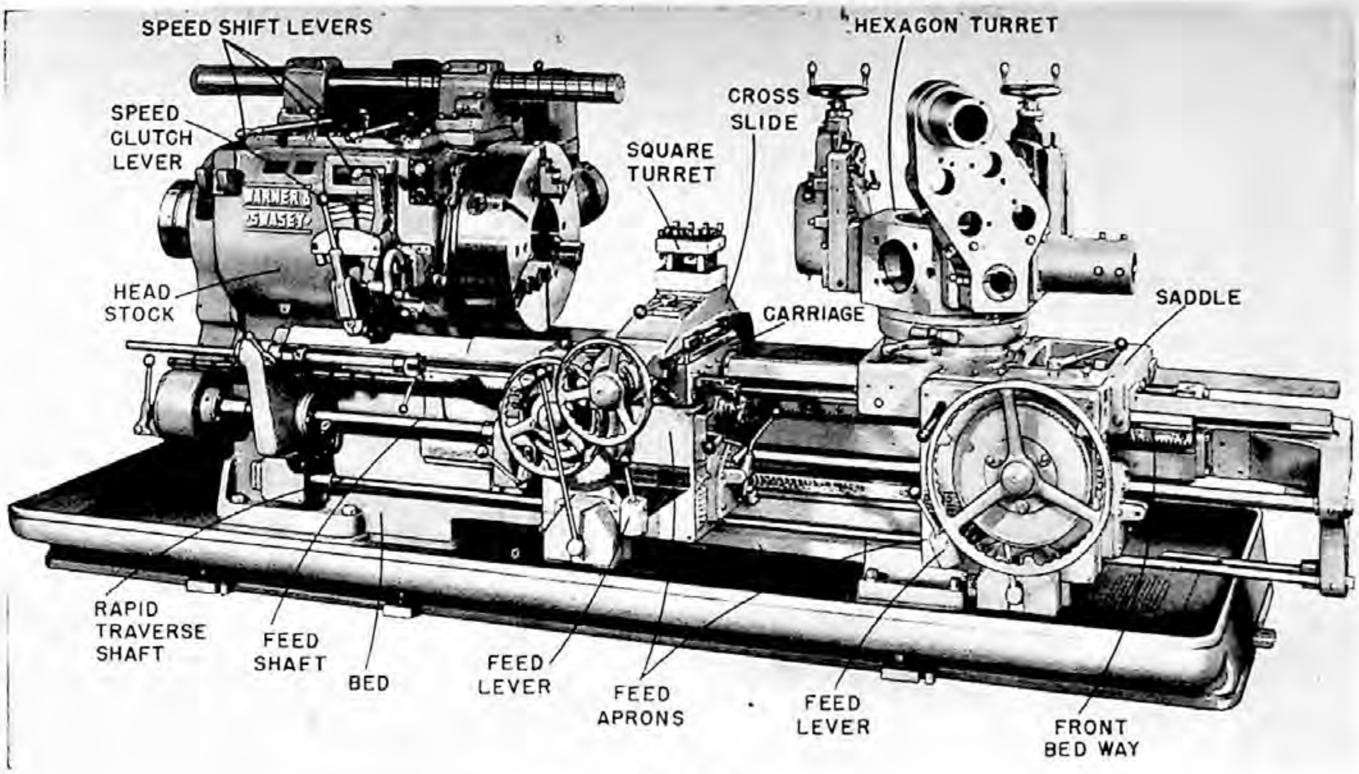


FIGURE 2

the tool stations permits sequential cutting on repetitive work, either in multiple or in combination with each other. Therefore, the ratio of production to setup time is favorable, and allows small to medium size lots to be machined on a production basis.

Types of Turret Lathes

The basic designation "hand-operated horizontal turret lathe" will henceforth in this article be shortened to "turret lathe".

There are two types of turret lathes: ram-type and sliding saddle type. Ram and saddle-type machines may be equipped for bar or chucking jobs, or both, by the simple addition of standard attachments to the basic machine. The ability of a turret lathe to serve interchangeably as a bar or chucking machine is one factor which increases its usefulness as a production machine for small and medium size lots.

Many sizes of turret lathes are built under the general classification of ram and saddle-type machines, but all such machines are quite alike in general design and construction. Differences in details of construction between certain sizes of turret lathes occur because the individual machine size is designed for best efficiency in its particular capacity for work.

Ram-type turret lathes are obtainable with swing capactiy to 20 inches and capacty for gripping bar stock up to 2¾ inches. The swing of sliding saddle-type turret lathes ranges from about 16 to 28 inches, and from about 2½ to 13-inch capacity through the spindle. It is thus clear that ram-type machines are generally smaller in size than sliding saddle machines and are also equipped with smaller main drive motors.

The construction and method of operation of the end tool slide on the turret lathe is the key to its designation. For example, the hexagon turret of a ram-type machine is mounted on a ram slide which operates within a channel in the saddle. (*See Figure 3*). This saddle is bolted to the machine bedways at some location along the bed determined by the length of the individual job to be produced in the setup. The ram slide may be fed (*out of the saddle toward the work*) or returned, either under power feed or manually by the turnstile wheel.

From the above, it is apparent that the ram slide extends progressively out of the saddle support as the cut progresses. The limit of this forward travel as well as the limit of return travel is determined by fixed stops contained in the saddle. Consequently, the maximum travel of the ram-type tool slide is a function of the design of the saddle unit. Part of the maximum travel is used to index the turret; the remander comprises the working stroke.

The hexagon turret of sliding saddle-type machines is mounted on a saddle which fits directly to the bedways of the machine. (*See Figure 2*). Therefore, the overhang of the cutting tools from the supporting saddle remains constant, regardless of the position of the saddle along the bed. Forward and return travel of the saddle is limited only by the length of the bed itself.

In view of the turret slide construction of these two types of turret lathes, a general basis for assigning jobs to the machines can be established.

The ram-type machine is best suited for bar work within its range and for chucking work where the overhang of the ram can be kept short. The lighter construction, and the short turret strokes, make the ram-type turret lathe a fast handling, easily operated machine for relatively small work.

The sliding saddle-type turret lathe with its longer stroke and more rigid turret mounting, is suitable for longer and heavier bar jobs, or chucking jobs which require long turning and boring cuts.

Aside from the standard machine types previously described, a few standard alternatives in design are available from the manufacturers. For example, turret lathes can be obtained with longer than standard beds, with gap beds, or with cross-feeding hexagon turret slides. (*See Figure 4*). In these instances, the machines would be known as long-bed machines, gap-bed lathes, or cross-sliding turret machines.

Turret lathes, particularly the ram-type, are available with several types of headstocks. The headstock will be described in more detail later in this article.

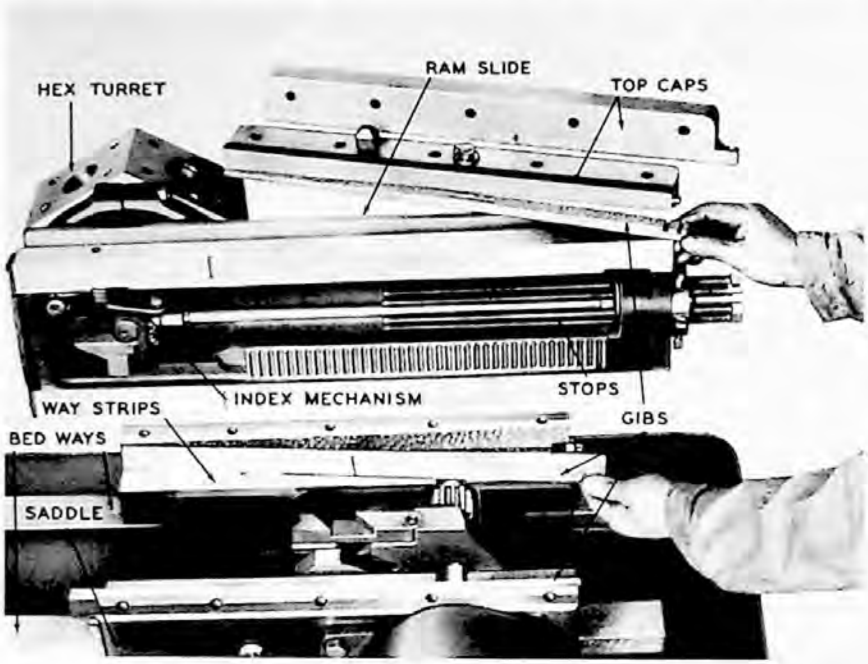


FIGURE 3

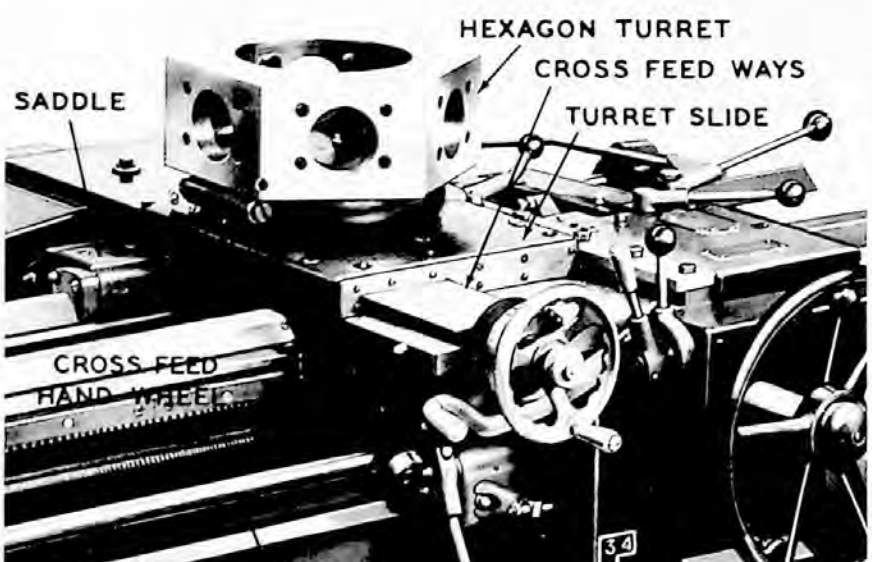


FIGURE 4

The Power Train

Figure 5 illustrates the power train between the main drive motor and cutter in a turret lathe.

The main drive motor connects with the machine headstock, usually by means of flexible "V" belts. In some cases, the motor is mounted to the headstock of the machine with the motor shaft coupled directly to the machine drive shaft. A choice of gear combination in the headstock transfers power and speed to the machine spindle according to the r.p.m. desired.

A gear box is fitted to the back end of the headstock. Gears in this box connect the spindle with the main machine feed shaft. Thus, the rotation of the machine spindle is always in relation to the rotation of the feed shaft according to a fixed ratio.

This is particularly important where thread - chasing operations are to be done on the machine and is taken into account in the design of lead-screw thread chasing attachments. It also permits the calibration of tool slide feeds in "inches per revolution of the spindle".

A small High-Low shift gear box is furnished on most turret lathes between the gear box which transfers power from the end of the spindle and the feed shaft. Or, pick-off gears may be furnished, depending on the size and make of the machine. In either case, the purpose of this design is to permit a change in the ratio of revolutions between the spindle and feed shaft. Thus, feeds may be halved or doubled or the leads of thread chasing attachments expanded conveniently.

The machine feed shaft runs the length of the machine bed and extends through two tool slide gear boxes known as aprons. These ap-

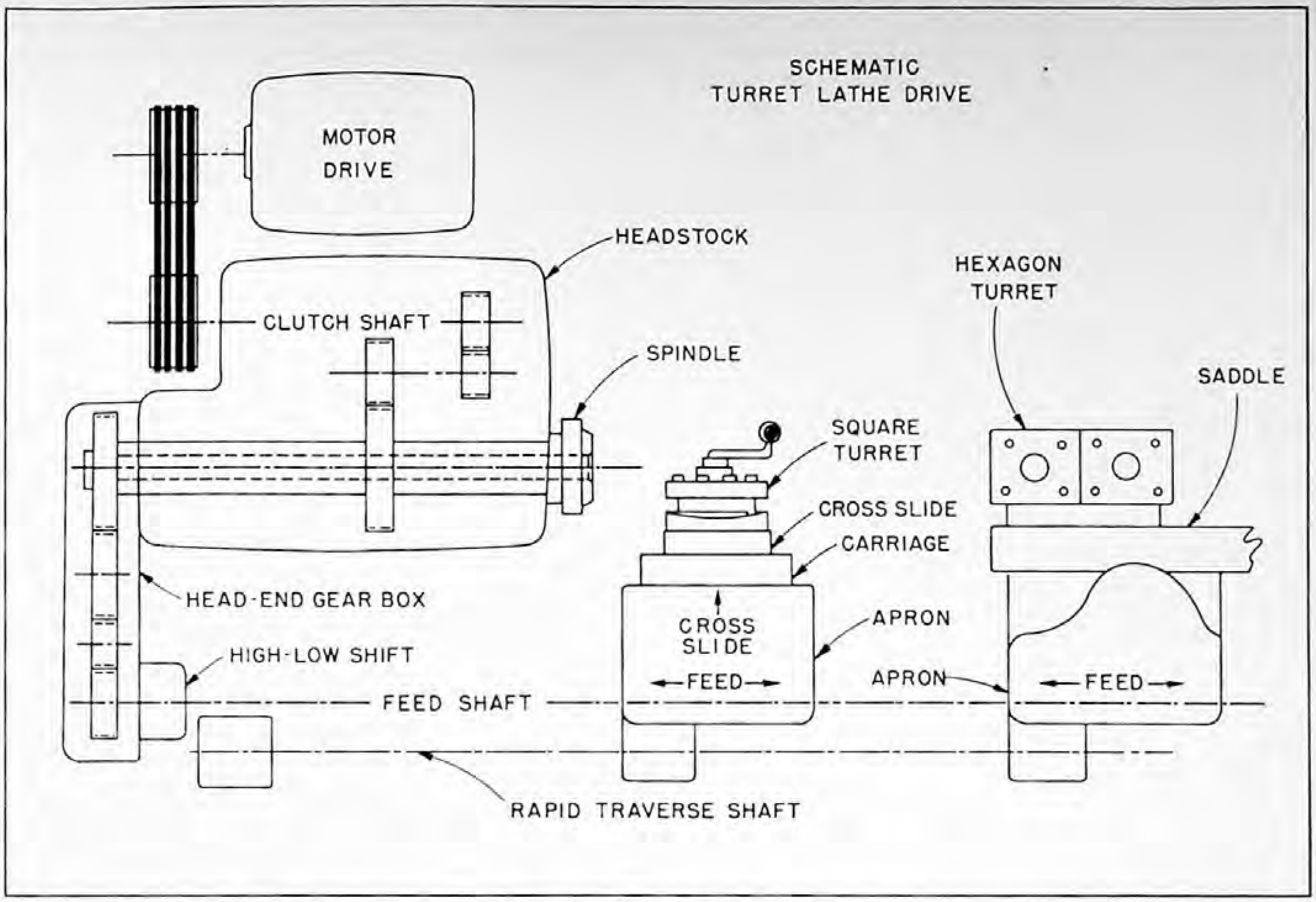


FIGURE 5

rons are attached to the cross slide carriage and to the saddle of the hexagon turret unit.

Gears are shifted in these aprons by means of feed levers to determine the rate of feed of the tool slides. Gears in each apron transfer power from the feed shaft to the tool slides through clutches, worm gears and racks and pinions.

Tool Slides

Standard turret lathes are provided with two tool slides, each of which is powered from the main feed shaft of the machine. One slide supports the hexagon turret for end working operations while the other slide, known as the cross slide, feeds optionally at right angles to, or parallel to, the bedways, and operates between the hexagon turret slide and the headstock of the machine.

Either one or both tool slides together with their carriages, saddles and aprons may be detached from the machine as complete units if a special kind of work indicates the need for additional swing clearance.

The hexagon turret slide of ram-type machines can be fed under power toward the work only. Turret slides on saddle-type machines may be fed under power either to or from the work.

Cross slides on both type turret lathes, if universal, can be fed under power in all four directions.

The word "universal" used in connection with turret lathes denotes the power feeding feature in four directions of the cross slide. Therefore all sliding saddle-type machines are universal turret lathes, and all ram-type turret lathes are universal except the very smallest sizes. The cross slide of the small turret lathe (*See Figure 1*), normally involves a short stroke and consequently is designed for manual operation. This is known as a plain cross slide.

Jobs which are well suited to the small ram-type bar machine with plain cross slides involve forming or facing from the tool block on the front of the cross slide and the cutting-off operation on the rear of the cross slide. Plain cross slides cannot be moved or fed longitudinally on the bed of the machine during the cycle of the job in the manner possible with a universal cross slide. This movement is accomplished only during the setup of the job and is determined by the overhang of the part.

The tool slides on ram and saddle-type machines are positioned by the operator adjacent to the part before power feed engagement. The feed levers are then engaged for the cutting operation. Retraction of the tool slide from the work is accomplished manually at the end of the cut.

On all sliding saddle-type turret lathes, power-operated rapid traverse is furnished to the tool slides to assist the machine operator in maneuvering heavier units to and from the work when not in feed.

Ram-type turret lathes, being smaller machines, are ordinarily not equipped with power rapid traverse to the cross slide. Furthermore, since the stroke of the hexagon turret ram is relatively short and the unit much lighter in construction, no power traversing is normally furnished for that unit.

All universal cross slides on ram-type turret lathes bridge across the two machine bedways. They are usually squipped with a four-station indexing turret on the front of the cross slide and a single cutter tool post on the rear of the slide.

Cross slides on sliding saddle-type turret lathes are built in this manner or alternatively supported from the front way and bottom rail only (*side hung*) depending on the manufacturer of the lathe. Side-hung cross slide carriages are equipped only with the four-position indexing turret.

All ram-type and sliding saddle-type turret lathes have six tool positions on the hexagon turret slide. On ram-type machines, tools may be mounted directly to the turret, while on saddle-type machines a tool holder is ordinarily required.

The hexagon turret of ram-type machines automatically indexes clockwise near end of return stroke. Most models of sliding saddle-type turret lathes are arranged so the hexagon turret may be indexed (*manually only*) at any point along the bed. Direction of rotation in the case of saddle-type machines may be clockwise or counter-clockwise at the option of the machine operator.

The four-position indexing turrets on cross slides of all types of turret lathes are unclamped, indexed, and clamped by hand. Depending upon the size and type machine, these turrets can be indexed automatically through the unclamping and clamping lever. The normal sequence of tool arrangement in the square turret implies a counter-clockwise rotation, although this may be varied at the option of the setup man or operator.

Turret Lathe Headstocks

Modern turret lathes are built with several kinds of headstocks. All headstocks, however, have certain common design characteristics. For example, a forward-reverse-neutral clutch drive shaft is included in each headstock to receive power from the main drive motor.

Within the head, one or more series of gear combinations are provided to permit speed selection. Finally, a spindle is mounted in the headstock and connected to the gear train. The face of the spindle extends outside the headstock in order to mount work holding devices. A gear connection on the back end of the spindles is usually provided so power from the headstock can be transmitted through a gear box to the feed shaft of the machine.

Six and 12-speed headstocks are commonly furnished in present day turret lathes. The six-speed headstock is normally furnished with a High-Low clutch so a quick change in speed from one suitable for turning to a reaming or threading speed can be obtained without actually shifting headstock gears.

The 12-speed headstock provides smaller increments of speed selection between the lowest and highest speeds and thus, in most cases, a cutting speed closer to the recommended speed for any given work diameter can be obtained. In a 12-speed headstock, all speeds must be selected by changing gears either manually, or hydraulically through clutches, depending on the manufacturer of the turret lathe.

Preselection of a spindle speed in a 12-speed headstock is available in most turret lathes. This process permits a cutting speed to be se-

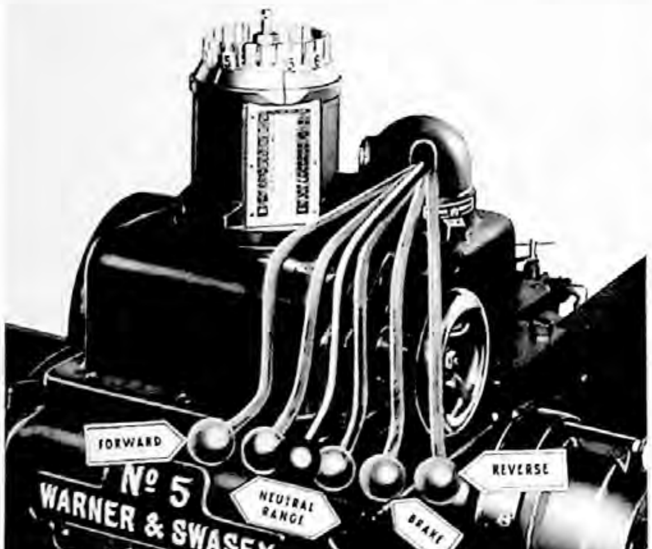


FIGURE 6

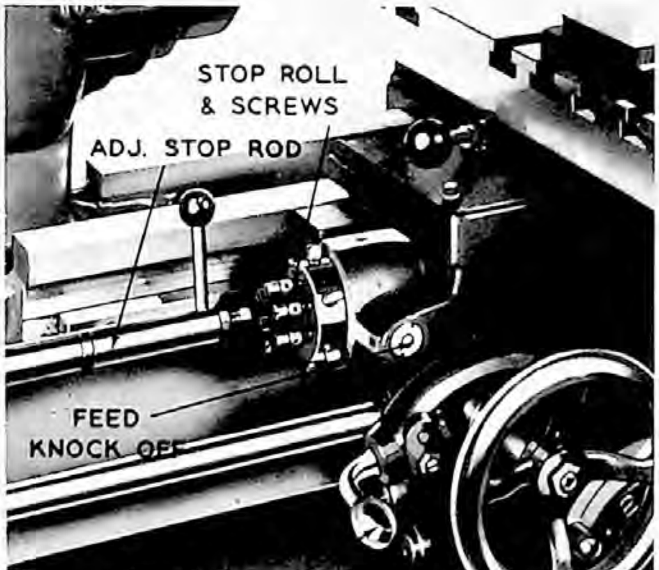


FIGURE 7

lected for the next cut in a job cycle while the immediate cut is in progress on the work.

Actual setting of the speed in the preselective process is done, in most cases, by rotating a handwheel to a dial setting. The engagement is then performed when the machine operator actuates a lever outside the headstock. This, in turn, institutes the speed shift either mechanically or hydraulically. (*See Figure 6*).

Many users of turret lathes prefer to install two-speed main drive motors on the machine. This doubles the number of available speeds at the spindle by utilizing the electrical push-button shift from the low to high motor range. A 12-speed headstock thus is increased to 24 speeds.

Depending on the design of the headstock, these additional 12 speeds may, in most cases, fall approximately between the 12 geared speeds of the machine. This must be true in an efficient headstock design so 12 additional useful speeds can be obtained without approaching a speed already in the machine.

In the case of the six-speed turret lathe, the use of the two-speed motor effectively converts the machine to 12 speeds without difficulty. For machines of this type, a certain arrangement of gears in the head is set for the job with the shift levers.

Thereafter, during the job cycle, a high or low speed can be obtained with the clutch lever on the machine and, in turn, each of these settings can be converted to another high or low speed by means of the electrical push-button shift. Thus, during the job cycle, the machine operator has a choice of four spindle speeds obtainable without shifting gears in the head. (*See Figure 1*).

Machine Stops

Every turret lathe is equipped with some system of positive-adjustable tool slide stops and feed disengagement mechanisms. Since

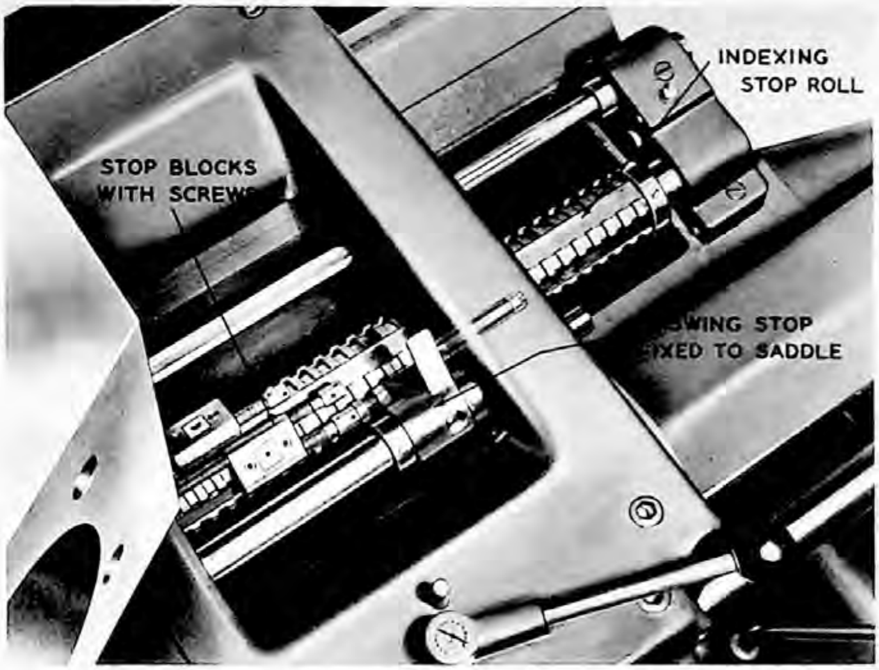


FIGURE 8

the turret lathe is primarily designed to take advantage of the many tools mounted in the turret which are presented in succession to the work on repetitive jobs, the function of machine stops and their proper setting is basic to the use of the machine as a turret lathe.

The cross slides of universal turret lathes are provided with a six-position stop roll which can be indexed by hand so one of the six adjustable stop screws can be lined up in turn with a stop rod. The stop roll is mounted in the cross slide carriage and, as it feeds longitudinally along the bed toward the stop rod, it reaches the end of cut position and the trip mechanism disengages the feeding motion. (*See Figure 7*).

The cross slide carriage may be brought to any of these six-adjustable stop positions either manually by the operator or the carriage may feed longitudinally up to the stop rod, at which point the feed disengagement mechanism is automatically actuated by the stop roll.

Positive stop or feed disengagement facilities are not provided for cross slide aprons when feeding away from the machine spindle, nor are positive stops available on most turret lathes for the cross slide when feeding at right angles to the bedways. In some models, the feed disengagement mechanism may be actuated by the "in" or "out" movement of the cross slide, but the actual end of cutting position of a cross slide when feeding crosswise must be controlled visually by the operator with the assistance of the micrometer dial on the cross slide screw.

Hexagon turret tool slides for all kinds of turret lathes are equipped with stop rolls which index in sequence with the indexing of the hexagon turret. (*See Figure 8*). Thus, for any particular turret face, an individual stop may be set to determine the longitudinal end-of-stroke position of the turret along the bed.

Details of construction of this stop roll mechanism vary between ram and saddle-type machines and among manufacturers of turret lathes. However, in all cases, the adjustment of a screw in the stop mechanism is involved which may determine the positive end of stroke position or the feed disengagement position or both.

Accuracy of machine stops on turret lathes has been improved greatly in recent years. A skillful operator can usually repeat the location of the tool slide with an accuracy of at least .002-inch.

INCREASING THE VERSATILITY OF THE TURRET LATHE

Description of modifications to the lathe and equipment which enable the standard turret lathe to handle a still wider range of jobs.

STANDARD turret lathes may be modified or equipped in many ways. When arranged with proper specifications, the machine may thus be able to handle a still wider range of jobs, or become better suited to a specific class of work.

It is the purpose of this article to outline some of the modifications and attachments which are classed as semi-standard or optional by turret lathe equipment suppliers.

Drive Equipment

Generally speaking, modern turret lathes are designed for larger motors than were permissible 15 to 20 years ago. However, it has not been the absolute practice of turret lathe builders to equip machines shipped with the very largest motor possible, as in many cases such motor sizes were unwarranted. As a consequence, owners of turret lathes who can justify the use of additional power in their machines because of changed cutting requirements should survey the capacity of those machines with the manufacturer, as it is likely that larger motors can be substituted without damage to the machine.

Drive motors may be mounted to a turret lathe in a variety of ways. For example, the motor may be mounted in the pedestal base, where it is completely protected from physical contact, and in which location it consumes less floor space. Or, the motor may be mounted on a vertical base behind the machine. The vertical base mounting in some cases permits the use of motors which will not fit in pedestal bases.

Although the use of line shafts has virtually vanished in the modern shop, countershaft drives for turret lathes are in most cases still available.

The control equipment necessary for the various electrical units on the turret lathe can be arranged either according to the Joint Industry Conference *(JIC)* standards or the National Machine Tool Builders' standards *(NMTB)*. The NMTB standards are generally considered sufficient and are approved for turret lathe installations, while the JIC standards tailor the control equipment to specific standards in certain industries. Both the JIC and NMTB standards specify the use of National Electrical Manufacturers Association *(NEMA)* components.

Hence, the user of turret lathes has considerable leeway in specifying the size of motor, how it shall be mounted, and its control equipment, all according to the individual requirements in his shop. Full use of these options may be taken by the user of the machine through negotiation with the manufacturer at the time of purchase, or the equipment may be changed over while in service.

Long Bed Machines

Experience has dictated the length of the turret lathe bed best suited to the particular size machine. Consequently, turret lathe builders furnish standard machines with specific length beds, although there is some variation in this length among different builders of the same sizes of machines.

However, depending upon the machine size, extra long turret lathe beds may be obtained for special-purpose application. These lengths may be as much as four feet longer than standard, and are generally specified when the machine is purchased. Such bed constructions are particularly suited to machining long shafts from bar stock or for casting jobs which overhang the spindle nose a measurable distance. Frequent use of long piloted boring bars, drills, etc., may justify the use of the long-bed machine so long tools may be cleared from work for indexing turrets.

Gap Bed Turret Lathes

As in the case of bed length, the swing over the bedways of standard machines is subject to modification. Standard swing clearances have been well established among the different manufacturers of turret lathes for different sizes of machines in accordance with the general size of the machine itself. Most average work suitable to the metal-removing capacity of a particular size machine falls well within its standard swing clearances.

However, there are many kinds of jobs which require extra swing capacity in a machine not normally capable of swinging that size part. For example, a large fly wheel whose diameter exceeds the swing over the bedways of a machine may only require that the bore and hub faces be machined. These cuts may be well suited to a rather light machine, whereas the swing required to hold the part in the machine might otherwise demand a much larger and heavier machine than necessary. Gapping out the bed solves this problem.

One manufacturer of turret lathes offers a sliding or adjustable

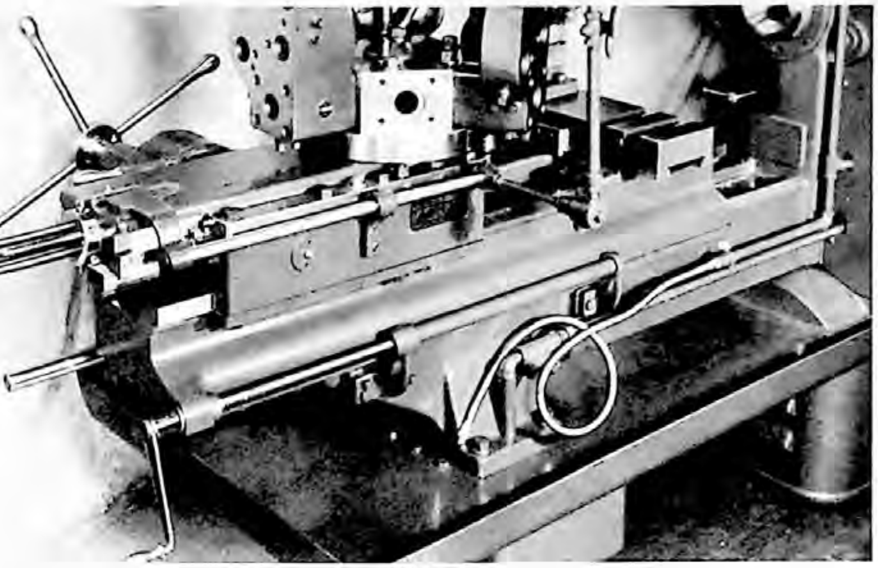


FIGURE 1

gap-bed ram-type turret lathe, which may be used for conventional work with the gap closed, or for large-swing work with the gap adjusted to a suitable opening. The gap may be opened or closed by means of a screw and crank mounted on the rear of the machine, as shown in Figure 1. It must be remembered that where fixed gaps are machined or cast into a turret lathe bed, this ordinarily limits the proximity of the cross slide carriage to the spindle nose.

Another use for the gap-bed machine occurs when oversize fixtures are required by the tooling arrangement.

Collet Chucks

The collet chuck is the universal method of holding bar stock in turret lathes. Thus, a large selection of collet types has become available for different kinds of work. Modern practice ordinarily specifies the push-out collet as standard, while the drawback collet may be used for specific applications.

Collets with extra capacity for short lengths are available and may be used with standard collet operating mechanisms.

Large turret lathes are equipped with adjustable collets, which compensate for the diametral variation of hot rolled bar stock. In some cases, this kind of collet can be applied to a smaller machine.

A "stationary closing" type collet is also available. This is sometimes called the Brown & Sharpe-type of collet, where the collet itself does not move longitudinally during the closing action. A collet of this design is especially capable of minimizing variation in longitudinal work dimensions which occur in the push-out and drawback collets during the closing action.

Most turret lathe builders can modify standard collet chuck and bar feed designs to handle larger-than-capacity sizes of bar stock. For instance, a two-inch collet chuck may be converted without difficulty to a 2¼-inch capacity unit, etc.

Frequently, knowledge of such options in collet designs permits the user of turret lathes to obtain a better balance of collet capacity between the various machines.

Reboring the Spindle

Ordinarily, when extra-capacity collet chucks are required on the turret lathe, the spindle must be rebored. The possibility of boring out the spindle, however, has additional implications for users of turret lathes who do not machine bar stock. For instance, castings with long extensions may be gripped in a three-jaw chuck, with the extension fitting into the spindle, thus reducing overhang of the part. Or perhaps special locating stops or fixtures may be adapted to the bored-out spindle, which might otherwise not be feasible in a standard spindle.

Spindle Noses

Turret lathe builders are currently furnishing machines with American standard flanged nose spindles. However, threaded nose spindles can still be furnished, if necessary, to maintain interchangeability with holding devices already present in the user's shop. Also, cam lock spindles can be furnished for the same reason.

Cross Slides

Turret lathes may be obtained with or without cross slide carriages. When furnished with such units, the machine can be termed "universal" or "plain," depending upon whether power feed is furnished to the carriage. Turret lathe builders provide the option to the user of specifying whether the machine should be equipped with a plain or universal cross slide, and the decision is normally made on the basis of the kind of work planned for the machine. Plain cross slides may be operated by the conventional screw and nut, by lever feed, or by a combination of both.

The hand-operated screw feed cross slide is best suited to machining steel where the mechanical advantage of the screw is necessary to overcome the cutting resistance of the material.

The lever feed cross slide is better suited to machining softer materials, such as brass and aluminum, and when used on such jobs which are ordinarily short-cycle, the speed of operation is greatly increased through the use of the lever feeding. Obviously, the combination lever and screw feed cross slide offers the widest range of application for different kinds of jobs if a plain cross slide is permissible.

Semi-automatic or automatic cross slides may be built to special order for many of the smaller sizes of turret lathes. When so equipped a machine can be used as an automatic cutting-off machine. If the job permits, one operator may tend both the turret lathe and another machine at the same time, thus dividing the cost of labor between the two machines.

Octagon Turrets

The conventional turret for end-cutting is hexagon or six-sided. Long usage of the turret lathe in the machining field has proved that this is the most generally useful turret. However, eight-sided or octagon turrets are available. Such turrets permit mounting additional tools for such jobs as small fittings, etc., where multi-step holes must be drilled and reamed.

Note the variety of drilling, boring, reaming, and threading operations performed from the octagon turret shown in Figure 2, which allows the total number of cutting edges to be separated over eight, rather than the customary six, tooling stations. This permits simpler tooling arrangements with resultant ease in setting and maintaining tools.

When an indexing two-jaw chuck is used in the production of valve bodies or other multi-sided parts, an eight-sided turret is also useful because of the number of tools necessary in the turret.

Ram Travel

Turret rams may be obtained with extra long strokes. It must be remembered that in the design of a turret ram and saddle construction, the ram travels between an adjustable forward stop and a fixed stop in its rearmost position. Slightly before the turret reaches its rearmost position, the indexing mechanism operates to index the turret to the next tool position. As a consequence, design considerations result in a usable length of turret travel, which must be exceeded for some jobs.

For example, if a long piloted boring bar is used on a ram-type machine to bore a certain length hole, the travel of the standard ram may prove to be insufficient to permit withdrawal of the boring bar from the hole before indexing. In such cases, the extra travel turret is necessary. Longer turning cuts may be taken with roller tools if the above means are provided to clear the tools from the work before index takes place.

Offset Turnstiles

In the construction of ram-type turret slides and saddles, the ram is hand-operated by a turnstile. A given distance exists as clearance between the face of the turret as it indexes and the turnstile handles. When long piloted boring bars or drills are used in the hexagon turret, additional clearance may be necessary between the end of the bar or drill and the handle of the turnstile. Builders of turret lathes are prepared to increase this distance by means of the offset turnstile hub when required.

Steady Rests

The use of steady rests is commonplace on turret lathes. The function of the steady rest is the same as that used on an engine lathe, i.e., to support long overhanging work.

A variety of steady rests is available for turret lathes. Ram-type machines may be equipped with a quick-acting steady rest which permits the use of the cross slide carriage on either side of the steady rest, depending upon the work.

Saddle-type turret lathes can be equipped with the same kind of

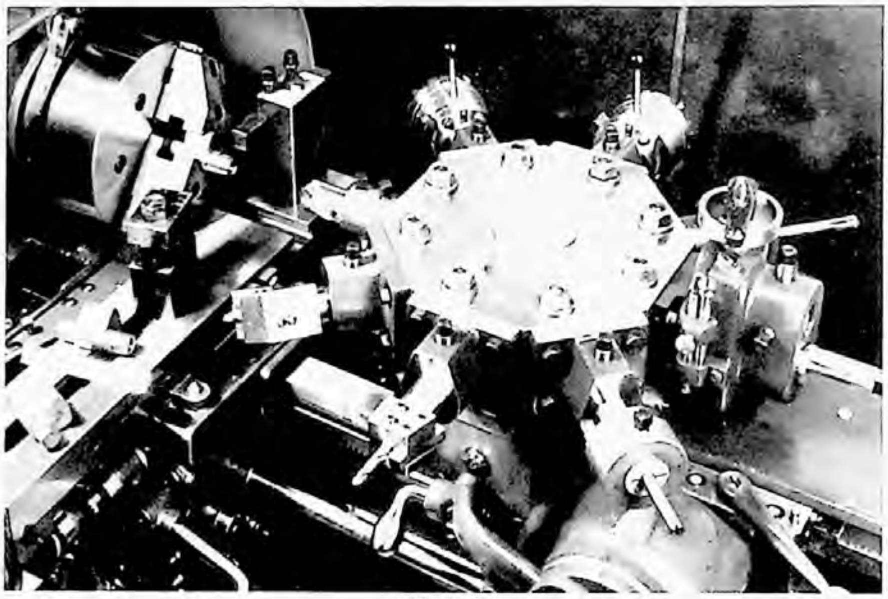


FIGURE 2

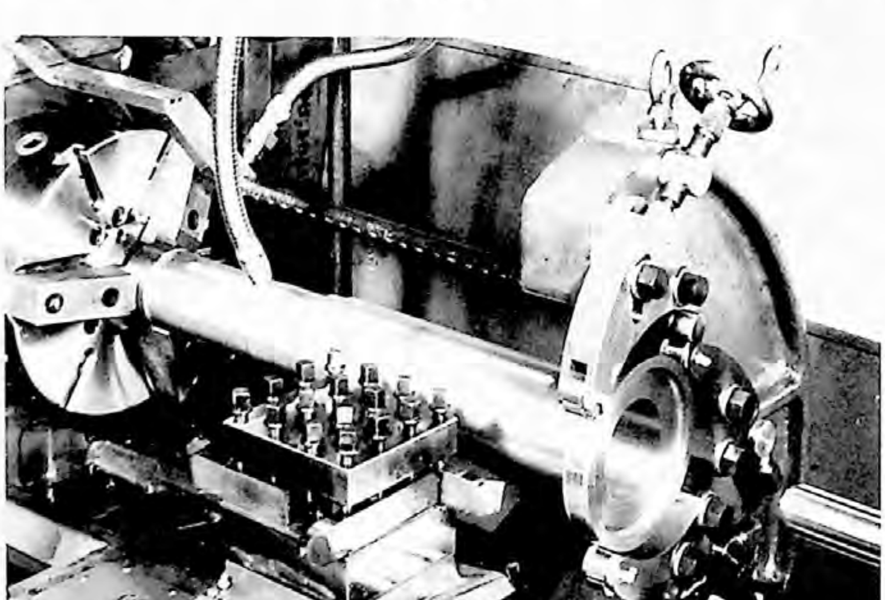


FIGURE 3

steady rest as above, and in addition "open type" steady rests are available which permit free passage of the cross slide carriage from one end of the work to the other.

A typical steady rest installation on a saddle-type turret lathe is shown in Figure 3. Note the adjustable top roll bracket and the free passage of the carriage on both sides of the steady rest. This steady rest may also be positioned along the ways of the machine during the setup, according to the work requirements.

Years of design experience with steady rests on turret lathes have produced units which are quick-set and universal for many types of work.

Cross Sliding Hexagon Turrets

While most turret lathes are furnished with "fixed center" turrets, turret lathes may be obtained with standard cross feeding hexagon turrets. Such units are invaluable for machining work with any of the following characteristics: (A) large and/or deep bores; (B) wide faces or recesses at the bottom of deep bores; (C) wide back faces; (D) large chucking diameters or holding fixtures which limit the mobility of the cross slide carriage or even require its removal from the machine; (E) large and deep internal tapers; (F) large diameter internal threading, either straight or taper; (G) multiple faces and bores in a complex job which requires tool positioning in excess of the available work stations and stops of a fixed center turret lathe.

Generally speaking, the cross feeding hexagon turret enables difficult work to be done in small quantities at low cost. The turret permits the combination of simple tooling, low setup time, and heavy-duty metal-removing capacity, with the natural advantages of the turret lathe for setting tools in multiple stations for successive cuts on repetitive work.

Split Hexagon Turrets

The hexagon turrets of ram or saddle type machines may be altered as shown in Figure 4 within limits to permit loading long shafts from the front or collet end of machine. When this recess or gap is machined out of the turret within allowable limits, the strength of the turret is not reduced. This should not be classed as a special arrangement of a turret lathe so much as a "trick" which lathe users may find profitable in specific cases.

The part shown in Figure 4 is formed and threaded at both ends and in large quantities. Stock is fed through the turret from the front of the machine to an adjustable stop at the rear of the spindle. A spring is attached to the turret for back-indexing. The cross slide cam is designed to prevent the cross slide stop from catching until the proper revolution is reached.

Drill Speeders

Devices are available for ram and saddle-type machines which speed up the drill by auxiliary means. When very small holes are to be produced in the turret lathe, the drill speeder often permits the drill to cut at proper speeds where the spindle of the machine cannot rotate fast enough to produce that cutting speed. Figure 5 shows a motor driven drill speeder mounted to the turret of a ram-type lathe.

It is found that when the drill operates in a direction opposite to the rotation of the lathe spindle, a more nearly true hole can be drilled than with a drill held rigidly in the hexagon turret itself. No adequate explanation of this phenomenon is known, but experience shows that this action occurs.

Drill speeders can be obtained with sensitive hand feeding arrangements *(not illustrated)* which permit the use of the unit on extra small drilling operations where the strength of the drill is not great.

The drill speeder may be designed for electricity or air in accordance with users' preference.

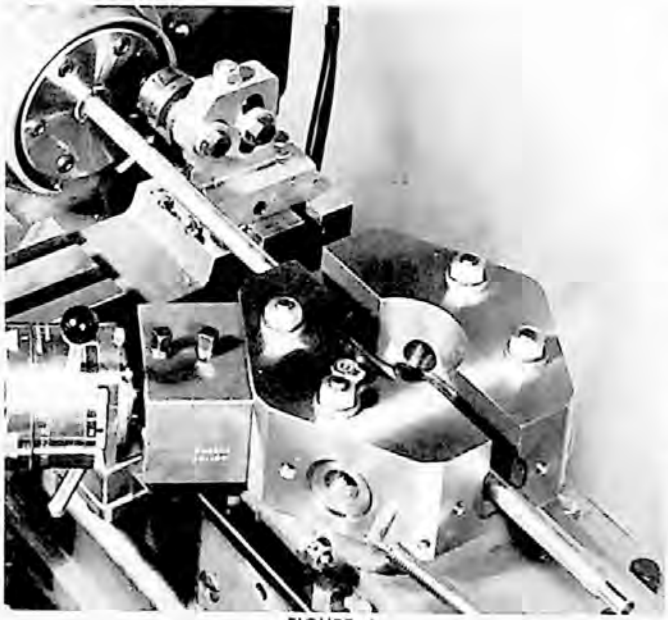


FIGURE 4

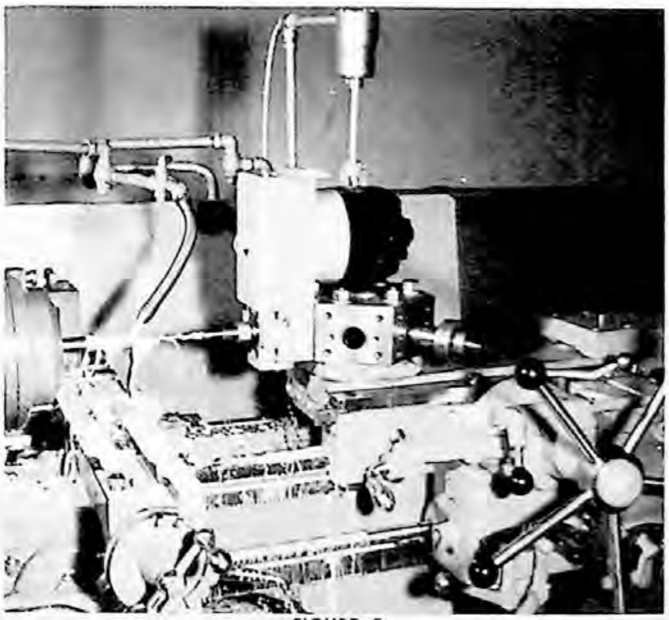


FIGURE 5

Overhead Cutoff Slides

In many cases, the front and rear tool posts of a standard cross slide are "used up" with forming, facing, chamfering, etc., tools. In such cases, an additional station is needed for the cut-off tool. It may be mounted as shown in Figure 6. This is a hand-operated cut-off slide, which, in effect, provides one more work station on the cross slide of a standard machine where all available tool stations are occupied by other types of tools.

Overhead Chasing Attachments

Tapping and threading operations on turret lathes are performed in various ways. The conventional lead screws, leading-on attachments, thread chasing attachments, die heads, solid taps, collapsing taps, etc., are well known to users of turret lathes. However, there is a class of work which is not adequately handled by the forementioned units.

For example, an eight-inch diameter thread on a brass casting, when produced on a ram-type turret lathe, could not, of course, be cut with a die head. It is most likely that the job cycle on such a part would be, generally speaking, quite short, and thus the threading operation should be conformable in speed.

The operation of a standard thread chasing attachment is not especially fast, and therefore, the overhead thread chasing attachment becomes applicable. This attachment allows these large threads in soft materials to be cut quickly. When the tool is pulled down into position, the half nut is automatically engaged and the unit feeds across the work. At the end of the threading stroke, the lever is automatically disengaged from the work and the half nut released so that spring pressure may return the threading slide to starting position.

Cross Slide Stops

When close diameters must be machined or parallel faces with close limits between them are to be held, specific measures must be taken to indicate the position of the cross slide with respect to the work. The ordinary cross slide dials and feed trips are adequate for conventional tolerances, but may not work in cases where special tolerances are required.

Therefore, standard cross slide units can be equipped with dial indicator arrangements which permit the machine operator to adjust tools to the work within more precise limits than is possible with standard equipment.

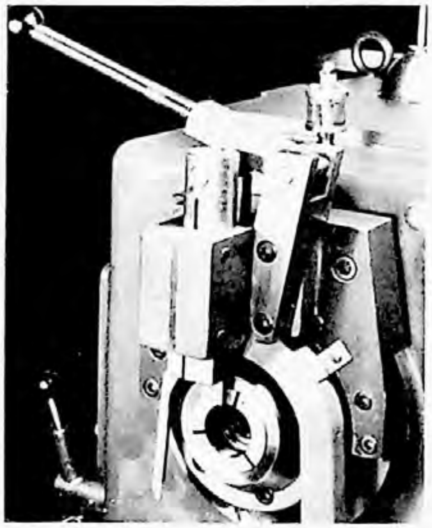


FIGURE 6

THE FACTORS IN GOOD TURRET LATHE TOOLING PRACTICE

Information needed by machine operator and tool engineer to produce work in the shortest time consistent with the number of pieces in the lot

Turret lathe practice differs from the operation of engine lathes, multiple spindle screw machines or other types of turning equipment on several different points. The most important point is the necessity to produce parts economically in the dangerous region of 5 to 2,000 pieces per order. If produced inefficiently, work quantities within these limits are large enough to damage shop economy, yet are not large enough to warrant special tooling and equipment universally accepted as cost reducing measures.

If, then, the turret lathe is a machine tool for producing work basically in the middle range of lot sizes, it must be the aim of every machine operator and tool engineer to tool up the machine and operate it with types of tooling and methods which produce work in the shortest time consistent with the number of pieces to be produced. The many factors involved in observing this aim comprise the principles of good turret lathe practice.

With good turret lathe practice as the goal, the machine operator must:

1. Be informed as to the correct care and maintenance of turret lathes.
2. Be familiar with the proper feeds and speeds used on various materials with different types of tools.
3. Know how to grind and set turret lathe tools.
4. Understand the technique of handling the various elements of the machine and how it relates to requirements of the operation at hand.

The tool engineer should:

1. Have a knowledge of machineability and how it is affected by the shape and strength of a workpiece, as well as the holding device used.
2. Be prepared to calculate horsepower consumed at a cut and understand how tool designs and machine capacities impose limitations on permissible power consumed at the cut.
3. Be able to establish proper design of work-holding devices as required by different shapes and strengths of workpieces, surface finishes, concentricity, and limits of parallelism.
4. Be able to estimate turret lathe production and relate tool costs to production rate and lot sizes.

Both the machine operator and the tool engineer must:

1. Know how the basic cutting operations are handled on a turret lathe; that is, turning, facing, drilling, boring, reaming, forming, threading and contouring operations.
2. Understand the principles of multiple and combined cuts for reducing production time.
3. Recognize that the total success of a job lies in the degree of cooperation between the tool engineer and the machine operator.

Further reference to these important factors in good turret lathe practice will be made in future articles in this series. However, at this point it is advisable to discuss in detail five basic

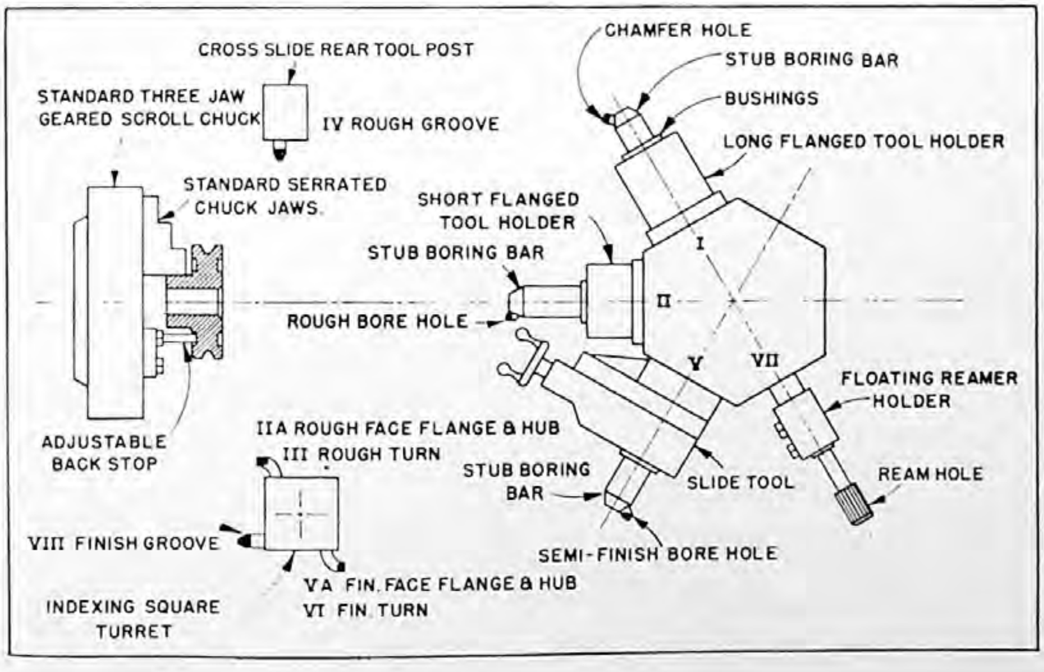


Fig. 1 A typical small lot turret lathe setup for machining a cast iron "V" belt sheave. Standard tool holders are used together with stock carbide tipped cutters. Note that sufficient clearance is improbable between the chuck jaw and the back face of the rim thus necessitating a second operation to face this surface.

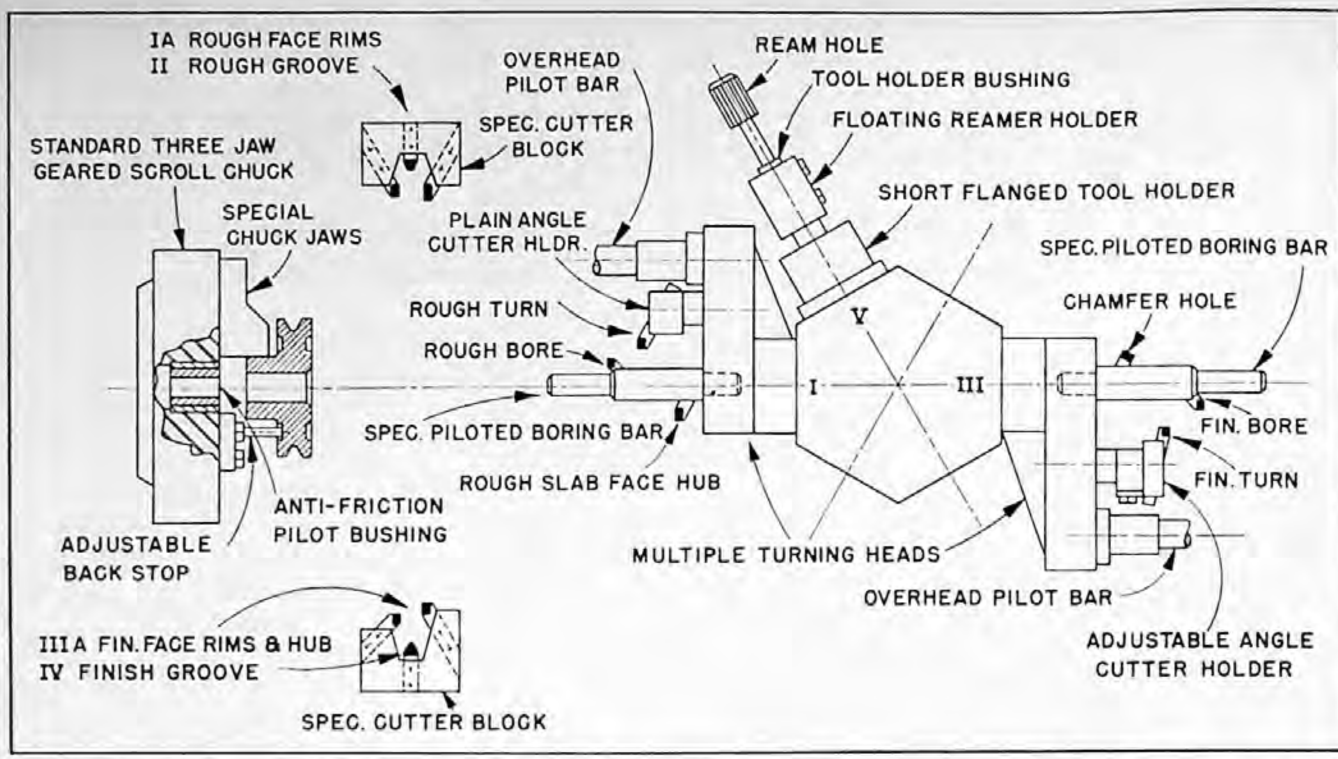


Fig. 2. This illustration shows how special tooling and some standard tool units increase production for work lots in the middle range. Note how cutters are arranged in multiple on the hexagon turret and then combined with other cuts arranged in multiple on the cross slide.

phases in turret lathe practice which greatly affect the efficiency of any tooling job:

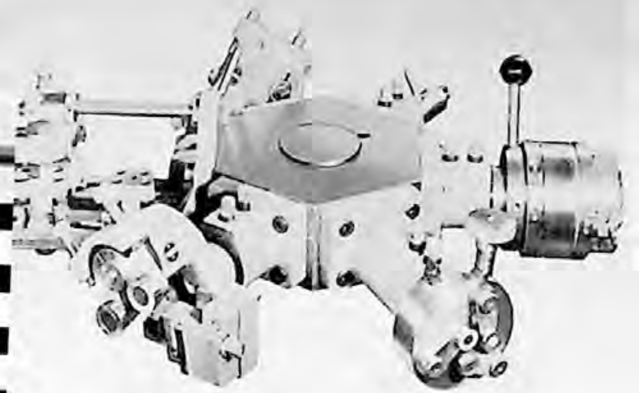
1. OUTLINE OF TOOLING METHOD. The number of pieces per order and how often it is repeated always controls turret lathe tooling. A choice between special and standard tooling must constantly be made when producing parts in the middle range of lot sizes. For example, as shown in Figure 1, by using the least expensive tooling for small lot production a medium size single-groove vee belt sheave would be held in standard chuck jaws and be rough and finish bored, chamfered and reamed in four hexagon turret stations. The cross slide tools would rough and finish turn, groove and face one side of the flange and one side of the hub in four stations for a total of ten cutting stations to machine the part.

With special tools for somewhat larger lots, see Figure 2, special chuck jaws and piloted tooling would permit heavier speeds and feeds through more efficient gripping and increased support for the boring tools. Rough and finish turning, boring, chamfering, and slab facing of the hub and reaming would be done from the hexagon turret in three stations. Straddle facing of the flanges and grooving would be done in two stations on the cross slide, this totaling only five cutting stations. Compare these 5 cutting stations for the special tooling with 10 stations required for simplified tooling.

Between these two extremes there is a place for the permanent arrangement of standard adjustable universal tools and holders. Such tooling can minimize setup time to produce small lot quantities and yet is flexible enough to reach into the field of special tools with the added advantage that their cost can be spread to cover the majority of jobs produced on the machine. For these reasons, the standard universal bar and chucking tools should be considered minimum equipment for any turret lathe.

Additional factors affect the outline of tooling methods, for example, accuracy, finish, shape, material and stock allowance of the part. In removing surplus metal, the number of cuts taken on any surface should be sufficient to hold tolerances without excessive gaging time due to tool wear. Close concentricities or the shape of the part may demand special holding devices.

2. TYPES OF DURABLE AND PERISHABLE TOOLS. It might seem unnecessary to criticize the use of 5 horsepower tools on a 50 horsepower turret lathe, yet this frequently happens. Cross slide tool blocks should be rigid and designed with ample support under the tool. Wherever practical, hexagon turret tool holders should be piloted for roughing cuts and the cross section of all types of cutters should be as great as possible. Cutting tools should be adjustable to compensate for wear, and workpiece and machine tool instability. Cutting tools should also be selected with due regard for the job. There is still no all purpose cutting tool. High speed steel, the cast alloys, cemented carbide and others all have individual applications for which they are particularly suited. Any single job might include more than one type.



Typical standard bar tools used on a ram type turret lathe. Working clock wise from the die head, they are: center drilling tool, combination end forming and turning tool, multiple cutter turner, single cutter turner, combination stock stop and start drill, and the self-opening die head.

3. SELECTION OF TYPE AND SIZE OF MACHINE. Not every job that will swing on a certain size turret lathe belongs on that machine. Turret lathes are available today with a wide range of collet capacities for bar stock work and swing capacities for chucking work. Usually some overlapping of such capacities exists between machines, necessitating a consideration of other factors:

a. Will the work stroke of the hexagon turret tools require the use of a ram type or saddle type machine?

b. Will the increasing overhang of the ram type turret slide prove harmful as the cut progresses or should the sliding saddle machine be selected because of the constant turret overhang feature?

c. Does the job call for a power feed cross slide or will a hand-operated slide be satisfactory?

d. Does the nature of the job require a geared head turret lathe which offers numerous speed selections or should a gearless head turret lathe be used? Perhaps in this latter case the axis of the spindle must be held in line with the axis of the cutting tools for close boring; head gears and clutches working in oil create heat which is not conducive to the maintenance of spindle alignment.

e. Is the speed of the machine correct, and is the required power available? Turret lathes are equipped with drive motors from 3 to over 50 horsepower. A 2:1 ratio 2-speed motor is frequently desirable. It allows push button speed shifting and, by virtue of running the drive shaft at faster than standard speeds, permits the use of larger than standard drive motors without exceeding the torque capacity of the headstock. For instance, a 10½ h.p. 1800/900 r.p.m. motor may usually be substituted for a 7½ h.p. 1800 r.p.m. single speed motor.

f. Are tool clearances available? Will a die head swing over the cross slide and over the top of the ram when indexing the turret? Will the swing over the cross slide horn on saddle type machines permit positioning of the square turret behind the workpiece to reduce the overhang of hexagon turret tools?

g. If two machine sizes and types seem acceptable in all other respects, handling time may be a consideration. Some sizes of ram and saddle type machines have equivalent workpiece capacity, yet handling time on a saddle type machine may be double that required with the ram type.

4. THE USE OF MACHINE ELEMENTS. Machine elements are parts of the machine; it is well to use them as follows:

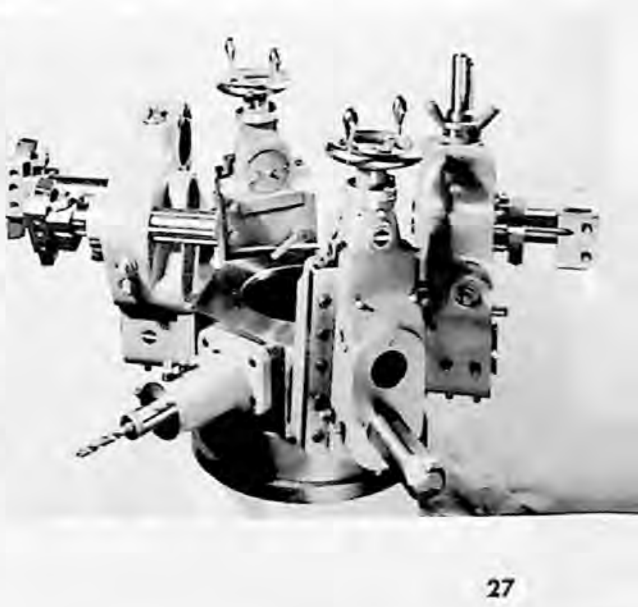
a. The saddle of a ram type machine should be clamped to the bed so that minimum turning of the ram turnstile handles is required to advance the hexagon turret, yet it should be clamped far enough away from the work so that long drills, boring bars and other extended tools clear the tool posts, handles and coolant pipes during indexing.

b. The tools on the hexagon turret should be arranged to minimize head gear speed shifting for different spindle speed ranges.

c. Tools on the hexagon turret should where possible be arranged in multiple and in relation to the cross slide tools so that these multiple cuts can be taken in combination with the cross slide cuts.

d. Machine stops should be set.

Variety of tools for a sliding saddle type turret lathe. Reading clockwise from the drill station these tools are: multiple turning head with two adjustable angle cutter holders in position, a slide boring tool, and empty tool station, a single adjustable turning head with one plain angle cutter holder in position, a slide tool with a stub boring bar mounted in place, and the drill shown mounted in a taper drill socket and flanged tool holder.



5. MAINTENANCE OF MACHINE ACCURACY BY PROPER CARE, CLEANING AND LUBRICATION. A turret lathe is a precision tool built to produce precision work. To retain its original accuracy, it must be carefully maintained. Collet chuck and scroll chuck accuracies can be preserved by frequent cleaning. All other exposed wear surfaces should be cleaned by wiping them with a lint-proof rag and not with an air hose. Ram type turret slides and saddles should be taken apart periodically and cleaned, particularly so if exposed to cast iron dust or brass chips.

Misaligned or out-of-level turret lathes may defeat the best laid plans of both the tool engineer and operator to produce accurate work. A turret lathe is not inherently capable of permanently maintaining alignment of bedways to spindle axis because the bed section cannot be enlarged at the expense of other machine elements. Therefore, a turret lathe must rest on a firm foundation which takes into account the weight of the machine, tools, materials around the machine, and location of the machine with respect to the building beams, pillars and type of flooring.

A wood floor is a poor foundation for a turret lathe. Even a wood layer over concrete is not too desirable. A thick bed of concrete is the most desirable choice with the legs of the machine resting on heavy steel plates and lagged through the plates into the concrete itself. On such a foundation, the turret lathe may easily be leveled and releveled from time to time. A turret lathe that is out of level or twisted is very difficult to operate and will not bore or turn satisfactory. Also, the bearings and bed surfaces may wear unevenly so that it may become impossible to relevel the machine to produce accurate work.

The leveling or untwisting operation on a turret lathe cannot be done with a carpenter's or machinist's level. A proper level is shown in Figure 3.

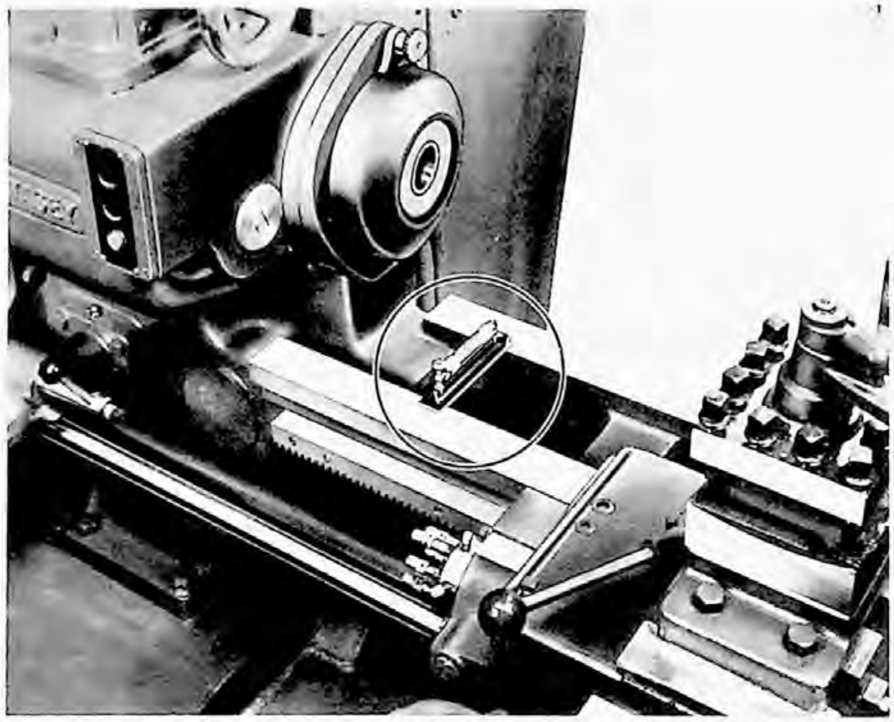


Fig. 3. The illustration shows a sensitive, adjustable spirit level in position under the headstock of a ram type turret lathe during the leveling and aligning operation.

It is difficult to overestimate the importance of proper machine alignment to good turret lathe practice. Most manufacturers of turret lathes are prepared to furnish detailed instructions about leveling their machines and strict adherence to these instructions pays rich dividends in the accuracy of the work produced and the life of the machine.

Heavy castings or forgings should not be rested upon finished machine surfaces nor should the hexagon turret be abused by violent indexing. Lapping compound or grinding attachments should not be used on the turret lathe unless special precautions are taken to remove their by-product. Finally, lubrication schedules should be closely followed.

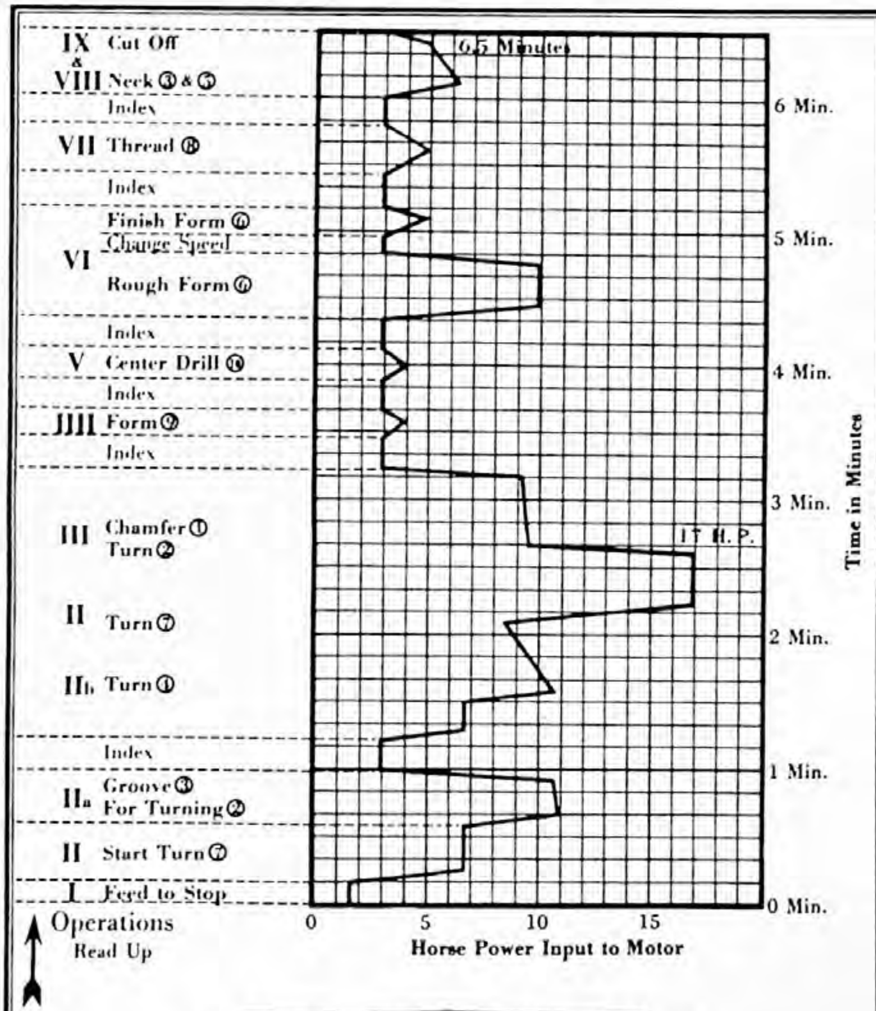
TOOLING PRINCIPLES. In many respects, the five basic facts of good turret lathe practice are inseparable from several principles of tooling. In fact, the complete subject of good turret lathe practice is a complicated combination of teamwork between the turret lathe manufacturer, the machine operator, the tool engineer, and the machine maintenance engineer. However, these tooling principles are a good yardstick with which to measure the efficiency of any turret lathe setup.

These principles are:

1. Do not be satisfied necessarily with the setup previously used.
2. Total time for the job should be kept at a minimum by balancing setup time, work handling time, machine handling time and cutting time.
3. Reduce setup time by using universal tooling equipment and by arranging the heavier flange type tools in a logical order and keeping them in a permanent setup.
4. Keep work handling and chucking costs down by selecting proper standard equipment and by using special equipment when it is justified by large lot quantities and savings possible.
5. Reduce machine handling time by using the right size machine for the job and by taking as many multiple cuts as possible.
6. Reduce cutting time by using: *a.* multiple cuts *b.* combined cuts *c.* increased feeds for rigid tooling *d.* increased speeds by use of proper tools.

MOTOR SELECTION for the TURRET LATHE

How to pick the right size and type drive motor on the basis of job analysis and other considerations



Actual Time & Horse Power Chart

Taper Stud--S. A. E. 1035 Steel

Floor to Floor Time--6.5 Minutes

Figure 1

A machine tool may actually be considered as a power conversion device. Its driving motor receives power from the electric lines and converts it into energy in the form of heat at the tip of the cutting tool. When considered in this way, the machine tool itself becomes of secondary importance and merely the means to an end—that of producing the work piece to the desired shape and size.

Of primary importance is the supplying of adequate driving power and the shaping of cutting tools to remove the greatest volume of metal per unit of energy expended. Overpowering of machines is not desirable because of the unnecessary expense of investment and the possibility of damaging the machine tool through unwarranted power transfer.

Any discussion of power requirement on turret lathes is very timely under present conditions in view of the widespread application of carbide cutting tools.

To obtain acceptable tool life, carbide tools should be operated at 3 to 4 times the speed of high speed tools and at heavier feeds. However, because carbide tools perform operations similar to high speed tools, it is very easy to overlook the increase in power requirements.

It is the purpose of this article, therefore, to outline some of the factors affecting the choice and horse power rating of motors for turret lathes.

As with the automatic, the turret lathe performs in combination such operations as drilling, turning, forming, threading, etc. Because of this, great variations in power consumption are encountered during the work cycle. This is illustrated by the chart in Figure 1. This chart shows the power input to the motor in the production of the taper stud shown in Figure 2. Operations are identified on the lefthand side of the chart; all tools are carbide-tipped. The tooling layout for this part is shown in Figure 3.

Experience has shown that the

average turret lathe job requires a power input of approximately the same general pattern as that shown in Figure 1. For this particular job, the high peaks in horsepower are 17, with a root mean square horsepower of 7.8. The ratio between the two is 2.18. Therefore, if a standard motor has the necessary thermal capacity, mechanical strength, maximum running torque, and speed regulation, a motor can be selected with a continuous rating approximating one-half of the peak horsepower required. Since a standard motor does not have such capacity, a compromise selection must be made.

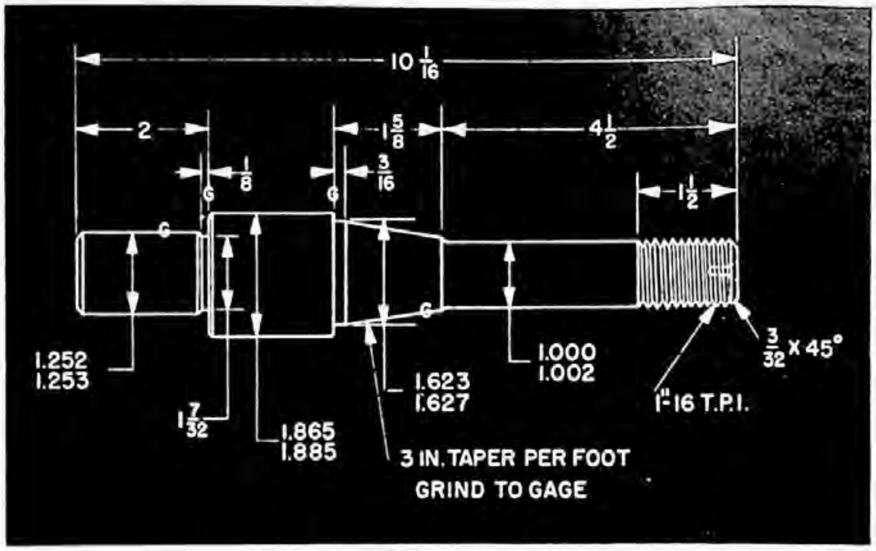


Figure 2

Obviously, it is impractical for the machine shop operator or tool engineer to calculate the peak and root mean square horsepower for each and every job; first, because it is laborious, and second, because the average turret lathe is used for various types of jobs of widely varying power requirements. To eliminate this difficulty, two methods of motor selection are offered to cover the average run of turret lathe work. The first method covers applications where the lathe is used for making a wide variety of products of a general class. The chart shown in Figure 4 is used for those jobs classified as standard duty or heavy duty, depending upon the material to be machined, the class of tooling, and type of cutting tools used. It is recommended that this chart be used in conjunction with a list of recommended motor sizes for standard and heavy-duty applications for different sized turret lathes. Such recommendations can be obtained from various turret lathe manufacturers.

The motor size for heavy-duty work is the largest motor that can be used safely on a turret lathe, and the motor for standard duty is usually one size smaller. Unusual jobs expected to require

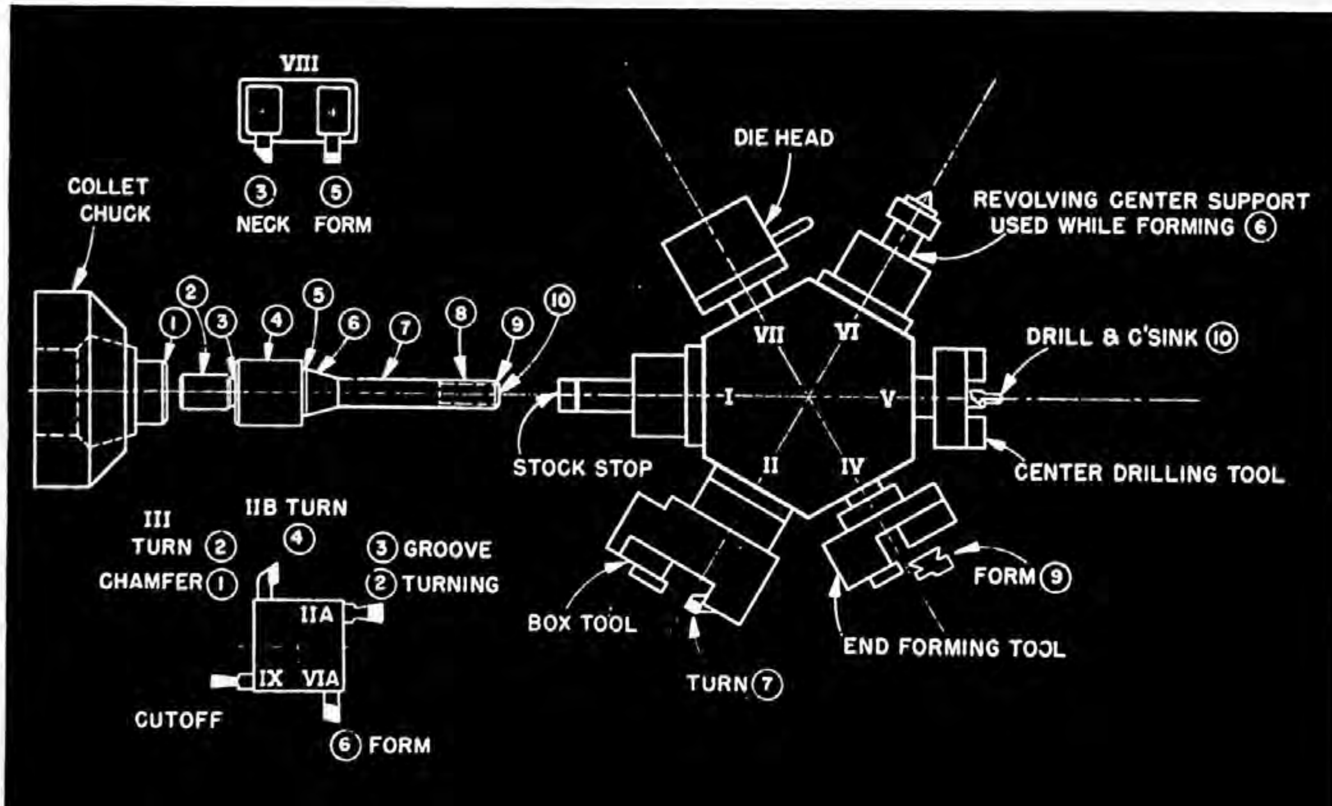


Figure 3

Material	Type of Tooling and Recommended Motor Duty			
	Stellite or High Speed Steel		Carbides	
	Drill-Bore-Turn Simple Tooling	Bar Turner or Equivalent Tooling	Drill-Bore-Turn Simple Tooling	Bar Turner or Equivalent Tooling
Aluminum, Magnesium and Their Low Tensile Alloys; Bronze (Low Tensile)	Std. Duty	Std. Duty	Std. Duty	Hvy. Duty
Aluminum and Bronze High Tensile Alloys	Std. Duty	Std. Duty	Hvy. Duty	Hvy. Duty*
Brass	Std. Duty	Std. Duty	Std. Duty	Std. or Hvy. Duty
Cast Iron; Malleable Iron; Steel (Free Cutting)	Std. Duty	Std. Duty	Hvy. Duty	Hvy. Duty
Steel Alloys (High Tensile)	Std. Duty	Hvy. Duty	Hvy. Duty	Hvy. Duty*

*High Tensile Alloys may require Extra Heavy Duty Motors because of High Cutting Torque required. AC Motors on full voltage will carry approximately 100 percent Momentary Overload Without Stalling.
Note: Refer to turret lathe manufacturer for recommendations on extra heavy duty applications.

Figure 4

extra heavy-duty motors should be submitted to the turret lathe manufacturer for specific recommendations. Occasionally, a larger motor may be permitted if the lathe is operated at faster-than-standard drive shaft speeds.

Warner - Swasey Nomograph

The second method for calculating power requirements was derived from an extensive metal-cutting research program conducted at the Warner & Swasey Company. The results of this work are shown on the nomograph, Figure 5. Among other things, this nomograph establishes the various materials, such as bronze, cast iron, screw stock, etc., in their correct order of machinability.

It is a well-known fact that the power required to remove a certain volume of metal depends upon the time expended in the operation. A convenient unit of power is therefore HP/cu. in./min.

Tests have shown that the HP/cu. in./min. remains essentially constant regardless of the combination of feed, speed, and depth of cut. This fact has made possible the construction of the nomograph which, at first glance, may appear to be somewhat complicated but which simply illustrates that:

(a) for a given diameter, the r.p.m. used result in a certain cutting speed;

(b) with a given cutting speed, the feed per revolution and a specified depth of cut result in a certain number of cubic inches per minute of metal removed;

(c) depending upon the material being cut a certain horsepower is required for the number of cubic inches of metal removed per minute.

It is important to note that the use of this nomograph determines the horsepower consumed under certain cutting conditions and that the amount of head loss or machine tool inefficiency in terms of horsepower should be added to the figure obtained from the nomograph in order to actually determine the motor size required. Conversely, if the net horsepower available at the cutter is known, the nomograph can be used to establish values for any of the variables such as, speed, feed, or depth of cut.

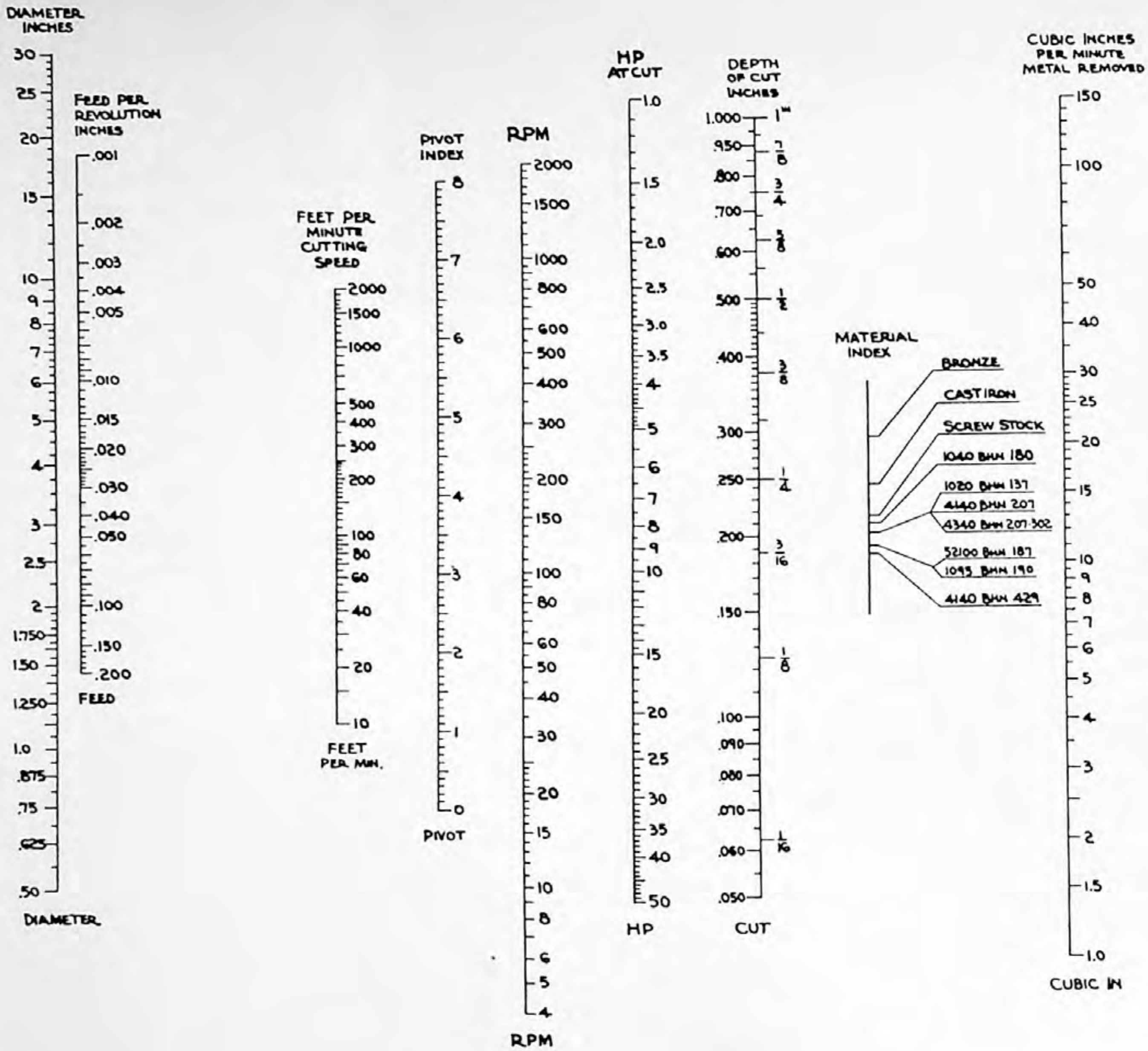
For finishing cuts, there is seldom, if ever, any need for concern about the power limitations of the machine. However, when hogging cuts are taken, power limitations must be recognized and considered and it is for this class of work that the chart is used.

The choice of cutting speed used on the job is based upon recommendations and experience. A variance in cutting speed of ±10% to 20% may, however, often be encountered.

The depth of cut is usually de-

Metal Cutting Chart

Showing Relation Between Diameter - RPM Cutting Speed - Feed - Depth of Cut - Cubic Inches per Minute & Horsepower Required for Various Materials



Step 1 Select Surface Cutting Speed

Step 2 Draw a Line From Diameter (Outside) Through Surface Cutting Speed To RPM Scale.

Step 3 Select Nearest R.P.M. on Machine.

Step	Draw a Line: From	To or Through	To Get
4	Mean Diameter of Cut	RPM	Mean Cutting Speed
5	Mean Cutting Speed	Depth of Cut	Pivot Index Point
6	HP at Cut	Material Index Point	Cubic Inches per Minute
7	Cubic Inches per Minute	Pivot Index Point	Feed

Figure 5

termined by the geometry of the work piece and the amount of stock to be left for the finishing cut. This leaves the feed per revolution as the only factor that ordinarily varies over a wide range. It is in the selection of the feed that available power and power requirements must be established.

Power, of course, is not the only factor that will limit the feed to be used on a roughing cut. Other factors are:

(a) Rigidity of work piece

(b) Rigidity and strength of tooling (fixtures, cutter holders, etc.)

(c) Strength of cutters

(d) End thrust of drills

Each of these factors requires individual study in addition to the consideration of power.

There are also a great number of jobs, especially when multiple cuts are taken or when roller turning tools are used, for which the use of maximum permissible tool feeds would seriously overload the motor.

The metal-cutting chart in Figure 5 does not allow for actual

Motor Rating	*Material*	*Bronze (80-10-10)*	*Cast Iron*	*Screw Stock*	*SAE-1040 Bh-180*	*SAE-1020 Bh-137 SAE-4140 Bh-207 SAE-4340 Bh-207-302*	*52100 Bh-187 SAE-1095 Bh-190*	*SAE-4140 Bh-429*
	Surface Speed Per Min.	*600*	*250*	*350*	*300*	*250*	*200*	*200*
5 H.P.	Depth of Cut	.187	.187	.187	.187	.187	.187	.187
	Feed Per Rev.	.012	.016	.009	.010	.010	.011	.010
7½ H.P.	Depth of Cut	.187	.187	.187	.187	.187	.187	.187
	Feed Per Rev.	.020	.027	.014	.016	.016	.019	.017
10 H.P.	Depth of Cut	.250	.250	.250	.250	.250	.250	.250
	Feed Per Rev.	.017	.023	.012	.012	.015	.016	.014
15 H.P.	Depth of Cut	.250	.250	.250	.250	.250	.250	.250
	Feed Per Rev.	.025	.035	.020	.022	.021	.025	.023
20 H.P.	Depth of Cut	.375	.375	.375	.375	.375	.375	.375
	Feed Per Rev.	.020	.035	.017	.019	.021	.023	.021
25 H.P.	Depth of Cut	.375	.375	.375	.375	.375	.375	.375
	Feed Per Rev.	.025	.040	.020	.022	.026	.025	.023
40 H.P.	Depth of Cut	.500	.500	.500	.500	.500	.500	.500
	Feed Per Rev.	.037	.050	.025	.030	.032	.035	.032

Figure 6

power losses on the turret lathe. If these exact losses are not known, they can be quickly compiled with a reasonable amount of accuracy. For instance, on a 20″ chucking machine, a 15 h.p. drive motor is provided. A good average figure to use in accounting for head losses and other elements of machine inefficiency is 15%. In other words, using a 15 h.p. motor on this particular turret lathe makes 12.75 h.p. available for cutting purposes. It is this figure that is used in conjunction with the metal-cutting chart. The ultimate answer of feed per revolution then represents the permissible feed at 100% motor overload.

The exact feed indicated is very seldom available on the machine. Under this condition, it is necessary to select either the next higher or lower feed.

The proper selection of feed should therefore be left to the judgment of the user. If the selection of the next higher feed overloads the motor, the amount of overload can be determined by working back on the chart with the feed selected to find the actual horsepower that is required compared with the horsepower available.

Motor Overloads

Motor overloads are satisfactory if used with discretion. If the heavy cuts which overload the motor are of short duration and comprise only a small percentage of the work cycle, then an overload should be used to get the most efficient over-all performance. However, where the heavy overloading cuts are of long duration and comprise the major portion of the work cycle, it is recommended that the rated motor load not be exceeded. If the feed indicated per 100% of motor load is not available, then a second check should be made at the next lowest spindle speed and the next highest feed. This usually results in a closer approximation to the rated motor load.

Tool Life

To obtain the maximum rate of metal removal in the least amount of time, tool feeds, speeds, and depth of cut are very important items and should be considered in the following sequence:

(a) Depth of cut
(b) Feed
(c) Speed

To increase the rate of metal removal, and yet maintain maximum cutter life, it is recommended that the depth of cut be increased. Providing the depth of cut cannot be increased, the next most desirable factor to increase would be the feed. The least desirable effect on cutter life would result if the speed were increased. These charts compiled for determining horsepower requirements are on ideal conditions of tool shape and tool surface. Little, if any margin of safety is allowed for poor tool condition. The rate at which metal is removed with carbide tools makes it extremely important that cutting tools be closely watched so that the edges may be resharpened before they become too dull. Negative rake angles or dull cutting edges on positive rake tools may require an additional 50% to 75% of power over the same type of tool when properly ground.

All fundamental steps in tool grinding should be closely adhered to in order to produce an efficient tool which allows metal to be removed with the least amount of horsepower. Proper clearances and relief angles, as well as top rake angles, have a great effect on the power required. Honing or lapping the top face of the cutter is also recommended.

Figure 6 is a check chart, based on data obtained from the metal cutting chart, Figure 5, and is used for determining the power consumed under various cutting conditions. Factors of speed, depth and feed may safely be interpolated to approximate specific conditions. The chart is set up to incorporate a 15% average loss in horsepower at the tool. For example, a 5 h.p. motor at a 100% motor load is required if 80-10-10 bronze is machined at 600 surface feet per minute with a .187″ depth of cut at a feed of .012″ per revolution.

For another method, applied where the turret lathe is used largely for a particular known job, or where the heaviest job of a group is specified, the following steps are necessary:

1. The net horsepower for the heaviest cut, or cuts, if combined cuts are taken, is calculated by formulas for published charts.

2. The machine loss in horsepower for the speed being used is added to the next horsepower and the sum is multiplied by two-thirds.

3. The next larger size of standard open A.C. motor above the horsepower calculated in step No. 2 is selected as the proper motor to be used on the job.

For totally enclosed, fan-cooled motors or D.C. motors, a factor of four-fifths is used in step No. 2.

This method provides for overloading the open A.C. motor 50% for the heaviest cut, which is usually of short enough duration so that serious overheating of the motor is not encountered. For unusual jobs involving a rapid succession of heavy cuts, or cuts of long duration, the cutting data should be referred to the turret lathe manufacturer for specific recommendations.

Selecting a motor for a specific job, or establishing a set of cutting conditions consisting of speed, feed and depth of cut which come within the horsepower limitations of a given machine tool rests with the accurate determination of power consumed by one or more cuts during the work cycle. It is of utmost importance to have available an accurate means of calculating such power requirements for a wide variety of cutting conditions.

THE CROSS-SLIDING TURRET LATHE

Full description of the kinds of work and job conditions which are solved to advantage by the cross-sliding turret machine

THE CROSS feeding hexagon turret is one of the many useful horizontal turret lathe constructions which enable difficult work to be done in small quantities at low cost. The cross feeding turret lathe produces at low cost because it combines simple tooling, low setup time and heavy duty metal removing capacity with the natural advantages of tool setting in multiple stations for successive cuts on repetitive work.

The cross feeding hexagon turret lathe shown in **Figure 1** is a standard machine. If differs from the conventional fixed center turret lathe only with respect to the four-way feeding motion of the hexagon turret which gives it distinct advantages for a certain class of hard-to-handle jobs.

Figure 1 shows how the indexing hexagon turret is mounted on top of the carriage which slides under hand or power feed transversely to the machine spindle center line. The turret carriage is fitted to a saddle which moves longitudinally on the machine bed as in the case of fixed center turret machines. The machine illustrated is also equipped with a full length lead screw, half nut bracket, and chasing dial for thread cutting.

The larger turret lathes, or saddle type machines, are the only lathes ordinarily equipped with cross feeding turrets as optional equipment, since the kind of work best suited to the cross feeding turret is usually beyond the swing capacity of the smaller ram-type turret lathe.

A part with any of the following characteristics may be profitably machined in small or medium size lots on a cross-feeding turret lathe:

1. Bores which are large and/or deep.

2. Wide faces or recesses at the bottom of deep bores.

3. Wide back faces.

4. Large chucking diameters or holding fixtures which limit the mobility of the cross slide carriage, or even require its removal from the machine.

5. Large and deep internal tapers.

6. Large diameter internal threading, either straight or taper.

7. Multiple faces and bores in a complex job which require tool positioning in excess of the available work stations and stops of a fixed center turret lathe.

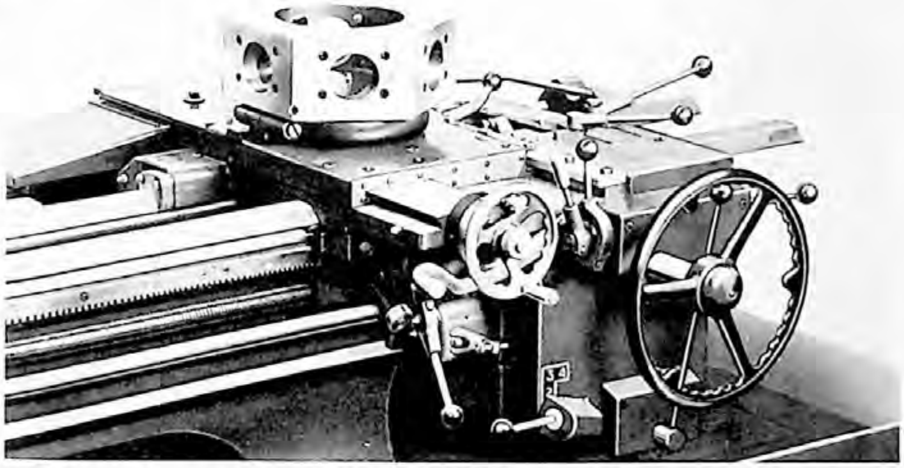


FIGURE 1

Standard tools may be easily arranged in a permanent universal setup on the hexagon turret of the cross sliding machine.

Figure 2-1 shows long and short flange tool holders which are mounted to the turret faces for holding the shank-type tools shown elsewhere in the illustration.

Figure 2-3 is a three-slot tool holder in which shank-type facing, turning and forming tools may be mounted for various operations from the turret.

Figure 2-4 illustrates a double-end boring bar supported on two opposite turret faces by specially designed flange tool holders. This style boring bar is rigid and, being supported at two points, permits deep boring and facing cuts to be taken, with tools mounted in the ends of the bar, at maximum feeds.

Figure 2-5 illustrates a heavy duty drilling tool holder.

Figure 2-6 shows a few of the many angular stub boring bars available for use in boring relatively shallow holes.

With boring and facing tools mounted in a three-slot tool holder or in the double-end boring bar, it is a simple matter to machine tandem or parallel faces, . step bores and similar surfaces with a reduced number of tools by simply adjusting the cross and longitudinal positions of the hexagon turret. A large, graduated dial is normally furnished on the hexagon turret turnstile wheel, so that longitudinal positions of the saddle unit may be established quickly without the necessity of setting positive machine stops. This speeds up positioning the tools when machining parallel faces and step bores of various depths.

When cutting operations, such as the seven previously described, are performed on a fixed center hexagon turret, individual tool stations and tools are required for each surface to be machined. It is not uncommon, with certain types of work, to find that the total number of tool stations required exceeds those available on the machine. This condition may be avoided through the use of special tooling if job requirements are to be met with the fixed center turret.

Standard attachments are available for the cross feeding hexagon turret machine which further increase its flexibility.

Figure 3 shows a standard taper attachment mounted at the rear of the turret to permit straight tapers to be machined on the work within the limits of the attachment. Conventional taper attachments mounted to the cross slide carriages of turret lathes are ideal for turning outside tapers on a part, but where deep internal tapers are required, it is not as practical to hold a long boring bar in the square turret of the carriage for this type cut. A bar of that nature lacks the rigidity necessary to remove metal at rates comparable with the capacity of the taper attachment and double end bar on the cross-sliding turret.

An additional advantage of the taper attachment for the cross sliding turret lathe lies with the possibility that special contour plates may be used in conjunction with the taper attachment for curved boring. Such a plate is illustrated in **Figure 4**. The double end boring bar is used with the taper attachment in this illustration for producing the inside contour of a shell part.

Figure 5 shows a special tool mounted on a cross-sliding turret to produce a complex face contour. This contour is difficult to machine with standard equipment unless one of the many electrical or pneumatic tracing attachments is used. Installation of such attachments is expensive and often restricts—to some extent—the universal nature of the turret lathe for other work; hence the advantages of the simple device illustrated, which is low in cost and which may be removed from the machine readily or left in place without unduly inhibiting the function of the machine for standard work.

The device in **Figure 5** operates in this manner. A swinging arm is mounted to the saddle or fixed portion of the cross sliding turret unit. When in operating position, this arm is swung up into a groove at the end of a cylindrical rack which fits through a special tool holder housing. A pinion gear in the housing meshes with the rack and rotates a vertical spindle to

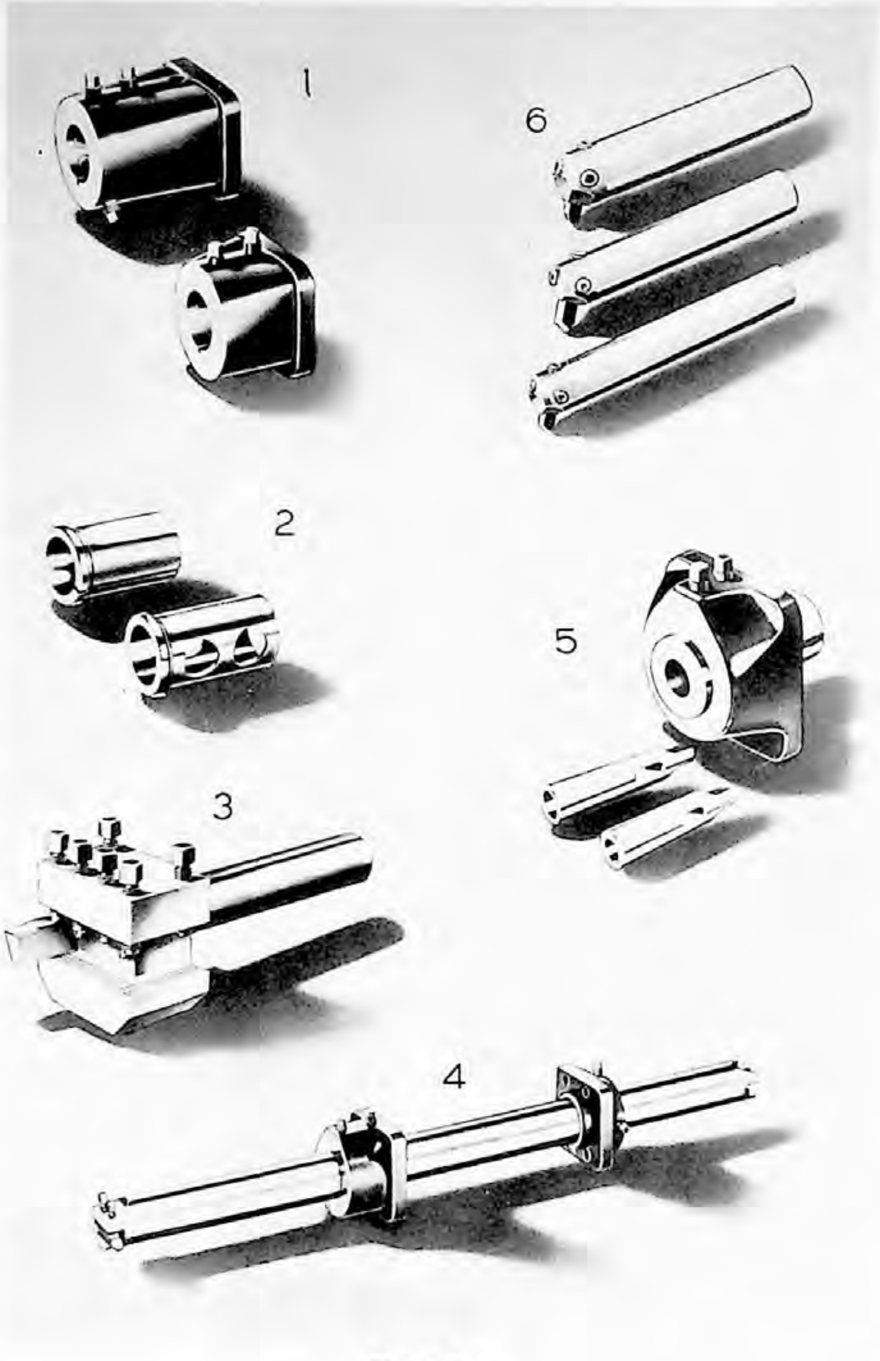


FIGURE 2

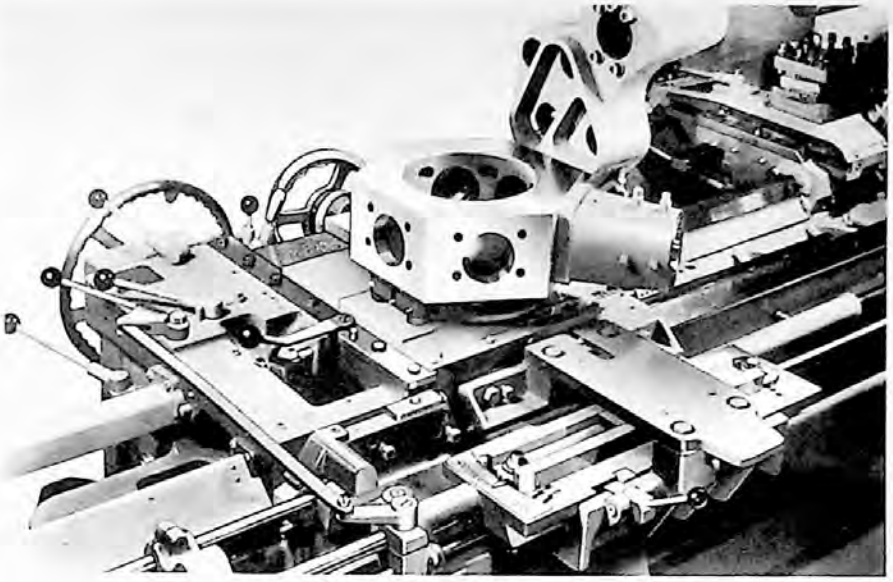


FIGURE 3

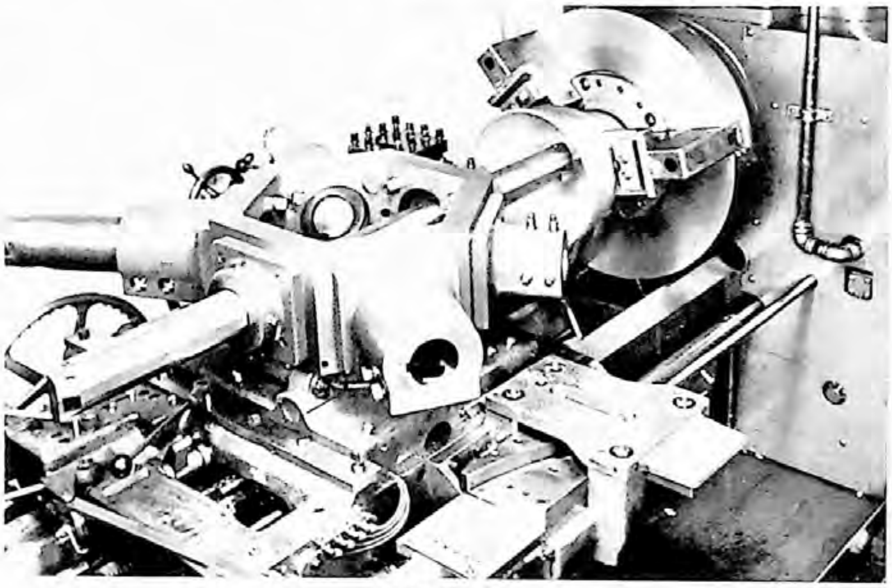


FIGURE 4

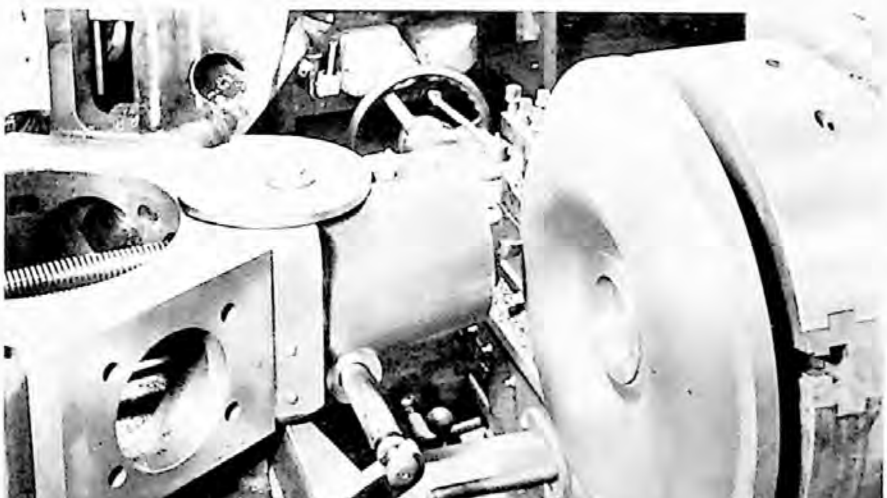


FIGURE 5

which a cam is mounted.

When the cylindrical rack is held securely by the swing arm and prevented from moving at right angles to the machine center line, and when the cross feed is engaged on the turret, the turret unit moves across the cylindrical rack and, in so doing, imparts a rotating motion—through the vertical spindle—to the cam. This cam actuates a roller which is connected through a tool block to the cutting tool. Therefore, depending upon the design of the cam and the rate of cross feed, a curved contour will be machined on the part.

An adjustable threading tool holder, as shown in **Figure 6**, is available for the cross sliding hexagon turret when threads must be chased with single point tools in large diameter holes. Since the threading tool is mounted to the face of the cross sliding hexagon turret, the entire unit may be adjusted away from the machine center line in accordance with the size of the hole in which the thread must be cut. This reduces tool overhang and insures maximum tooling rigidity regardless of hole size. In addition to this adjustment, the tool itself is designed with a slide which moves at a 29-degree angle. In effect, this duplicates the action of an engine lathe compound for feeding-in the tool at a slightly less acute angle than the 60-degree standard form tool when rough machining a thread.

In operation, the cross sliding turret is adjusted so that the point of the threading tool just touches the work. The next few roughing passes are then taken by moving the tool into the work at the 29-degree angle by adjusting the threading tool slide. For the roughing cut, this throws the brunt of cutting action on the leading edge of the threading tool, and produces a thread which is smooth and chatter-free.

The final finishing cuts are taken by adjusting the cross sliding turret for depth at right angles into the work rather than by moving the threading slide at the 29-degree angle. By adjusting the cross sliding turret, the threading tool feeds directly into the work and thus cuts on both sides of the 60-degree angle to produce a thread to gage size and finish.

Figure 7 is a schematic sketch of the hexagon turret adjustable threading tool holder in position with respect to both the work and the turret. Either a full-length lead screw or a leader and follower is used to advance the single-point tool into the work at the proper pitch. Shown in the sketch is the taper attachment previously described in this article which may be used to cut internal taper threads.

Three work sketches and job setups serve well to illustrate the various applications of the cross sliding turret to actual jobs.

Figure 8 shows a typical job which can be set up with standard tools on the cross feeding turret. Notice the use of the double end boring bar, stub bars and three-slot tool holder for machining all of the surfaces indicated on the drawing. This is a common part which involves deep boring and bottom facing. Such work is a "natural" for this type machine construction. The rough and finish facing cuts on surface "J" are machined in combination with the rough and finish boring cuts taken with the hexagon turret double end boring bar. This combining of operations is a basic principle exercised in good turret lathe practice.

Figure 9 illustrates the use of this machine for large work which requires taper boring, bottom facing and machining a large, coarse pitch, internal thread. Standard tools are again used throughout, with the exception of the back facing bar in Station 5 of the hexagon turret. This bar is special, due to the extreme length of face "H", and is the only special in the setup beyond certain grinds on some of the tools.

To produce this part, the machine must be equipped with a taper attachment for the cross sliding turret and the thread chasing attachment for the apron of the turret. The sketch also shows the longitudinal turret dial for gaging the position of the hexagon turret along the bed for the different facing cuts. The adjustable thread chasing tool previously referred to, is mounted in Station 8 of the hexagon turret.

Figure 10 illustrates another common application for cross feeding turret machines. This particular part is almost 32 inches in diameter and requires that the machine bed be "gapped" out. Because of the size of this part and others similar to it, the machine gap becomes rather wide, and it is not considered advisable to equip this particular turret lathe with a standard cross slide carriage unit.

This means that all facing, turning, boring and like cuts have to be taken from the hexagon turret of the machine which naturally falls within the specifications of a cross feeding turret. Note the presence of innumerable step faces and bores in the work which must be machined as well as the taper bore. It is easily understood that this type work, if done on a fixed center turret lathe with standard tools, would require many turret stations. Note, too, that if the required stations exceed those available, the cost of special tools is incurred. For small to medium size lots, this cost may not be easily recovered in a reasonable length of time.

It is not to be inferred that the cross sliding action of this type machine limits its ability to be used as a fixed center turret lathe. Most turret lathes having this feature are designed with a rugged, positive stop which sets the position of the hexagon turret crosswise to the bed on dead center. When locked in this position, the turret may be indexed from station to station as with the fixed center machine, and tooling normally used on the fixed center machine mounted in place, if required.

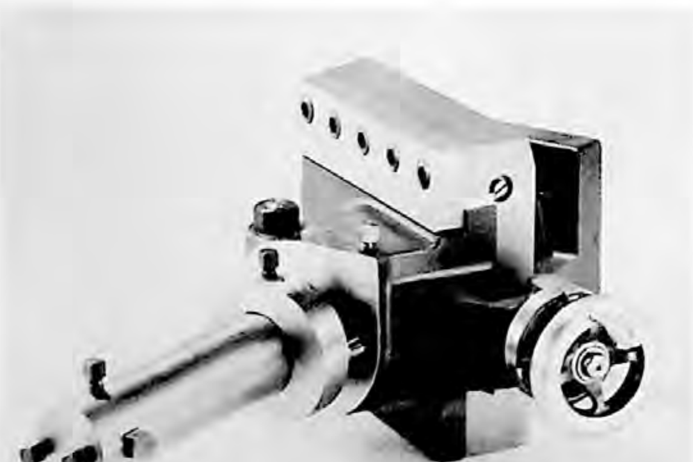


FIGURE 6

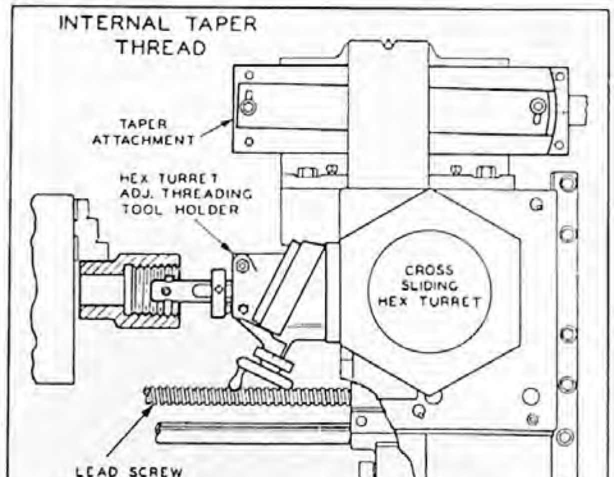


FIGURE 7

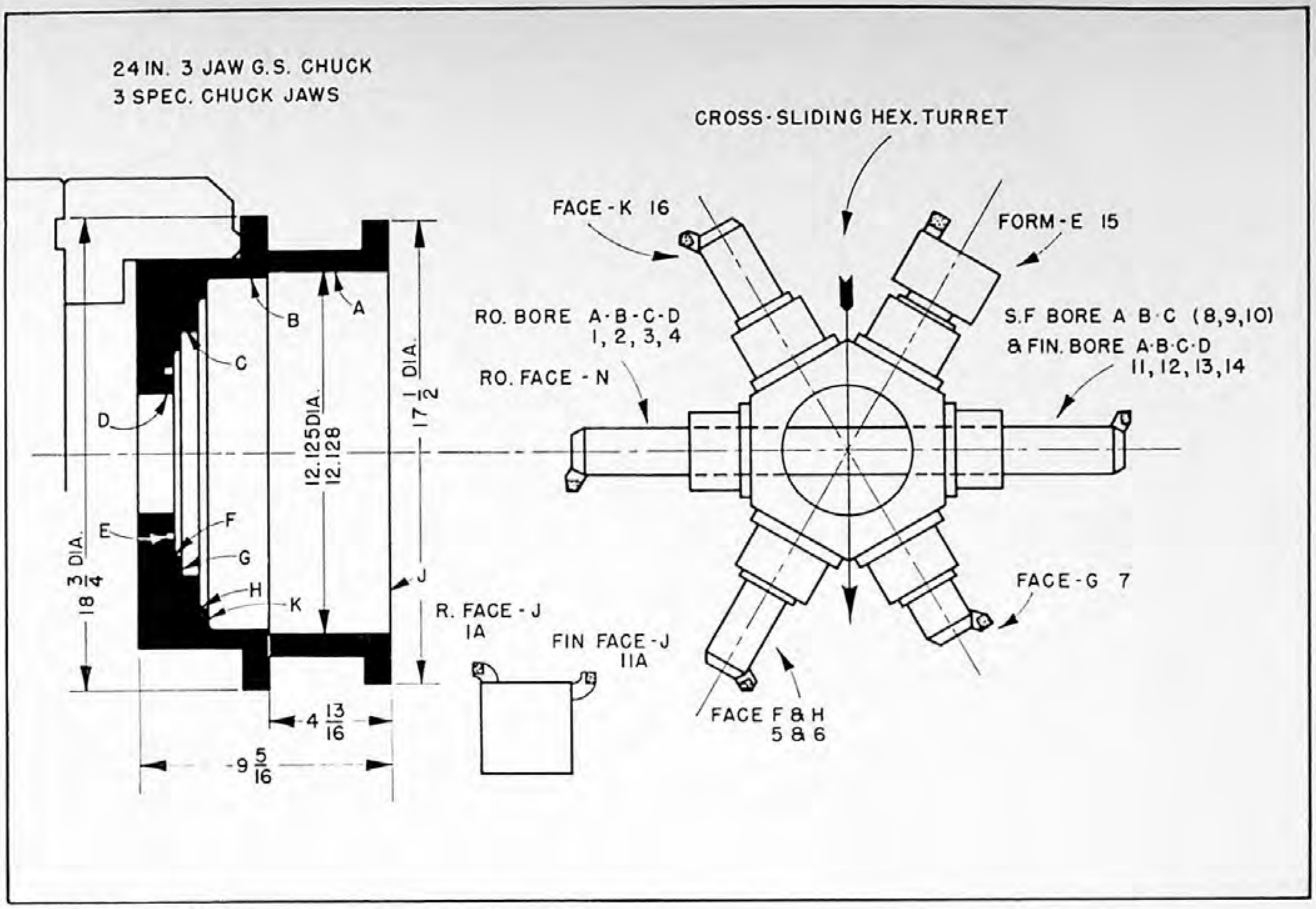
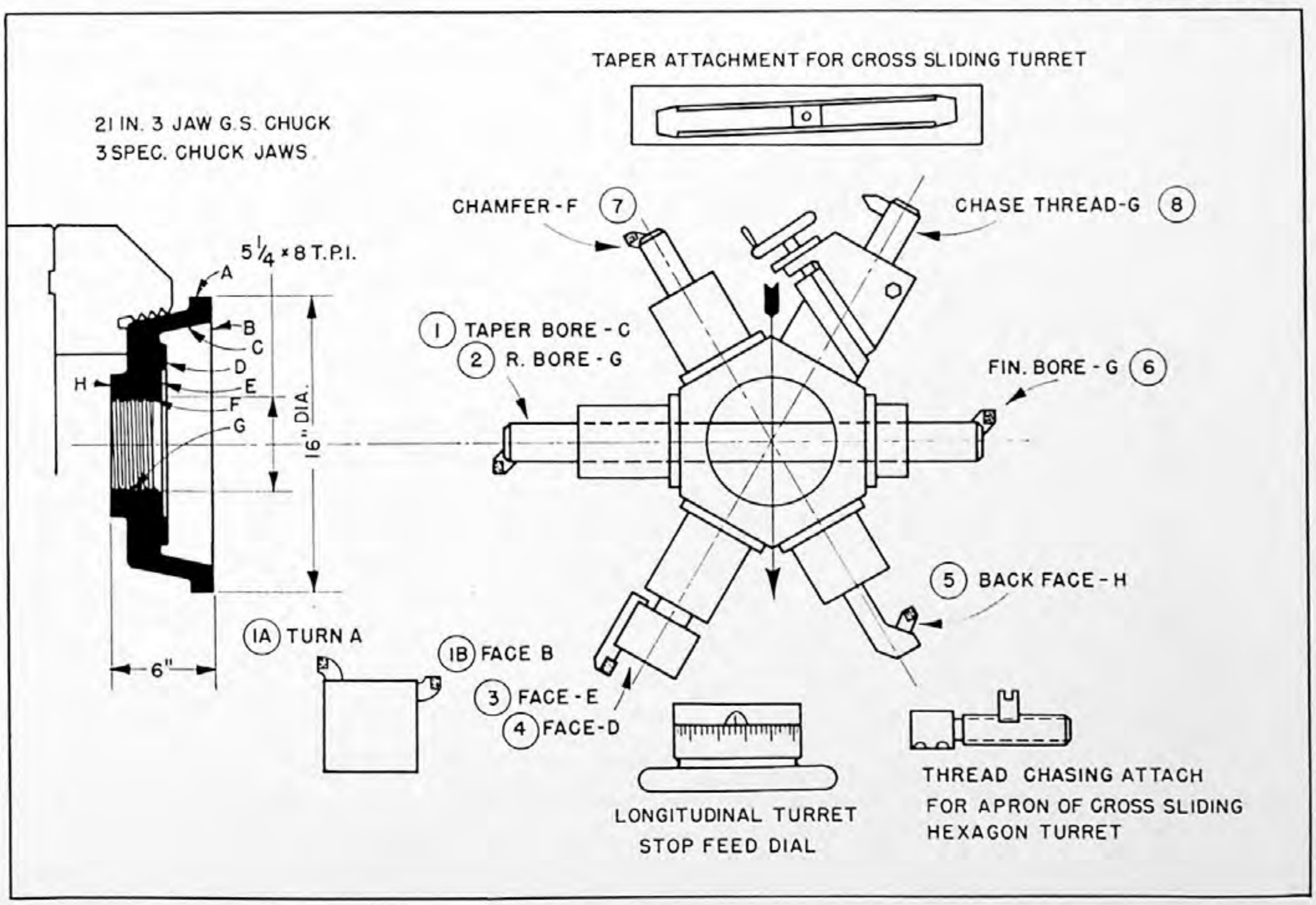


FIGURE 8 (ABOVE)

FIGURE 9 (BELOW)



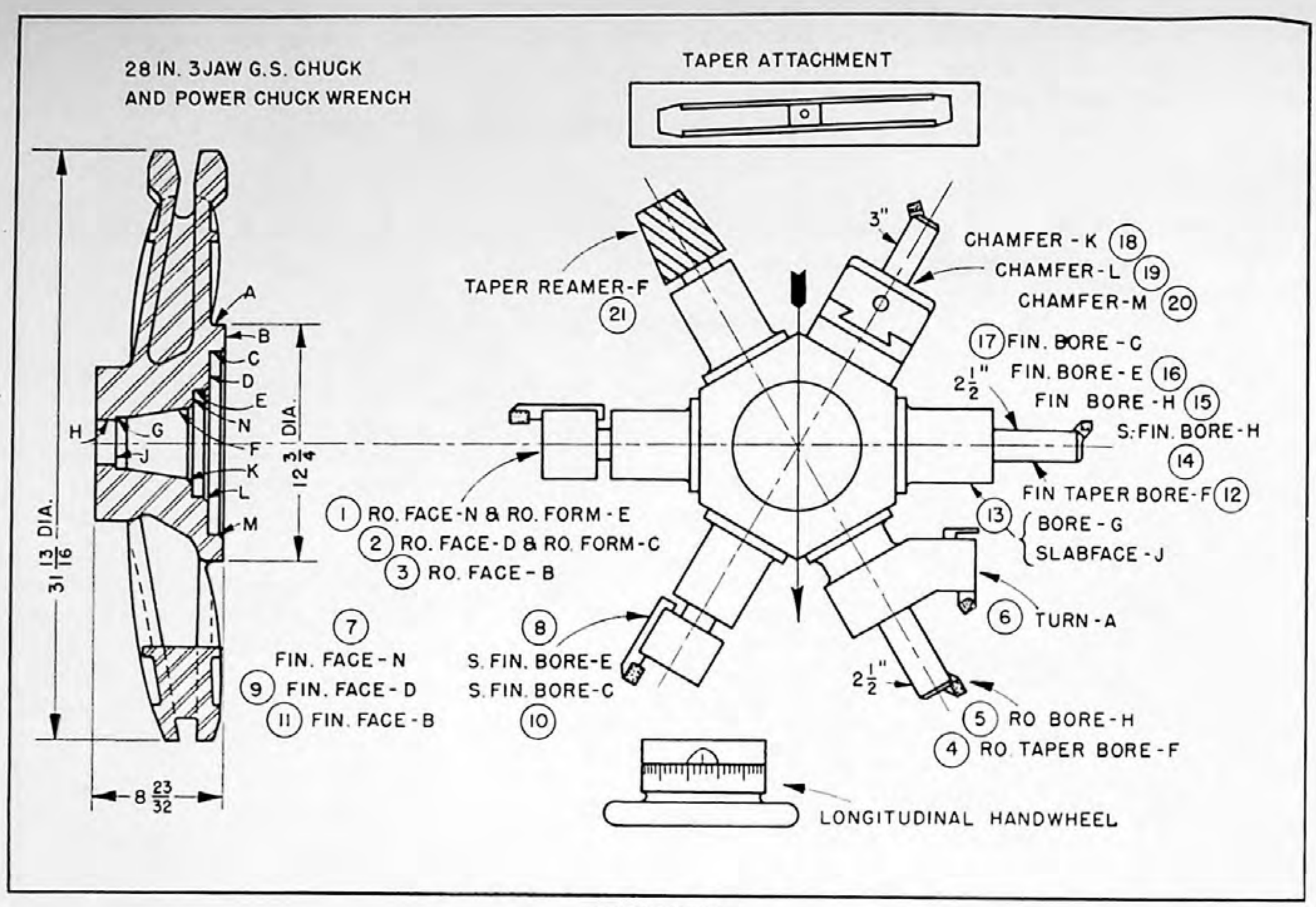

28 IN. 3JAW G.S. CHUCK
AND POWER CHUCK WRENCH
TAPER ATTACHMENT
A
B
C
D
E
N
F
K
L
M
H
G
J
12 3/4 DIA.
31 13/16 DIA.
8 23/32
3"
CHAMFER - K (18)
CHAMFER - L (19)
CHAMFER - M (20)
TAPER REAMER - F (21)
(17) FIN. BORE - C
FIN. BORE - E (16)
FIN BORE - H (15)
2 1/2"
S. FIN. BORE - H (14)
FIN TAPER BORE - F (12)
(13) BORE - G
SLABFACE - J
(1) RO. FACE - N & RO. FORM - E
(2) RO. FACE - D & RO. FORM - C
(3) RO. FACE - B
(6) TURN - A
(7) FIN. FACE - N
(9) FIN. FACE - D
(11) FIN. FACE - B
(8) S. FIN. BORE - E
S. FIN. BORE - C (10)
2 1/2"
(5) RO BORE - H
(4) RO. TAPER BORE - F
LONGITUDINAL HANDWHEEL

FIGURE 10

SPECIAL TREATMENT OF THE BASIC CUTTING OPERATIONS

PART I Turning; facing; boring

A MORE extensive and diversified field of application for horizontal turret lathes has been developed in recent years which results in a new meaning to the cutting opérations performed on this type of machine. Although the principles of turning, facing drilling, boring, reaming, threading, and tapping are not likely to change under present concepts of tool behavior, the variety and sub-types of common cutting operations have nevertheless kept pace with the new qualities of power, rigidity and accuracy incorporated into modern turret lathes.

Some of the methods by which basic cutting operations can be accomplished on a modern universal turret lathe follow:

Turning, Facing and Boring

Figure 1 illustrates one of the most important and extensively used tools for machining bar stock. This tool is a single bit turner, often referred to as a roller turner or a box tool. The design of this tool for use on modern turret lathes incorporates the rigidity and accuracy necessary to take deep cuts at heavy feeds and to close tolerances. Since the work is supported by two anti-friction rolls, it is unnecessary to use a center support in the tailstock or hexagon turret when turning long work. Because the tool permits efficient turning from the hexagon turret, it becomes possible, under certain conditions, to combine other cuts from the cross slide while the turning operation is being performed.

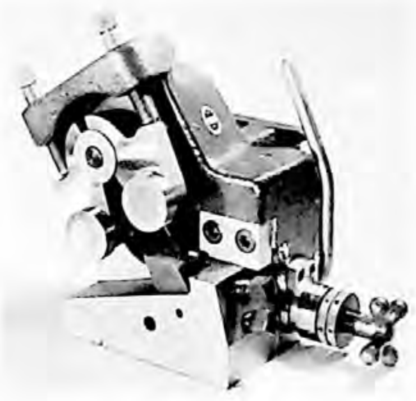


Figure 1

The rolls of this turning tool may precede or follow the cutting edge, depending upon the end result required on the work. If the rolls follow the cutter, the pressure built up between the rolls and cutter causes the rolls to burnish the work. This burnishing effect often fulfills finish requirements and the roll pressure assists in holding close turned tolerances on the part. It is not unusual for the tool illustrated to hold .0005—inch tolerances on turned diameters.

When the rolls precede the cutter, that is, roll in advance on a cold finished or previously turned diameter, close concentricity is obtained between this pilot diameter and the diameter being turned.

The box tool shown in the illustration is conventional in all respects except for the micrometer dial and knob which are added to increase flexibility for under-cutting or recessing work. If a long relief is required between two larger diameters, as might occur between two ends of a shaft, the rolls of the tool are set to pilot on the main bar diameter and the

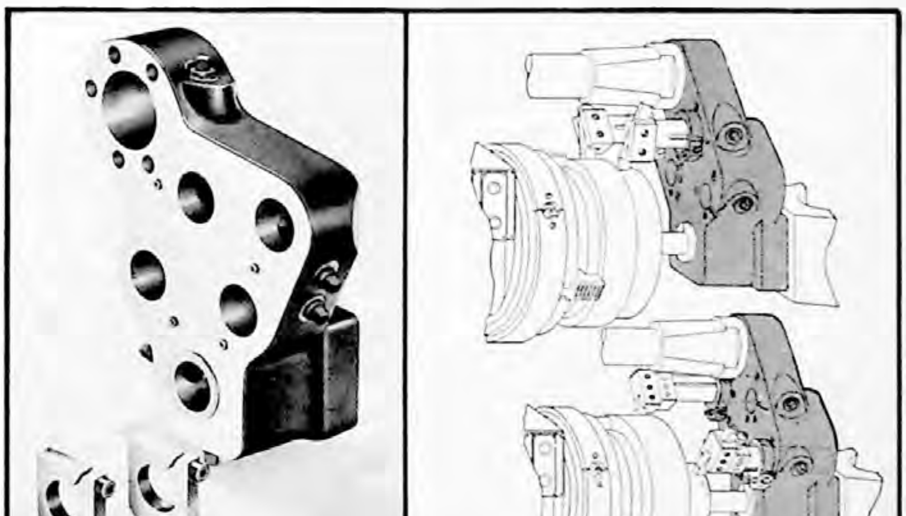


Figure 2

tool bit is advanced into the work by means of the hand and knob until the specified size is obtained. At this point, the turret feed is engaged to feed the tool along the length of work.

Figure 2 illustrates a heavy duty multiple turning head used for turning operations on chucking work. Wherever possible, turning cuts should be taken on a turret lathe from the hexagon turret. This permits the cross slide to be used for facing, forming and other types of cuts in combination with the turning cuts from the hexagon turret. This is a fundamental requirement to the efficient operation of the machine.

Other advantages result from the use of this type of tool for turning operations on chucking work. For instance, the head may be equipped with an overhead pilot bar and in some cases, a center hole pilot bar, which increases the rigidity of the setup, and permits heavier tool feeds.

If a center pilot bar is not used, then a center drill, drill or a boring bar can be mounted in the center hole of the turning head. This saves both cutting and handling time because the turning operation is thus combined with other turret mounted tools.

Since the turning cutters are set to size after being mounted in the turning head, it is only necessary to index the turning head into position and engage the feed in order to take like cuts on successive work pieces. This eliminates the need for the machine operator to reset the cutting tools to size for each piece as is the case where turning tools are mounted on the cross slide.

The accuracy of turned diameter, when taken in this manner, becomes a function of the accuracy of the machine elements, such as lockbolt bushings, bedways, etc., and also, the rate of wear between work piece and cutting edges of the tool. Since most overhead turning tools operate in a nearly vertical position, slight errors in alignment due to indexing mechanisms, etc., reflect to a minimum extent on the work piece.

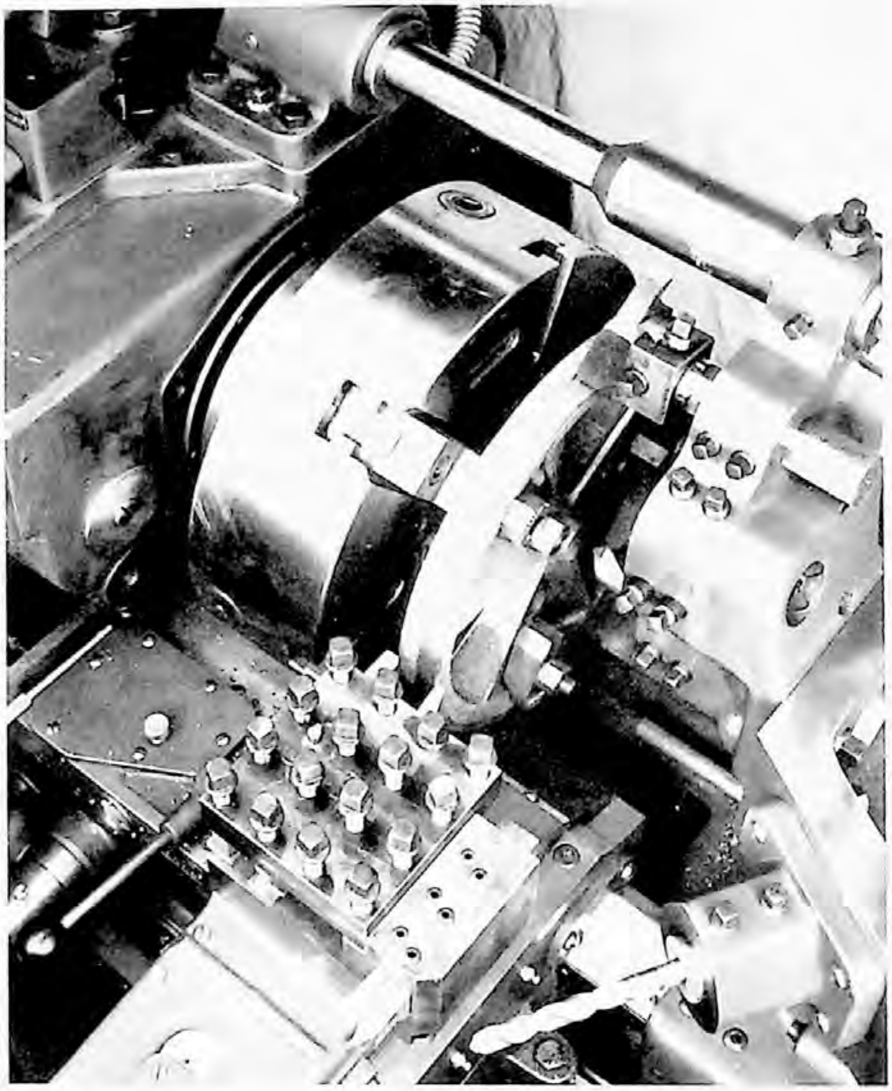


Figure 3

Expressed in another way, an error of .0005-inch in setting a turning tool held in the cross slide of the machine results in twice the error, or .001-inch, in the diameter of the work piece. The same amount of error in setting an overhead tool would hardly be measurable in change of diameter on the work.

Figure 3 illustrates an approved arrangement of tooling for machining a fan pulley. Note the overhead pilot bar which supports the multiple turning head mounted on the hexagon turret.

Combined with overhead turning from the hexagon turret is a centering operation performed with a drill mounted in the center hole of the turret. These two end working tools combine with two tools held in the square turret on the cross slide for straddle facing the rim of the pulley.

A common error often found in tooling setups of this kind is occasioned where a drilling operation is combined with an overhead turning cut. Under certain conditions, this method is fully approved. In many cases, however, a greater saving in machining time results if only the center drilling operation is combined with overhead turning and the drilling operation taken separately in the next turret station.

For example, if the turned diameter is considerably larger than the drilled hole, it is most likely that the cutting speed, determined by the type of turning tool and outside diameter of the work, will be too slow for drilling. Furthermore, if the drilling depth substantially exceeds the length of the turning cut, the extent of the effective combined cut is equal only to the length of the turned outside diameter.

This means that the drill, extending out in front of the turning tool, cuts at a reduced feed for a distance equal to the difference between the depth of the hole and the length of the turn. Unless the machine operator applies a suitable spindle speed for drilling and then, at the commencement of turning, reduces the spindle speed to suit the turning operation, a considerable loss in machine time will result.

By combining centering with turning, indexing the turret one position, and then drilling, the right spindle speed is applied to the drilling operation.

Figure 4 illustrates a setup which includes turning, counterboring and facing operations arranged for a special setup.

The part is a long centerless ground tube counterbored at both ends to a tolerance of .001-inch faced on both ends with one end turned on the outside diameter for a short distance.

To produce this part, the turret and ram slide are removed and replaced by a special slide to operate in the saddle of the machine. Due to the length of the work piece, a fast acting roller support is mounted on the special ram slide to support the outer end of the tube. The other end of the tube is held in a wrenchless chuck.

Also mounted on the special ram slide is a block which holds a counterbore tool used for boring, facing and chamfering the end of the tube. A second block holds a cutter for turning the outside diameter. These tools are positioned so they cut simultaneously during the feeding stroke of the special ram slide.

Shown in the photograph immediately in front of the special ram slide is a lever which the ram slide contacts during its forward feeding stroke. This lever is connected, through linkage, to a nonrotating rod mounted in the spindle of the machine. The front end of this rod carries another counterbore tool for boring, facing and chamfering the chucked end of the part. With this tooling arrangement, the cutters work simultaneously on both ends of the work piece, thereby reducing both cutting and handling time. This method of tooling makes possible a high degree of concentricity between the two end counterbores,

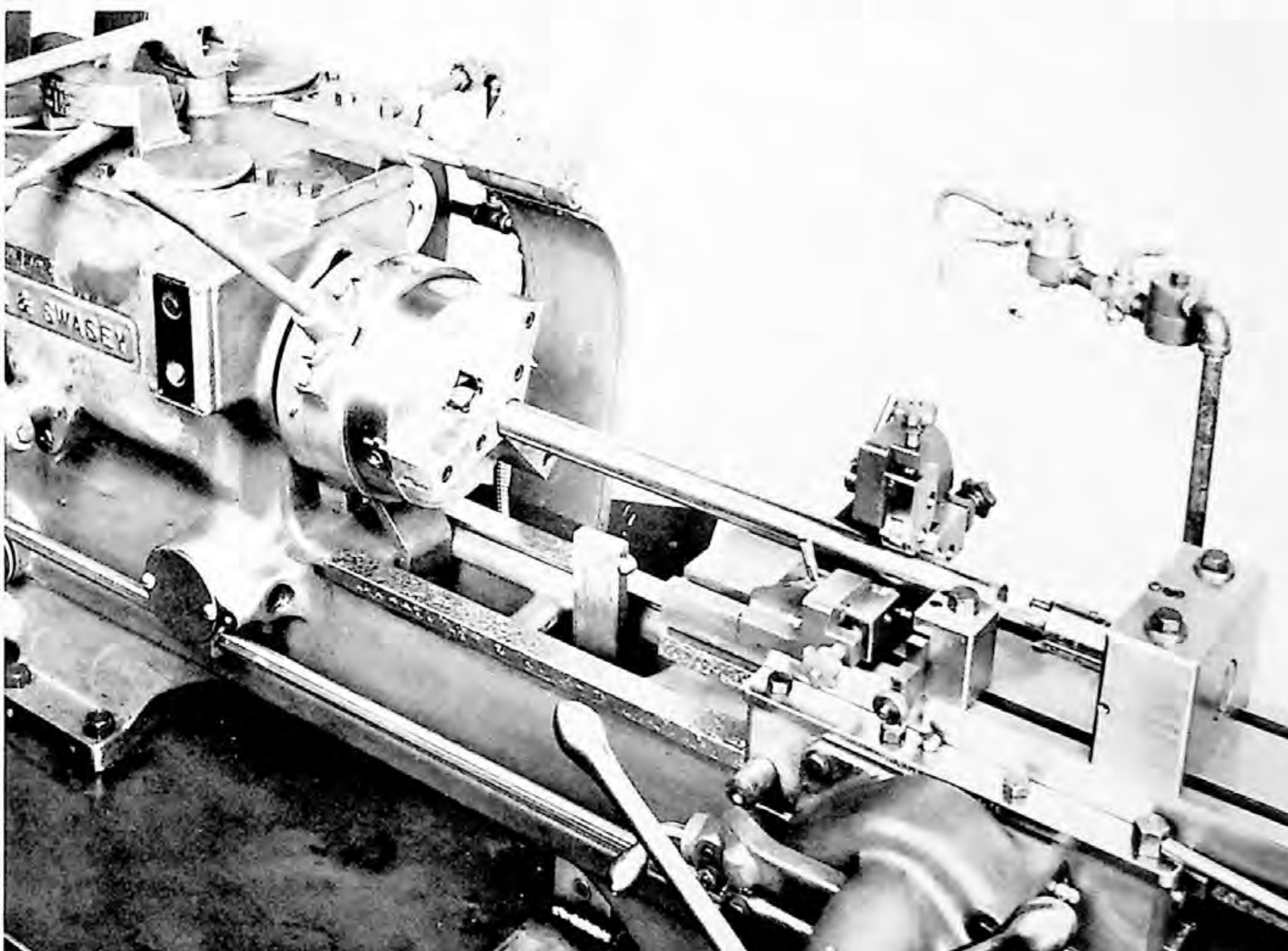


Figure 4

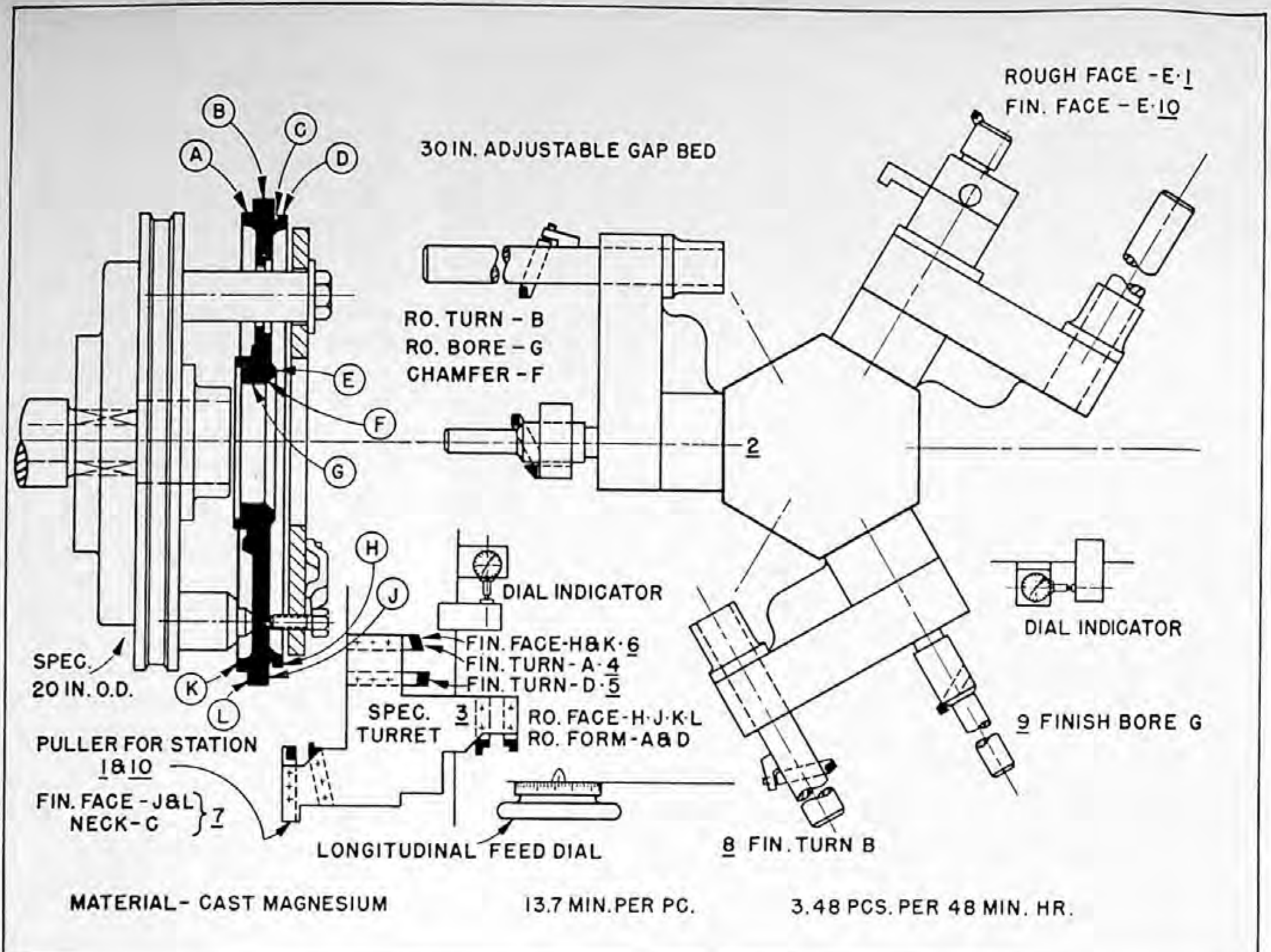


Figure 5

because both ends are machined in the same operation without re-chucking.

Figure 5 illustrates a medium lot size job involving simple turning, boring and facing operations. Special tools are used primarily to overcome difficulties brought about by the size and shape of the part.

In this particular instance, the extremely large diameter of the cast magnesium cover requires the use of a gap bed turret lathe. Due to the large diameter of the part, it is not possible to hold overhead turning tools in standard turning heads.

This difficulty is overcome by mounting tools with suitable adjusting screws in the overhead pilot bars. Piloted type boring bars are used to obtain rigidity and accuracy, both of which are necessary in order to rough and finish bore the hole. The pilots overcome the possible loss of rigidity of stub bars designed with an amount of overhang as required by the recessed position of the part within the holding fixture.

A special indexing tool holder with overhanging arms is mounted on the cross slide and replaces the conventional four-sided indexing turret. This turret is specially designed to reach over and behind the large diameter work piece, and to hold enough cutters to produce the complex contour of the part.

A "puller hook" is combined in the block in station No. 7 of the cross slide. It is the function of this hook to connect with the traverse facing block mounted in stations Nos. 1 and 10 of the hexagon turret. This is a unique method of performing a facing operation from a hexagon turret which cannot feed cross-wise on its saddle.

With the cross slide operated under power feed, this desirable motion is readily transmitted to the facing block on the hexagon turret. Another advantage of mounting the facing block on the hexagon turret is that it allows a more convenient contact with the hub face of the part which is cradled within the work holding fixture. An additional benefit of this arrangement is that it relieves the already heavily loaded cross slide of another tool.

It is not desirable continually to re-position a cross slide from a large diameter working area to a much smaller diameter working area. This results in operator fatigue and loss in machine handling time. It is always better, where possible, to allow the cross slide tools to remain in the general area of the working surfaces, and to machine working surfaces in another area from the hexagon turret. Note the dial indicators mounted on the ram of the hexagon turret and on the cross slide. These dial indicators help the machine operator to bring constant pressure against the machine stops to control the size of the part, and also allows the operator to release the cutters quickly from contact with the work when the cut is complete.

In machining magnesium, this minimizes fire hazards caused by tools rubbing on the work during excessive dwell.

Figure 6 illustrates an adjustable slide boring tool for use on turret lathes. It is a standard tool and is commonly accepted as one of the most important tools used on setups for small to medium size production runs. It is a basic error to omit this tool in planning for the average run of work. Its value lies in its flexibility.

For instance, with stub boring bars held as shown in the upper right hand section of the illustration, precision boring cuts can be maintained by virtue of the adjustability of the tool. The slide tool may also be used with the stub boring bar for hand operated back facing and recessing operations as required.

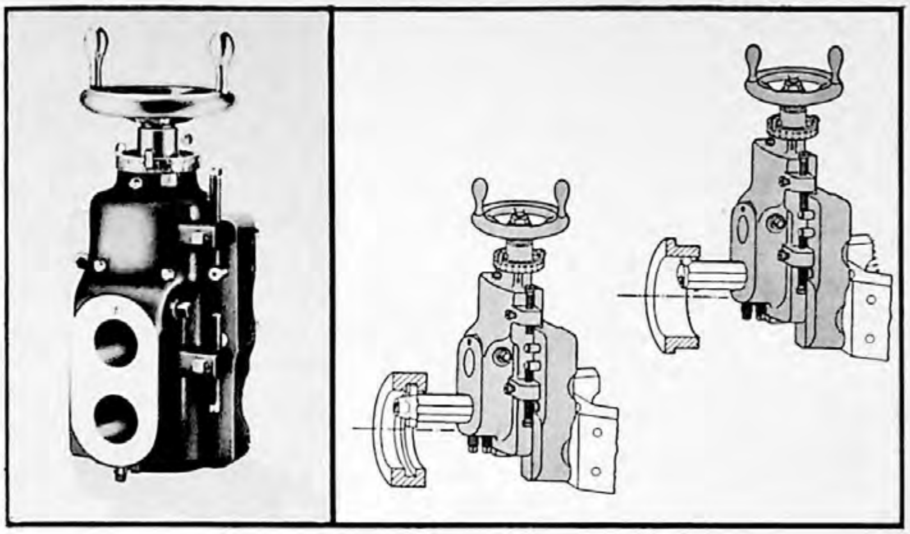


Figure 6

SPECIAL TREATMENT OF THE BASIC CUTTING OPERATIONS

PART II Drilling; tapping and threading; contouring

MACHINING a small cast iron pulley which requires simple operations such as turning and boring can usually be done on a production lathe, chucking automatic, or turret lathe. In such instances, the process engineer is primarily concerned with lot sizes and point-of-least-cost as a guide to selecting the type of machine, rather than with the basic problem of how to do the job.

However, when a low or medium lot size job requires deep holes of large diameter, special thread characteristics, or generation of intricate, curved contours, it is usually assigned to a hand turret lathe. Therefore, a discussion of drilling, tapping, threading, forming, and contour turning operations will be of value to persons engaged in processing, tooling, or actual production of parts on the hand operated turret lathe.

Included in this article, dealing with these tools, are so-called "problem jobs" which, when efficiently tooled, clearly demonstrate the flexibility of the turret lathe.

Drilling

Several different types of drilling equipment may be used on the horizontal turret lathe. Most familiar, perhaps, is the two-fluted twist drill which is used to machine a hole from a solid piece of stock. Specifications for the drilled hole will necessarily vary with:

1. Requirements of the job.
2. Operations which follow drilling on the hexagon turret.

Depending upon the type of material and accuracy of the drill grind, it may be possible to drill a hole accurate enough so that no subsequent boring or reaming operations are necessary. Ordinarily, however, a drill is used to rough out holes.

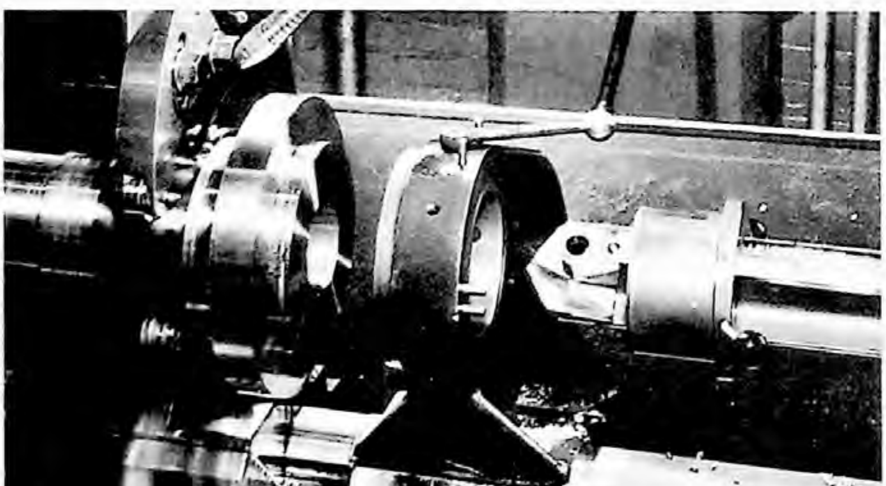


FIGURE 7

Three or four-flute core drills are also used in drilling operations. While core drills cannot be used to drill from the solid, they are useful in opening up the holes of forgings or castings to prepare for subsequent boring or reaming cuts. Inasmuch as a cast or forged hole in the rough work piece may run out considerably, it is usually advisable to chamfer or start bore the rough hole so that the chamfered cutting edges of the core drill can engage a true diameter at the start of the cut.

Since the core drill has three or four flutes, it is possible to increase the feed beyond that normally used with a two-flute twist drill. The larger number of flutes reduces the feed per flute and, within the horse power limitations of the machine, the drill feed can be increased proportionately.

It is difficult to produce a small diameter, close-limit concentric hole to a depth equal to eight or more times its diameter. The usual method of truing up a drilled hole with a boring bar cannot always be used because of resultant overhang and instability of the small boring bar required to fit within the hole. One method of overcoming runout is to use a core drill ground square on its end rather than with a chamfer.

If the hole is machined from the solid, a centering operation is performed first, followed by drilling with a standard two-fluted twist drill to open up the primary hole. At the conclusion of drilling, a boring bar is used to true up the hole for a depth of about 1½ drill diameters.

A three or four-flute core drill ground square on its end is next used to bore the remaining depth of hole. The size of the true bored hole should be equal to the size of the core drill. Since the core drill is given a true concentric start by the pilot bored hole, and because it is ground square on the end rather than chamfered, there is little likelihood that it will wander.

Still another method of drilling on the turret lathe involves the use of a spade drill as shown in Figure 7. A tooling method for drilling machine tool spindles is illustrated. Although its use on the horizontal turret lathe is not common, this type drill is extensively used on production drilling equipment.

In this particular case, the spade drill machines a deep hole, necessitating use of a supplementary steady rest shown between the drill point and the work. Mounted on the bar which holds the drill point is a pilot bushing which fits into the bore of the steady rest as the drill point is advanced to the work.

Use of spade drills for drilling large diameter holes without resorting to employing expensive twist drills is a more economical method. The drill point itself consists only of a flat piece of properly ground high speed steel, which is relatively simple and inexpensive to make. As the cutting edges dull, another sharp drill point can be quickly interchanged with the drill point with minimum interruption.

Using the tools shown in the illustration, a part may be drilled 3¾ inches in diameter by 30 inches deep in approximately one hour. Parts of this type are usually made from alloy steel. Holes can be drilled to a diametrical tolerance of .002-inch and with a maximum runout from end to end ranging from .005 to .010-inch.

The spade drill is not confined solely to deep drilling applications. Manufacturers of standard stub spade drill bars and tips offer tools for conventional shallow drilling on turret lathes. For instance, a four-inch diameter hole can be most conveniently opened up from an unpierced forging with a spade drill. Few shops carry fluted drills ranging up to this size.

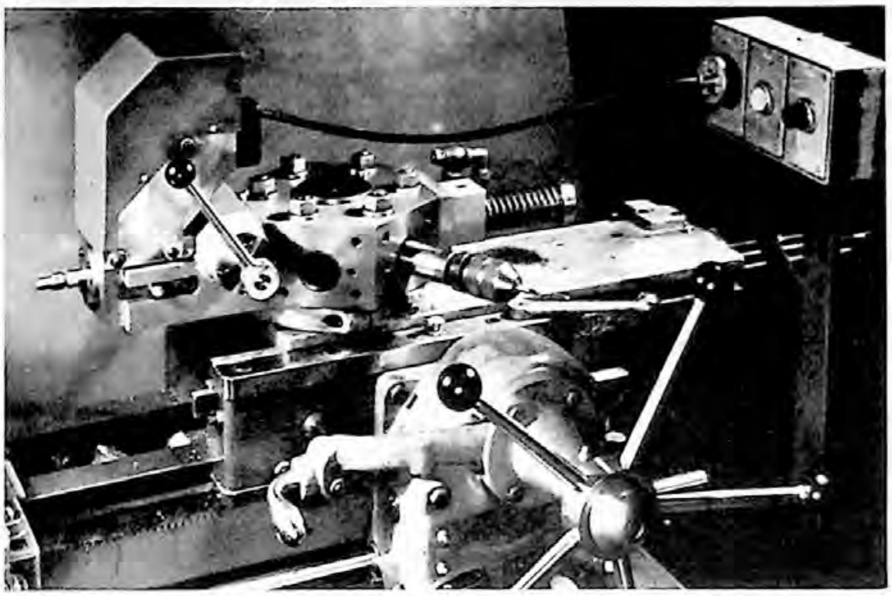


FIGURE 8

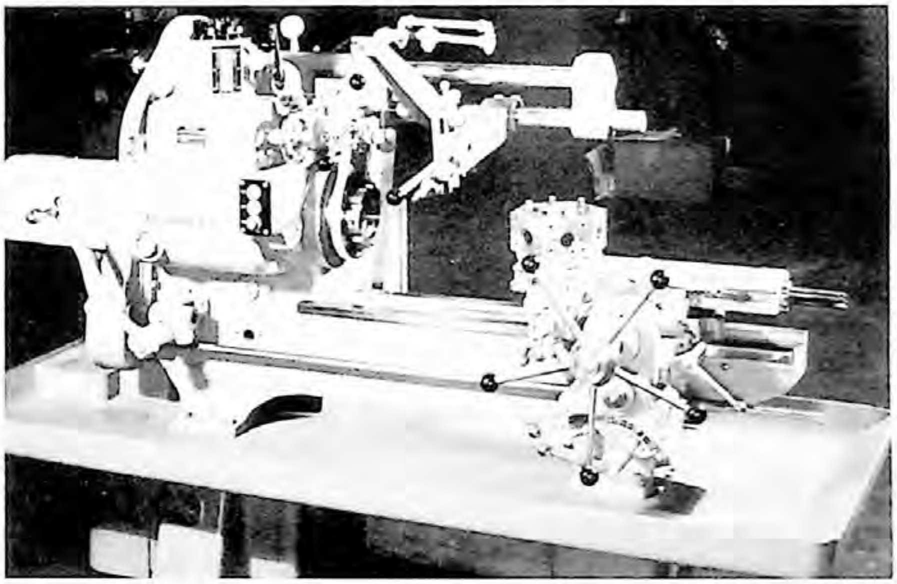


FIGURE 9

Figure 8 illustrates still another method of turret lathe drilling. The tool illustrated is known as a drill speeder.

It is a well established fact that runout can be more closely controlled if the drill is rotated in a direction opposite to work rotations, one function of the drill speeder shown. Note that it is equipped with a sensitive hand feed. The drill quill is spring loaded, and automatically returns to starting position when the handle is released.

The drill speeder may also be utilized for drilling very small holes. Frequently, the highest r.p.m. of the headstock does not provide proper cutting speed for small drills, making auxiliary speeding necessary. This is satisfactorily supplied by the drill speeder arrangement, only one type of which is shown in the illustration.

Threading and Tapping

It is superfluous to review in detail the various standard type threading and tapping devices available for use on turret lathes, such as the solid tap and die, solid adjustable tap and die, and self-opening and collapsing units. Turret lathes may be equipped with various types of lead screws to control accurately the lead or pitch of threads.

One of the most difficult threading problems on a turret lathe is cutting threads which exceed the capacity of die heads that fit the machine. Under such conditions, single point threading is applied. Various standard threading tool holders are available to facilitate this operation, some of which permit the threading cutter to be fed into the work for successive passes at 29 degrees for cutting a "Vee" form of thread.

Frequently, a wide variety of pitches on large diameter work must be cut on a turret lathe from readily machinable materials such as brass, aluminum or bronze. This is a fast cycle threading operation, and it is not ordinarily feasible to use die heads for such work mainly because of the size of the threads and the time required to set up die head equipment.

Figure 9 shows an overhead threading attachment, part of which consists of an over arm which supports a threading tool block. In actual use, the machine operator pulls the handle mounted on the threading tool block downward to engage the chasing cutter with the part. This action engages a half nut with a leader which feeds the cutting tool across the work. Through a spring loading arrangement, the arm automatically returns to its starting position when pressure is released on the handle. The leader can be quickly changed in order to cut threads of different pitches.

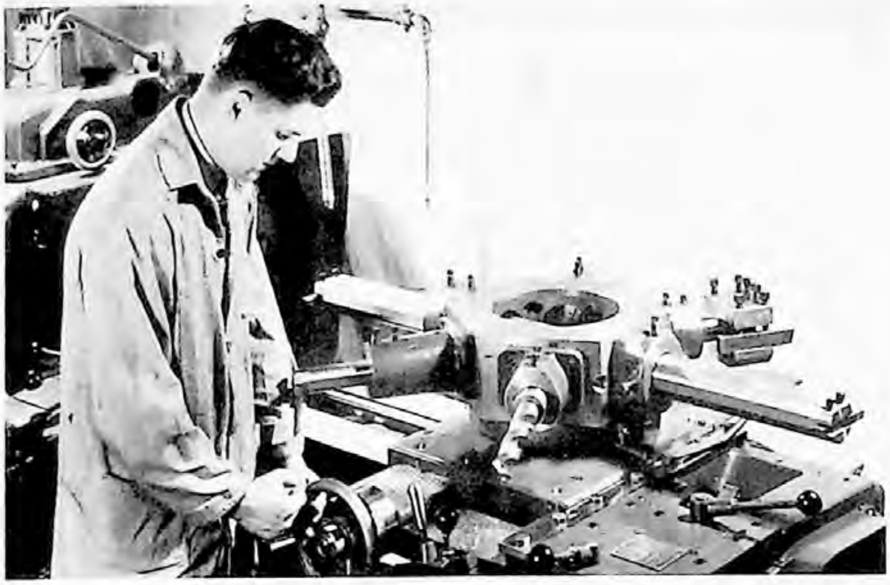


FIGURE 10

Cross Sliding Hexagon Turret Machine

The standard, horizontal-type turret lathe is ordinarily equipped with a fixed center hexagon turret. However, on some types of work, turning, facing, boring, threading, etc., may be done more efficiently on a turret lathe equipped with a hexagon turret which feeds crosswise. This type lathe, shown in Figure 10, is known as a cross-sliding hexagon turret lathe. The illustration shows the cross-sliding turret equipped with standard tools suitable for use on this type machine.

The primary function of a cross-sliding turret machine is to handle small to medium lot runs of chucking work where the cost of tooling must be kept to a minimum. Note the "through" boring bars which are ruggedly designed to permit deep hole boring with maximum efficiency. Another station of the turret provides a long flanged tool holder with a stub bar for boring work of relatively short overhang. Directly opposite the stub boring bar is a three-slot cutter holder in which forming cutters, facing cutters, etc., may be mounted.

Work best suited to the cross-sliding turret machine may have a very large, deep bore, or a deeply recessed surface which is faced.

FIGURE 11

Long back facing operations may also be accomplished under power feed. It is easy to see that a conventional fixed turret machine would require complex special tooling to accomplish these operations.

Sometimes, the size and shape of a work piece and the required swing of the holding fixtures eliminate the possibility of using the standard cross slide for cutting operations. In some instances, it may be necessary to remove the cross slide from the machine, in which case the capacity of the cross-sliding turret to turn, bore and face under power feed becomes useful.

The cross-sliding hexagon turret can be equipped with a taper attachment or with suitable attachments for threading.

Forming

Forming is the simplest means of producing curved or contour surfaces on a work piece. While it is considered a valuable method of producing such surfaces, it is not yet used enough by shops in industry.

Most turret lathe manufacturers offer a complete line of standard dovetail or circular form tool holders which can be applied to standard turret lathes. Other form tools are designed with rectangular shanks which are held in the turret. The circular or dovetail-type form tools have the advantage of longer life over the shank-type tools, although they are more expensive to make.

Figure 11 illustrates an internal circular form tool application on a saddle type turret lathe. This particular job consists of a work piece in two split halves which are fitted into the hinged fixture. The contours illustrated are machined with circular form tools mounted in special holders on the square turret.

The hinged fixture is worthy of further note. It is one of the most accurate means of holding cylindrical work on previously turned diameters for subsequent machining operations. In this respect, the fixture is superior to the ordinary collet chuck or scroll chuck in locating work. Briefly, the design of the fixture incorporates a nonmovable half or shelf, and a hinged half. Insertable bushings are located in the fixed and hinged half of the fixture, and ground in place so they may be adequately wrapped around the work piece during the gripping operation. This holds the work accurately and with minimum distortion, especially if the cylindrical work is extremely fragile.

The cutting-off or parting tool is familiar to most machine tool users, and therefore, does not require detailed explanation. Figure 12 offers an interesting application of a cutting-off operation on the hand operated turret lathe. A small standard turret lathe with an electric collet chuck and bar feed is equipped with a special cross slide operated by an air cylinder. Suitable limit switches and hydro-checks are included in the design so that the cycle of the cross slide, which carries the cutoff cutter, is timed in with opening and closing the collet and bar stock feeding. The end result of this

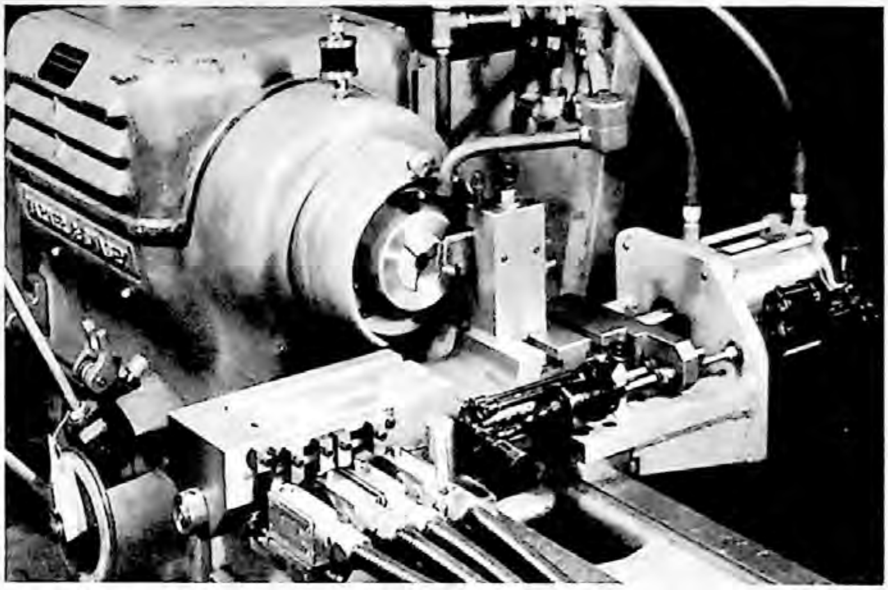


FIGURE 12

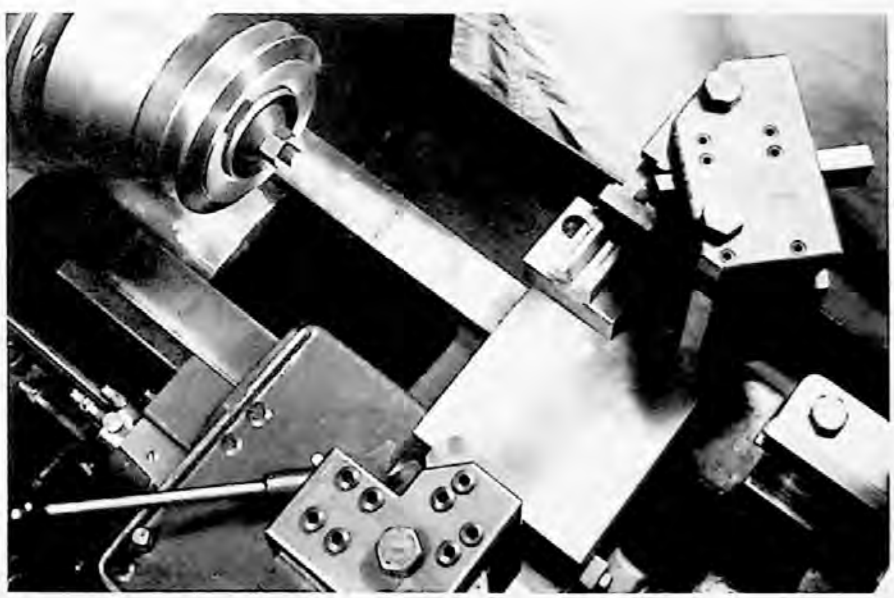


FIGURE 13

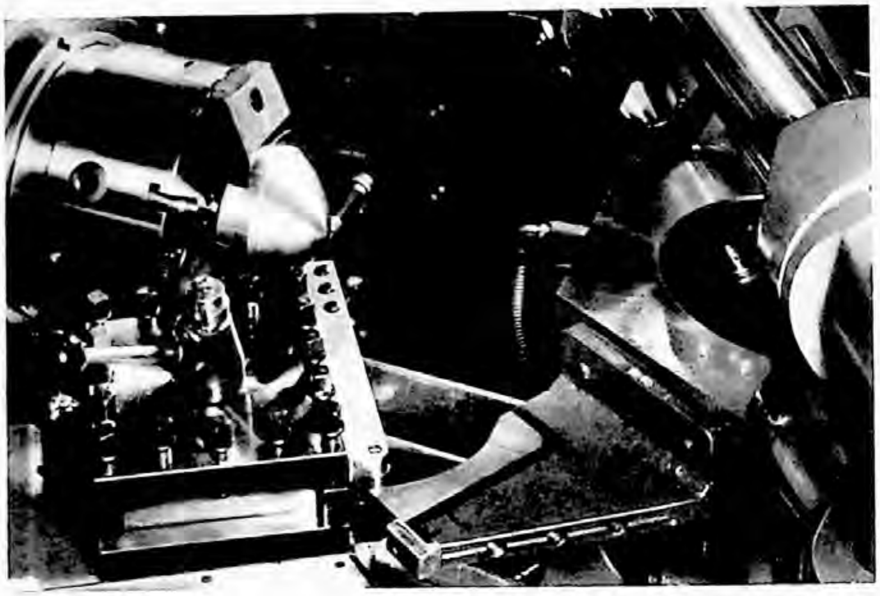


FIGURE 14

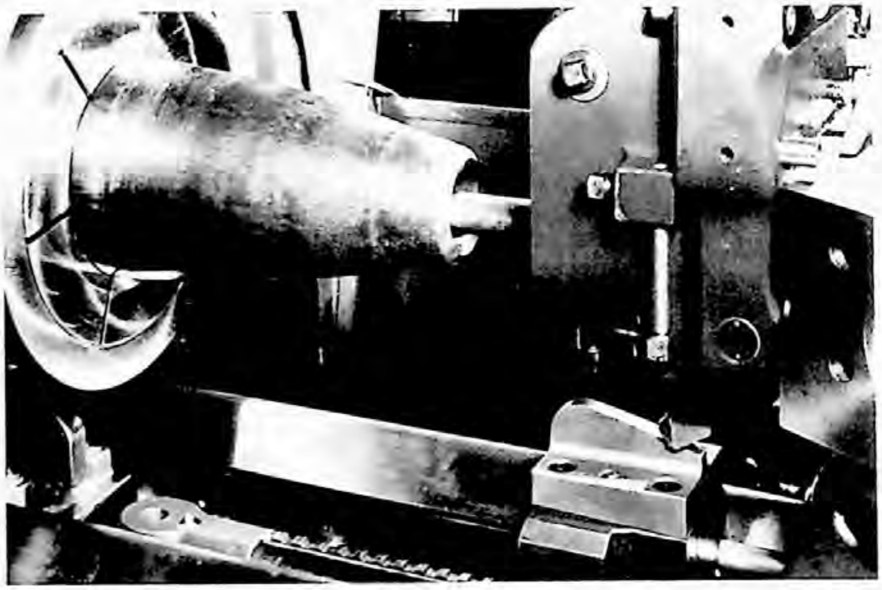


FIGURE 15

arrangement is an automatic cut-off machine secured with minimum expense without interfering with the basic machine for future use on conventional work.

Figure 13 illustrates another type of forming operation. The work piece mounted on the arbor fixture is a "Vee" pulley, and, in this case, the tools are arranged on a completely standard machine. Grooves and faces are rough machined with single bit tools mounted in the front cross slide block. These tools are set to cut on the center line of the part. The groove of the pulley is finish machined from the rear of the cross slide by skiving. The skiving tool passes beneath, or sometimes over, the top of the work piece tangentially and, in essence, "generates" the surface. Thus, the cutter can be fed rapidly across the work and produce a true generated surface. Accuracy of the cut is not limited to working to machine stops and operator feel as is the case where "straight-in" form tools are used. The skiving cutter is sharpened on the front face and has longer life than "straight-in" single bit tools.

Contour Machining by Generating

Frequently, surfaces become so large or intricate that use of form tools is not advisable. In these cases, contour machine attachments and tooling may be provided for the hand-operated turret lathe.

Many manufacturers of turret lathes offer tracer mechanisms or devices of various types which are used in conjunction with standard turret lathes for producing either complex or simple contours. These machine mechanisms ordinarily consist of a master cam and follower which actuates the tool holding slide by pneumatic or electric impulses. By substituting various cams, different contours are produced. Ordinarily, the disadvantages of this type of arrangement are the expense of initial investment, and the tendency to limit, to a slight degree, the applicability of the turret lathe for conventional work.

There are also mechanical means for producing complex contours on a turret lathe. Advantages attributed to mechanical systems are that most shops can economically build such mechanisms which, as required, may readily be removed from the machine so that the lathe can be freely used on conventional work.

The simplest and most familiar means of contouring on a horizontal turret lathe is the taper attachment, a standard device which may be fitted to most lathes at any time. Straight tapers or simple contours may be accomplished with this type attachment.

Figure 14 illustrates one method of producing a contour with special tools. A cam is mounted on one face of the hexagon turret, as shown. Mounted on the square turret of the cross slide is a slide arrangement with a cutter on one end. As the cross slide is fed under power, the supplementary slide mounted in the turret will follow the cam and generate an identical surface on the work piece.

Figure 15 shows a cam-operated, turret-mounted slide tool for boring. This slide tool is an adaptation of a standard slide tool and, in many cases, may be re-worked in a customer's shop from a standard tool.

This tool is spring loaded and does not have the conventional screw and nut so that its vertical travel may be determined by a cam mounted between the bedways of the machine. As the slide tool is fed along the cam rise, the movable part of the slide follows the contour of the cam and reproduces it on the work piece. This is a simple, well-regulated method of contour boring relatively short depths of bore and has been used successfully in many types of manufacturing operations.

Figure 16 illustrates a similar type of slide tool activated by an overhead cam rather than a cam between the ways. This arrangement is more suitable for contour boring to greater depths. Notice the slide tool in position over the overhead cam with the boring bar advanced well into the part. The finish boring unit is shown on the opposite face of the hexagon turret. Note the length of the bar which is stepped in order to clear the work as the contour is produced.

The overhead cam is mounted to the headstock of the machine, and the slide tool rides over the cam upon approaching working position.

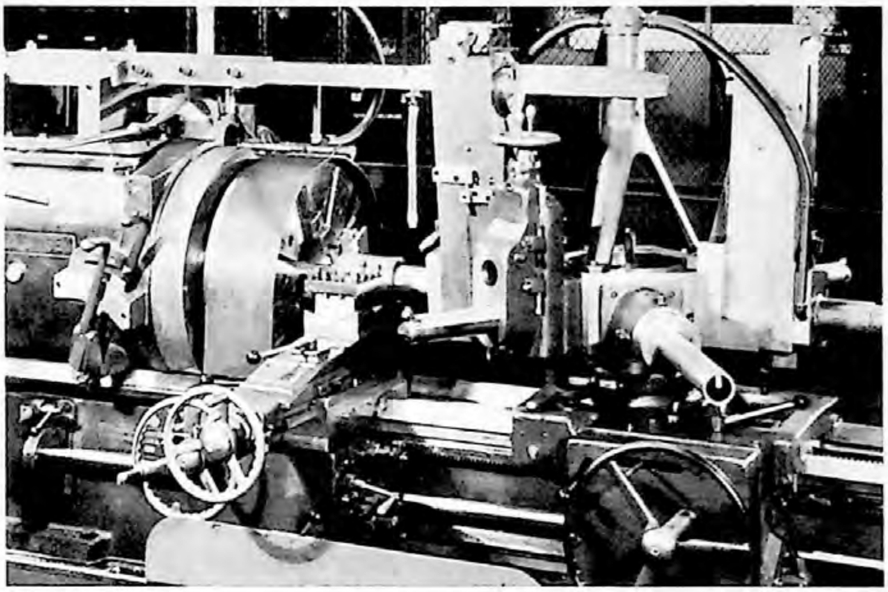


FIGURE 16

SPECIAL TREATMENT OF THE BASIC CUTTING OPERATIONS

PART III Forming, taper turning; contouring (cont'd)

TAPERED surfaces, work contours with simple curves, or a combination of both can be machined conveniently on the hand turret lathe.

Two basic methods may be used: 1. Forming. 2. Generating with single point tools.

Forming

One of the most efficient methods of machining a finished shape on parts produced on turret lathes is to use forming tools. Depending upon the other tools in the setup and the shape to be machined, form tools can be held in suitable holders on either the front or rear cross slide or in the hexagon turret.

Three type form tools—shank, dovetail and circular—are used according to company preference and the economics of tool selection. As is true with form tools used on other turning machines, the shank type is the least expensive but has the shortest effective tool life. Dovetail and circular form tools provide greater tool life coupled with ease in maintaining shape and sharpness of the cutter edge.

While the latter types are more expensive than the shank tool, they are extensively and profitably used where work quantities and complexity of form justify the cost. The circular form tool is usually cheaper to produce but is not as rigid as the dovetail tool because it overhangs the side of conventional holding blocks.

Several factors must be considered in determining the practicability of forming:

1. Cast or forged stock should be rough formed or turned before finish forming if finish and size are important.

2. Unusual materials, such as work hardening stainless steel, may require excessive tool maintenance and special lubricants.

3. Width of form, rate of feed and speed, must be related to horsepower available, rigidity of work piece, and strength of holding device.

4. Accuracy and trueness-to-shape cannot always be provided by forming. In such cases, single point generating may be required.

5. Ordinarily, heavy forming cuts from the cross slide cannot be combined with accurate turning cuts from the hexagon turret due to surface speed discrepancies and the likelihood of the work springing away from the heavy form.

Figure 1 illustrates a typical dovetail forming tool holder for the front cross slide. Figure 2 shows a circular form tool holder which can be used either on the front or rear cross slide. These holders are standard and may be purchased from most turret lathe manufacturers.

Ordinarily, form cutters can be positioned on the front or rear of a turret lathe cross slide at the

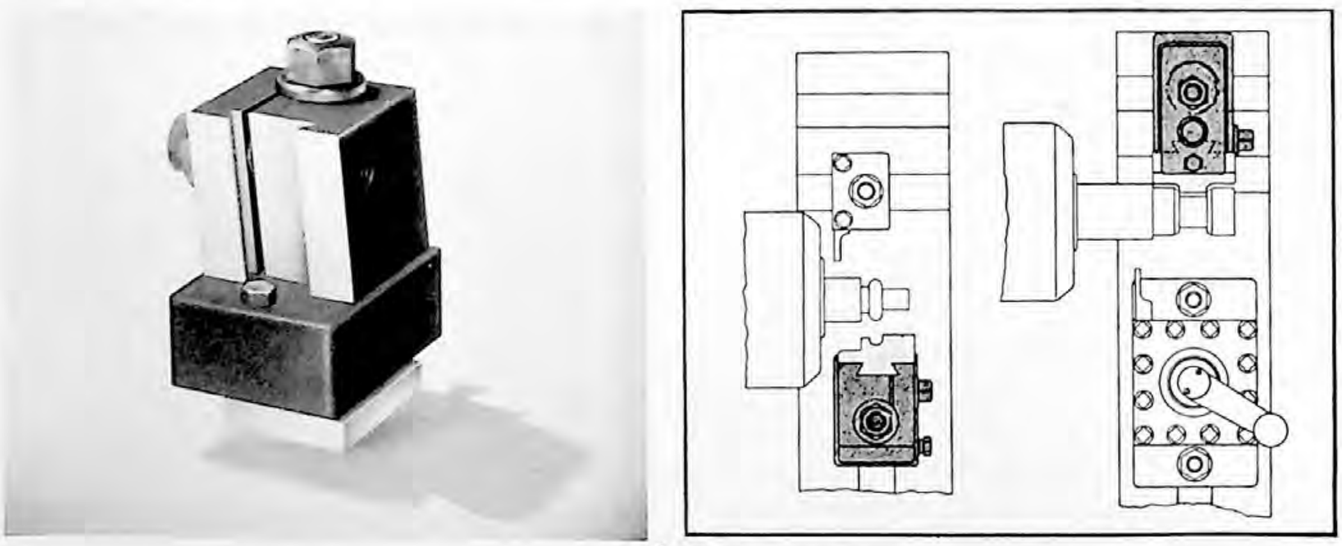
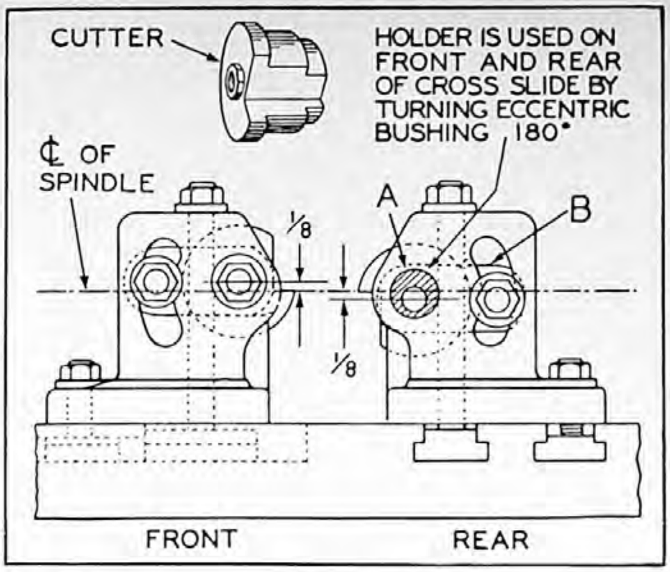


FIGURE 1



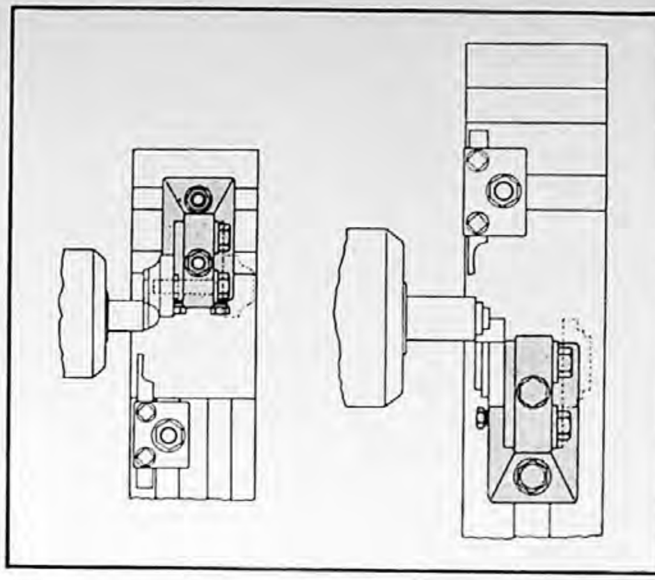


FIGURE 2

option of the tool engineer or set-up man. However, if chatter is encountered on wide form cuts, it may help to mount the tool on the rear cross slide. This is beneficial in many cases because the work revolves counterclockwise into the rear cross slide tool which is mounted upside down.

Under such conditions, any spring in the tool holder causes the unit to "heel" *away* from the work. The reverse is true in the case of a tool mounted on the front slide. Any amount of spring in the front holder causes it to "heel" *into* the work and the tool alternately to dig in and cut, which produces chatter.

The special block design (*see Figure 3*) illustrates how the effectiveness of a forming job can be increased. The size and finish requirements of the small steel ball is enough to require the use of form tools. A "straight-in" form tool on the front side of the block is used for roughing and a skiving or "undershot" forming tool is used for finishing. The roughing tool removes excess stock and controls the finish stock allowance essential to successful finish skiving with the rear tool.

Since the skiving tool passes beneath the ball, no machine stops are required for this operation, thus speeding up the operation and reducing some operator skill requirements. The skiving tool cuts progressively along its edge as it passes beneath the work, acting as a single point tool which facilitates maintenance of a true ball-form.

Note the rigidity of the tool block which permits increased tool feeds and how the two cutters are closely spaced to eliminate unnecessary slide travel. Both factors contribute to greater production and accuracy of work.

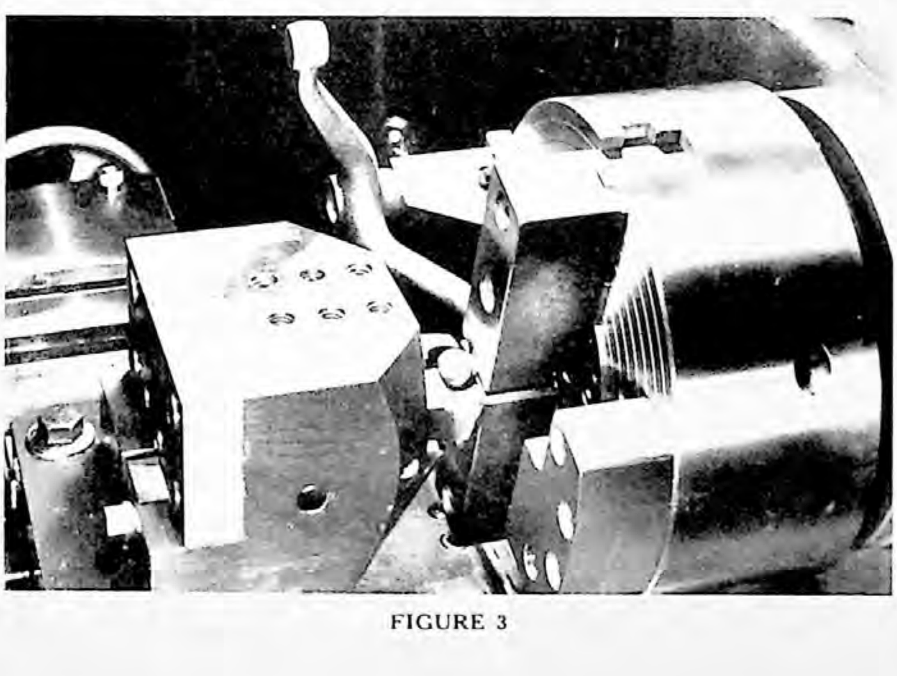


FIGURE 3

Generating with Single Point Tools

It is evident that forming is not the universal answer to all contouring problems encountered in machining parts on the turret lathe.

Single point generating may be a better solution when:

1. Cut is wide.
2. Number of form tools required exceeds available tool positions.
3. Material is difficult to machine.
4. Accuracy and trueness-to-shape is important.

Under any such conditions, single point tools may be used to generate tapered surfaces, simple curves or a combination of both.

The path of the single point tool may be controlled by either electric or pneumatic duplicating devices or mechanical attachments. This article deals with mechanical attachments, since they may be purchased or built with least expense and can be added to the turret lathe without extensive alterations.

Standard Taper Attachment

This device is too well known to users of turret lathes to warrant detailed description, but two factors in its operation are worth reviewing: 1. How to insure good finish. 2. How to maintain accuracy.

All other factors being equal, good finish is obtained with the taper attachment by feeding the tool in the proper direction for the taper cut. In order to determine this, the direction of back pressure from the tool, resulting from the cut taken and the movement of the cross slide required to produce the taper must be considered.

Cross motion of the cross slide must be in a direction opposite to the direction of the back thrust from the tool. When this condition exists, both pressure from the cut and longitudinal motion of the slide will force the sliding taper attachment block against one side of the guide plate. If these conditions are not satisfied, the back pressure of the cut will pull the sliding block to one side of the guide plate and the longitudinal movement of the cross slide will pull it to the other, thus causing steps so commonly found on taper work.

Accurate sizes may be maintained with the taper attachment by observing three important steps:

1. Attachment must be accurately located in the same position in relation to the cross slide each time it is used.

2. Cross slide unit must be located in exactly the same spot on the bed when the extension rod, which arrests the motion of the guide plate, is clamped to the bed.

3. Binder screw and extension rod must be loosened when the cross slide is in the same position as in the first step above.

These are all elements of good taper attachment practice but are sometimes overlooked in the use of this unit.

Figure 4 is a schematic sketch of the relation between feeding pressure and direction of the cross slide feeding motion, which is necessary to produce a good finish.

Not so well known is the adaptability of the taper attachment or special forms of the attachment for unusual applications.

For example, the outside diameters of a mortar shell in Figure 5 are machined by means of a taper attachment fitted with a special contour guide plate. Because of the curved contour it is necessary to replace the standard rectangular follower block, used in taper attachments for straight tapers, with a hardened steel ring having a projecting lobe on one side. This lobe rides on the contoured surface of the guide plate to produce the required contour on the work. It is generally considered good practice to design the follower lobe with a radius equal to the radius ground on the nose of the tool to insure accurate duplication of the plate contour on the work.

In this particular unit, because it is not possible to maintain the proper relation between tool back thrust and direction of feed at all times during the generation of a variable curve, special brackets are mounted on the cross slide and carriage of the machine.

Mounted within the telescoping

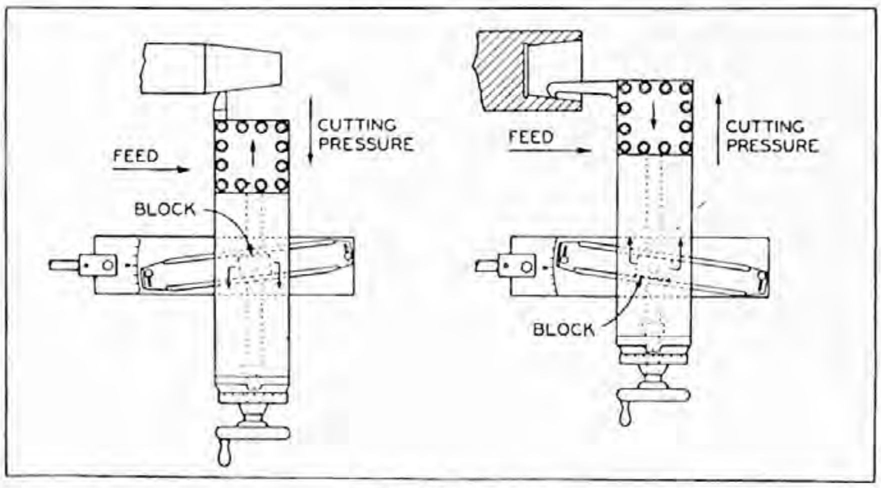


FIGURE 4

FIGURE 5

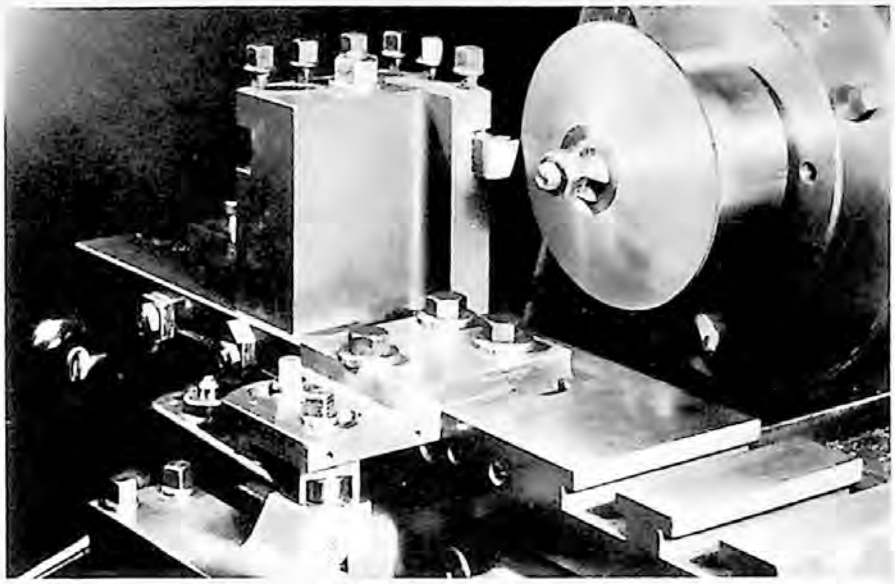


FIGURE 6

tubes which are attached to these brackets is a powerful spring. This spring insures that the cam follower lobe will guide or press against the cam plate surface regardless of the manner in which the path of the contour changes for any given direction of feed.

Generally speaking, standard attachments or units with special guide plates may be used for cutting curved or tapered contours whose axes lie in the direction of the machine spindle axis.

Frequently, however, tapered surfaces and contour faces must be machined at steep angles with the machine axis. On such jobs, the standard taper turning attachment cannot be used.

Figure 6 illustrates a variation of the taper attachment system which can be used for steep tapers. Clamped to the machine bed, a bracket carries the roller follower which engages an adjustable guide plate mounted in a bracket on the cross slide of the machine. The cross slide feeds under power along a path determined by the angle of the guide plate. Note how quickly this attachment may be assembled to or removed from the machine so that flexibility of the lathe for general purpose work is not destroyed.

Another special taper attachment used to rough and finish the spherical face of a hammer head is shown in Figure 7. In this case, a bracket is also bolted to the bed of the machine, and assembled to this bracket is a roll type follower fitted within an eccentric bushing. This eccentric bushing may be revolved approximately 45 degrees by actuation of the handle with the black knob, which changes the center of the roll follower a matter of several thousandths longitudinally along the bed. This determines the longitudinal position of the taper attachment guide plate for roughing and finishing cuts.

In other words, the spherical guide plate is mounted within the block fixed to the cross slide of the machine and fits over the roll follower which is mounted in the bed bracket. The path of the cross slide and the tools mounted thereon follow this guide plate as the cross slide is fed at right angles to the machine spindle. It is, therefore, a simple matter to take rough and finish cuts on the work piece with the same tool by simply moving the handle which clicks into detents and automatically positions the eccentric bushing with roll follower in the roughing or finishing position.

Rack Driven Spherical Turning, Boring Tools

Another important class of mechanical attachments for contouring are those which produce external or internal spherical surfaces on the work. Such an attachment is illustrated in Figure 8. When machining harder materials like cast iron or steel, it is always preferable to provide power feed to these attachments. As shown in Figure 8, this is accomplished by connecting the hexagon turret to the rack which drives the ball turning attachment through gearing. The attachment is shown in position at completion of cut.

A similar attachment mounted on the face of the hexagon turret for producing internal spherical surfaces is shown in Figure 9. This tool is also rack-driven by power

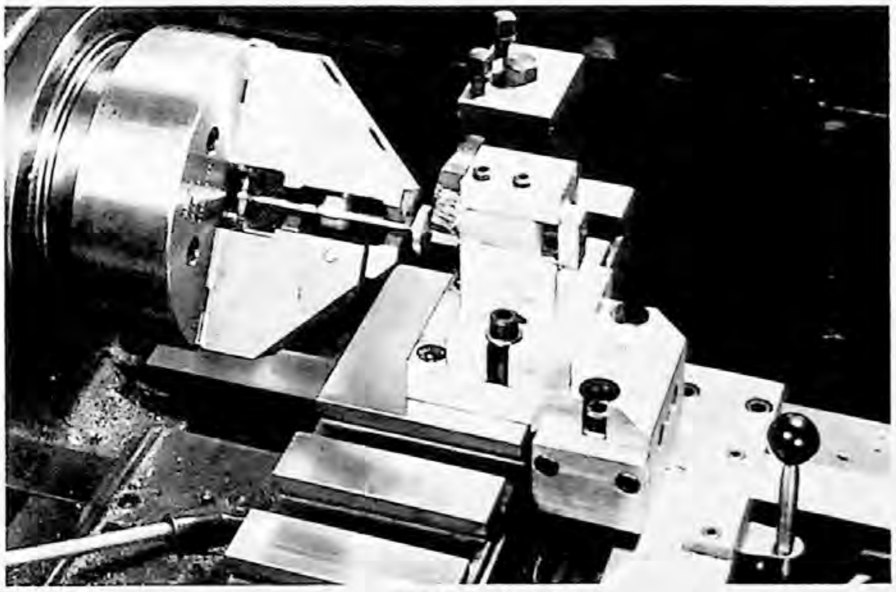


FIGURE 7

feed transfer from the cross slide of the machine. Note the special micrometer frame which is used for accurate setting of the spherical boring tool.

Another rack-driven tool is shown in Figure 10. This tool is adjustable to cut 45-degree tapers on diameters up to 4½ inches and may be used for external or internal operations on valve seats, etc. The cross slide driver block may drive from either side of the roller which is mounted in the end of the arm or link shown beneath the tool. As the cross slide is fed in either direction, the link rotates and transfers its motion through gearing to the tool block which holds the single point tool.

Note that the unit which contains the gearing and the link is adjustable crosswise in the block which is bolted to the face of the hexagon turret. This adjustment is used to set the diameter at which the taper must be cut. The cross slide may be easily adjusted to suit each new position of the link so that power feed may be transferred to the cutting operation.

Figure 11 illustrates a contouring tool which cuts both a two-degree straight taper and a 3½-inch radius on one end of the taper. The part shown in the fixture is made from aluminum. Requirements of the job are such that no separate blending of the radius and taper is allowed. This means that one tool following a continuous path must produce both taper and radius.

Design of this contour attachment is as follows: A fixed rod is mounted in the spindle and positioned so that it extends through the work piece to a position about flush with the end of the outside face of the work. On one end of the rod is mounted a bayonet lock collar. Mounted through the face of the hexagon turret flanged bracket is a sliding shaft which engages the bayonet lock collar on the fixed spindle rod.

Machined into this shaft is a

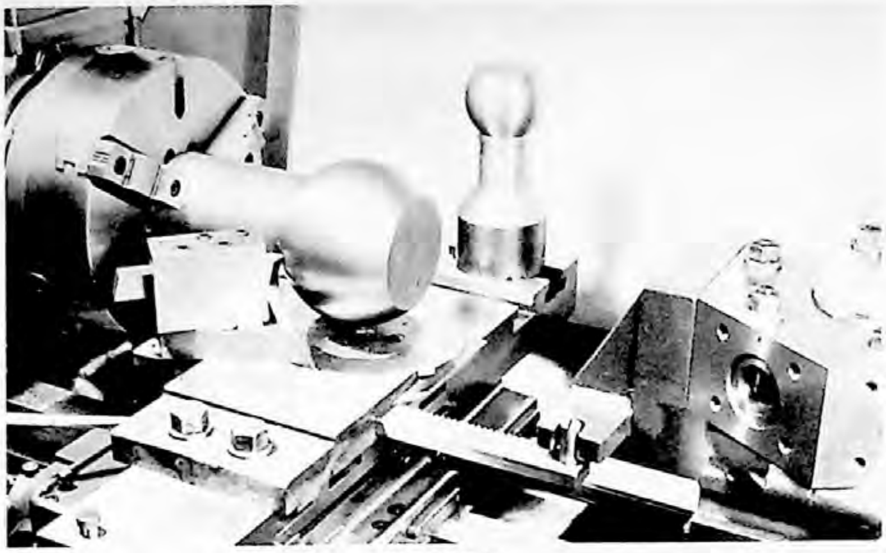


FIGURE 8

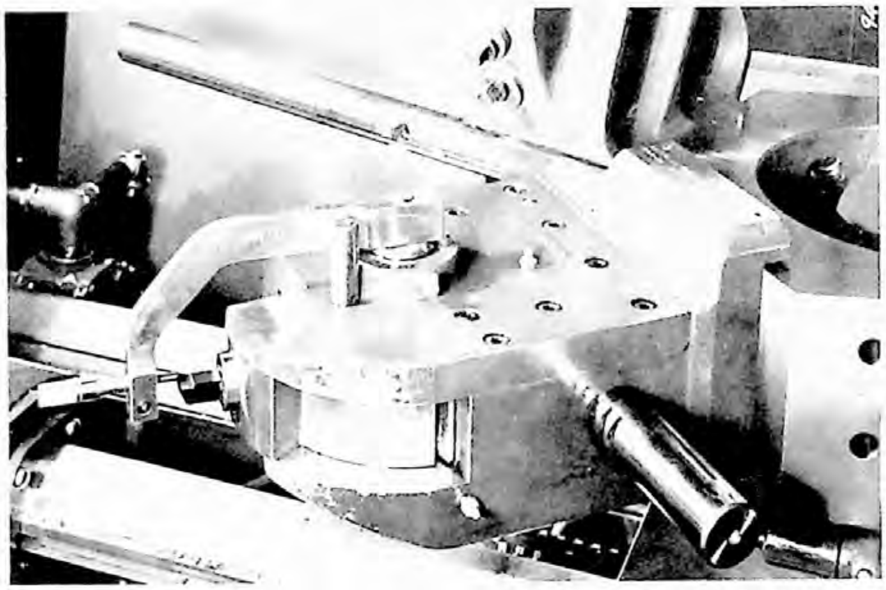


FIGURE 9

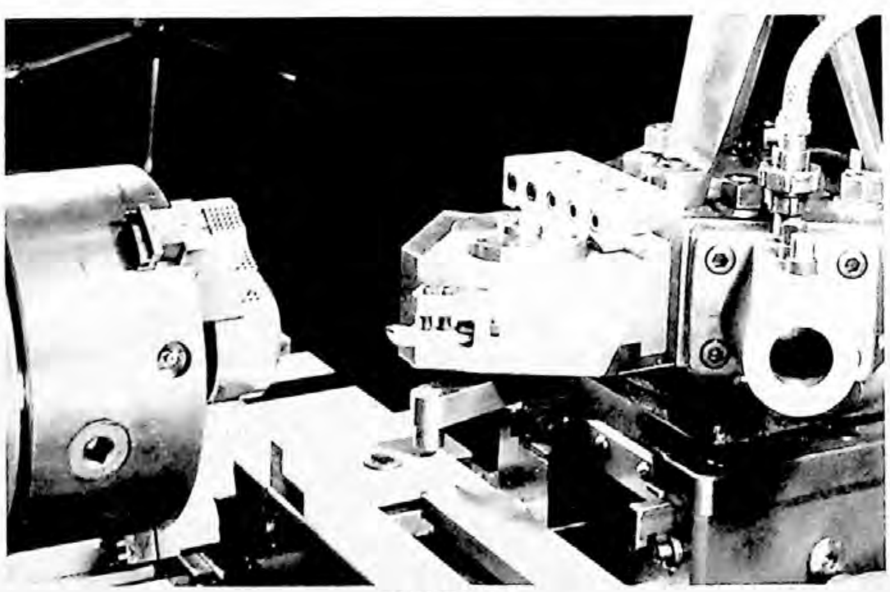


FIGURE 10

contour surface which duplicates the contour on the work piece. A roller follower is fitted against this contour path and is fixed to the special slide tool which is shown at approximately a 30-degree angle with the hexagon turret face.

As the hexagon turret is fed away from the work, the longitudinal motion of the sliding shaft is arrested by virtue of its coupling with the bayonet lock collar on the spindle rod. This causes the follower roll and the spring loaded slide tool to follow the path of the guide surface in the shaft, thus producing the required contour on the work.

It is necessary to set the mounting of the slide tool over at approximately 30 degrees in order to reduce the angle of attack between the follower roll and the cam track in the shaft when the 3¼-inch radius is machined.

Shown in the hollow of the hexagon turret is a connecting link between the station described above and a similar station on the opposite face of the hexagon turret. The latter station is used for finishing the same surface with duplicate equipment. The connecting link simply provides an automatic means of retracting the opposite guide bar while one turret face is in operation. The opposite face is then in position to engage the bayonet collar when that station is indexed into position for the finishing cut.

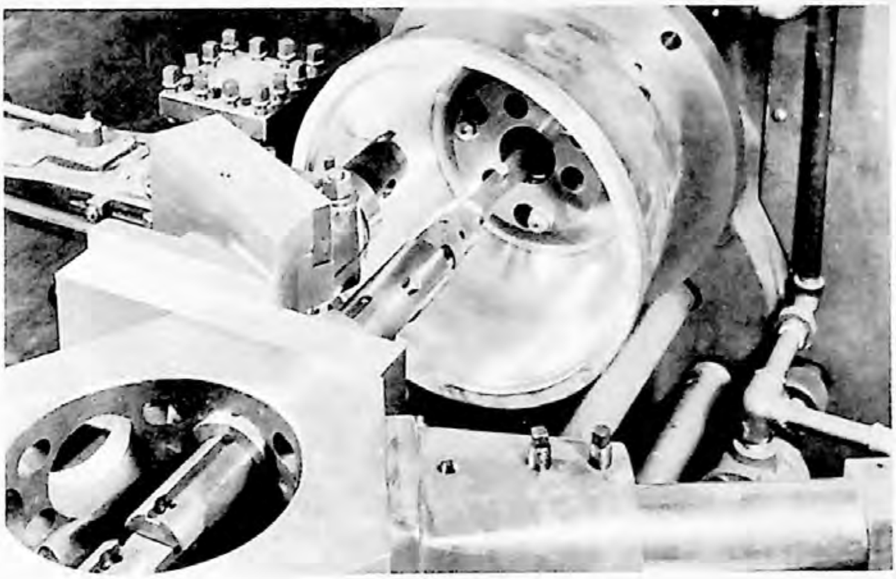


FIGURE 11

"TRICKS OF THE TRADE"

Ingenious ideas used by turret lathe operators which have added to the success of their jobs

TRULY EFFICIENT turret lathe usage requires the practice of many basic principles of operation. These fundamentals are the groundwork upon which successful operation is built.

Equally important—yet often overlooked—are the so-called "tricks of the trade" which consist of a wide variety of examples of ingenious thinking on the part of machine operators and others in contact with turret lathes.

This article, the seventh of a series, deals with such innovations which greatly add to ultimately successful turret lathe operation.

Spindle Stock Stop

Figure 1 illustrates a convenient way of positioning bar stock parts for second operation work where it is necessary to face or form the cut-off end to a length measured from a face established in the first operation. Providing the chucking diameter for the second operation is held to .001-inch or less, this stop can be used to face off parts to length within .002-inch.

The stop consists of a threaded spider bolted to the standard finger holder closing device which is used with collet chuck mechanisms. The threaded spider carries an adjustable stop rod which extends into the spindle. Position of the stop is locked with a check nut when the setup is completed.

Secondary Stock Stop

Frequently, on turret lathe jobs which have numerous surfaces to be machined and longitudinal dimensions to be held, the work is chucked twice in one operation. In a case of this kind, it is probable that all hexagon turret tool stations are occupied with tools and therefore, an auxiliary means must be provided to arrange for an additional or secondary stock stop for the second position of the bar during the cycle of the job. Figure 2 illustrates a simple stop that can be quickly fitted to a hexagon turret and used to supplement the regular or primary stock stop.

Nut Tapping Bar

Although the hand operated turret lathe is not the proper machine for production nut tapping, it can be used as an emergency measure for doing this operation. It is a waste of time to chuck, tap in and back out each nut individually because jobs of this type are usually small and require a fast cycle. The sketch shown in Figure 3 illustrates a method of doing an emergency job of this nature rapidly.

An extension-type nut tap is held in the collet chuck of the machine and a nut tapping bar is mounted on the hexagon turret. The bar is fitted with a slot and a locating pin so that the nuts drop into position and run over the tap held in the collet. Additional nuts are tapped until the shank is filled up. The tap is then removed from the collet and the nuts stripped off from the shank end of the tap.

Taper Turner

The conventional cross slide taper turning attachment is an extremely versatile unit and valuable to have on the machine as standard equipment. Frequently, jobs having tapered surfaces must be done on the turret lathe. Tapered surfaces readily lend themselves to production turning with the method shown in Figure 4.

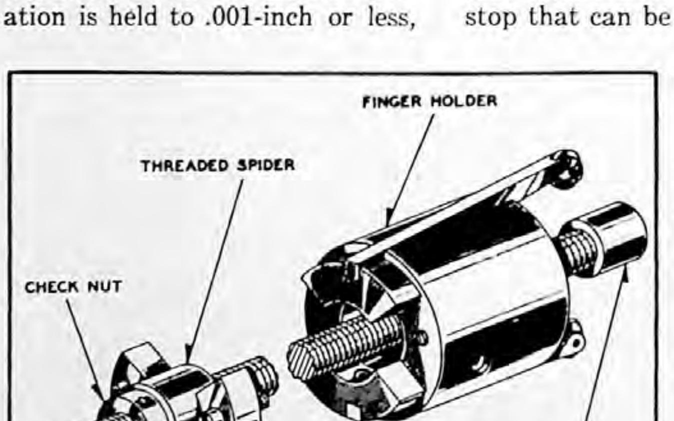


FIGURE 1

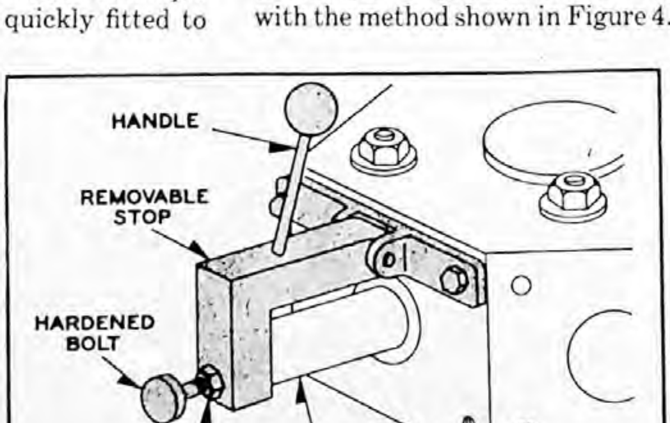


FIGURE 2

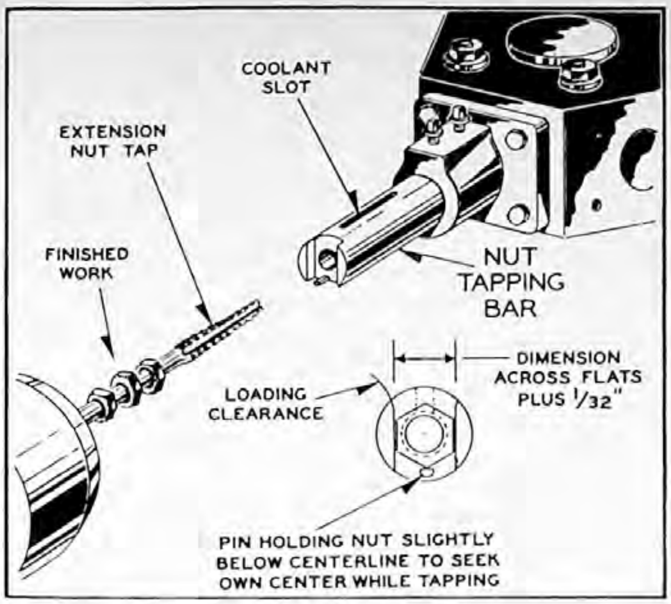


FIGURE 3

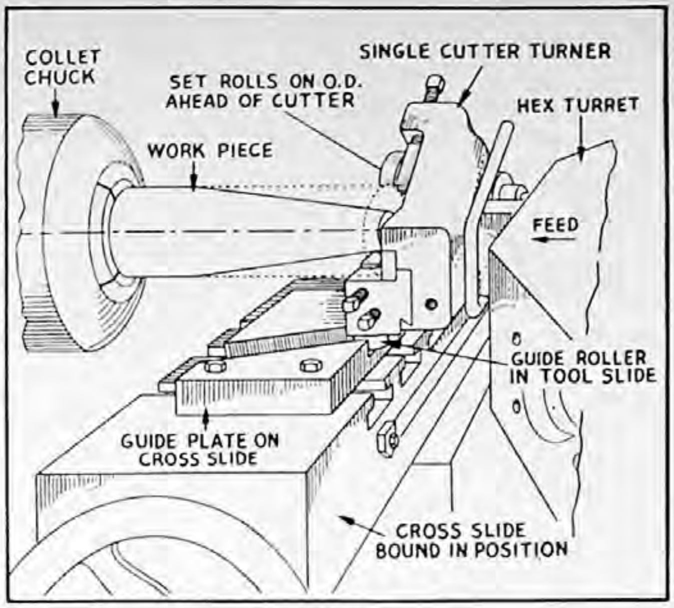


FIGURE 4

Using this guide, it is unnecessary to go through the routine of positioning and resetting the standard taper attachment for each piece. It is necessary only to index the hexagon turret and engage the feed. An additional advantage of this method is the support which the rolls of the roller turner provide to the part during the turning operation.

A standard single bit turner or box tool is fitted with an extra guide roller in the tool slide as shown in the sketch. Fitted to the cross slide is a guide plate which may be swiveled for different tapers or designed especially for each individual job.

In operation, the rolls of the roller turner guide ahead on the straight diameter of the part and, as the hexagon turret is fed toward the spindle, the guide plate controls the tool slide path of travel, thus conveniently machining the taper as required. Adjustment for diameter may be easily made within the limitations of the tool slide travel, by moving the cross slide in or out.

Cutting Tapers

Cutting tapers on the hand turret lathe is frequently a problem when the taper is so steep that it exceeds the capacity of the standard taper attachment. The arrangement shown in Figure 5 can be applied in overcoming this difficulty. A series of standard angles can be machined without using a taper attachment by combining both the longitudinal hexagon turret or carriage feed with a cross feed on the cross slide.

Table 1 lists typical angles for a Warner & Swasey 1-A Turret Lathe. Angles obtained by using this method, however, may not always meet job requirements. To obtain the exact angle in such cases, it is necessary only to compensate by means of the taper attachment on the machine.

For instance, if a combination of feeds on the cross slide and hexagon turret unit provide for cutting a 22-degree taper when a 24-degree taper is required, the taper attachment is set to change the angle from 22 degrees to 24 degrees.

Proper Gib Adjustment

Accuracy of the work produced on the turret lathe depends upon several factors, one of which is proper gib adjustment. Gibs are long tapered wedges used with sliding bearings to provide adjustment for wear and thus maintain initial accuracy of the slides for longer periods of time. The need for checking and making this adjustment is sometimes overlooked, and consequently, a basic element in the maintenance of machine accuracy is lost.

Proper gib adjustment on ram-type turret slides usually governs accuracy of the hexagon turret slide unit. If the gibs are too loose, the turret slide is apt to shift or "float" during the cut, resulting in incorrect size, poor finish or chatter. On the other hand, gibs set too tight are apt to cause undue wear on the bearing slides and make the turret slide difficult to move.

A tapered gib properly set up provides a clearance of .001-inch or less between the sliding parts. Through experience, this clearance has been found sufficient for free operation of the slide and, at the same time, to provide accuracy on turning cuts.

Under these conditions, although a slide operates "free," it is impossible to get a .001-inch feeler gage between the sliding surfaces. When adjusting gibs on the turret slide, particular care must be taken to be certain that the hexagon turret holes are maintained "on center."

Therefore, when tightening the side gibs, each one must be uniformly adjusted. If at any time the turret holes are found to be horizontally off center, they can be brought back to center through

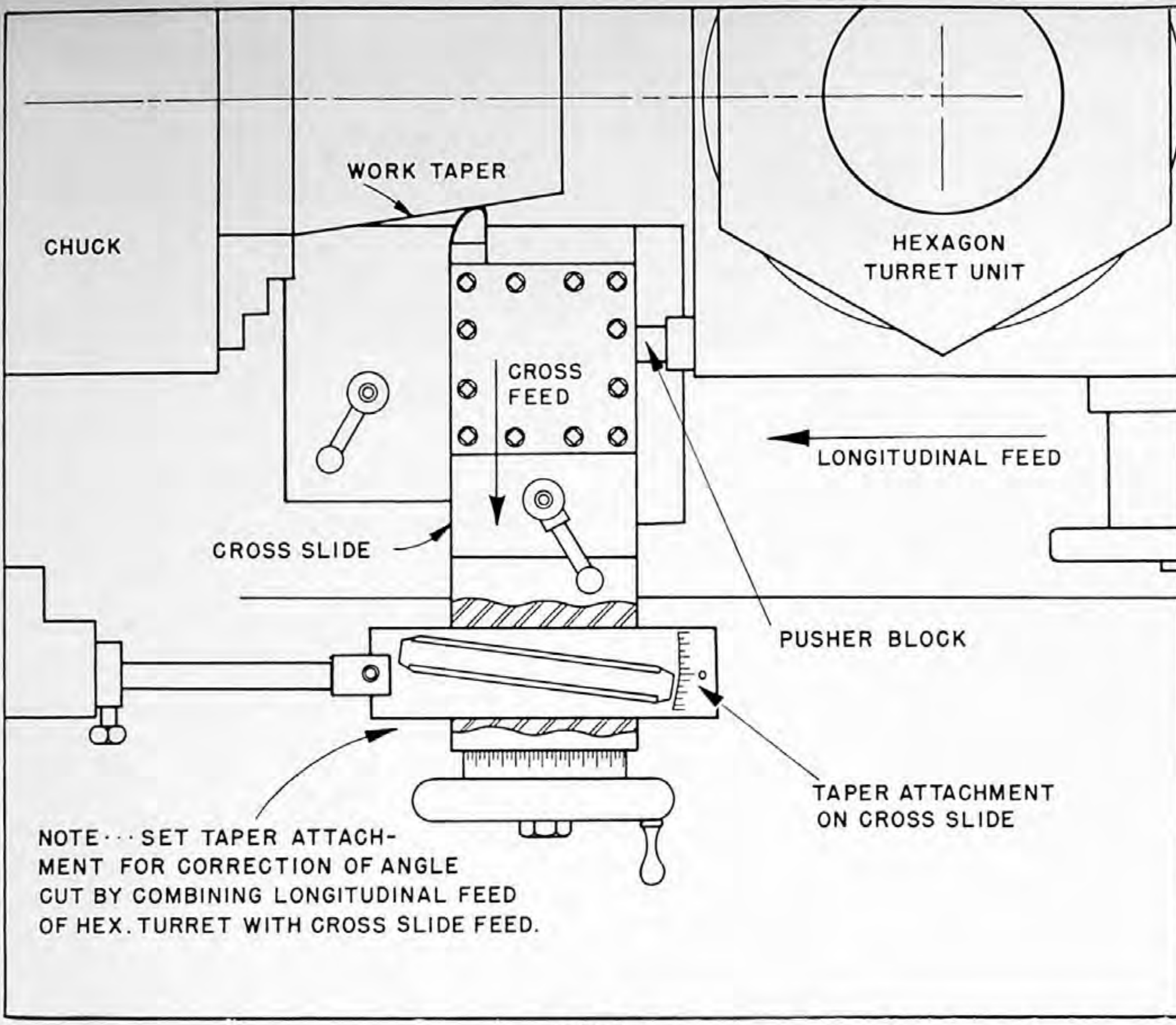


FIGURE 5

proper gib adjustment. By tightening one gib, and backing off the other, the turret slide can be adjusted back to center.

One method of checking turret hole alignment to the spindle is shown in Figure 6. A micrometer barrel is attached to a tube held in the spindle chuck and a solid plug is inserted in one turret hole. By taking a micrometer reading at the front side of the machine and comparing it with the reading at the rear side of the machine, the position of the turret holes is accurately determined. A maximum limit of .001-inch is usually allowed on the position of turret holes in relation to the center line of the work spindle.

Gibs are used in both ram and saddle-type turret lathes. Both machine operator and maintenance man should recognize the importance of keeping gibs in proper adjustment at all times. Turret lathe manufacturers supply service manuals which outline complete instructions for maintaining proper gib adjustment.

Adjustable Single Turning Head

One of the most flexible standard tools on heavy duty turret lathe chucking setups is the adjustable single turning head. This tool, with its adjustable slide block, can be quickly changed over from one setup to another with little effort, yet maintain extreme accuracy. Turret lathe operators have found that by adding the adjustable single turning head to the universal chucking setup, a greater variety of work can be produced.

Although the adjustable single turning head is particularly adapted for use in small lot production where quick changeovers are necessary, provision is also made for adjusting the slide block accurately and holding it for long run jobs.

Since the adjustable single turning head is designed with one stationary tool holder hole and a movable hole in the adjustable slide block, it is used for many different jobs where multiple cuts are required with one pass of the tool station. One common use for the adjustable single turning head is drilling and rough turning simultaneously.

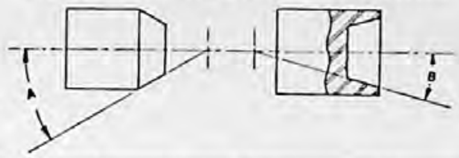
Figure 7 shows a high speed steel drill or core drill being used to rough out the hole in a forging or casting while a tool held in the adjustable slide block rough turns the outside diameter preparatory to finish turning. For quick removal of metal it is usually possible to combine a carbide-tipped turning tool with a high speed steel drill using heavy feeds and high spindle speeds.

It is good turret lathe practice to follow combination roughing cuts with a finishing cut with another adjustable single turning head equipped with a stub boring bar in the center hole, and a carbide-tipped tool in the adjustable angle tool holder in the slide block. This method of finish boring and turning can also be done with a piloted boring bar through the center hole with a spindle pilot bushing to support the boring bar.

One adjustable single turning head in a typical chucking setup can be arranged with an adjustable angle cutter holder in the stationary hole in the head and a plain angle cutter holder in the adjustable slide block. With this setup, it becomes easy to make fine adjustments for finish turning of outside diameters. Since both cutter holders have micrometer dial adjustments, it becomes easy to change the setup quickly from one or two outside diameters on one job, to different diameters on another job.

Angles That Can Be Cut by Combining Cross Feeds and Hexagon Turret Longitudinal Feeds with 1-A M-470 and 2-A M-510 Warner & Swasey Turret Lathes

For Turning Chamfers— Cross Slide Feed Away from Spindle Nose

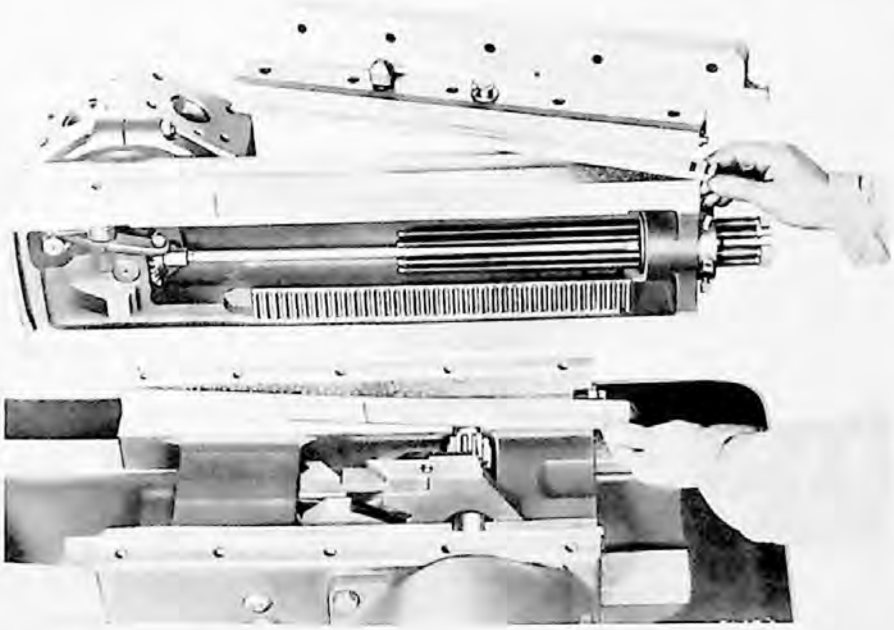


For Boring Tapers— Cross Slide Feed toward Spindle Nose

Angle 'A'	Cross Feed	Long. Feed	Angle 'B'	Cross Feed	Long. Feed
4°	.0022	.037	3½°	.0022	.037
5°	.0029	.037	4½°	.0022	.027
7°	.0039	.037	6°	.0022	.020
9½°	.0029	.020	8°	.0039	.027
12½°	.0029	.015	11°	.0039	.020
17½°	.0073	.027	15°	.0054	.020
23°	.0022	.006	20°	.0054	.015
30°	.0054	.011	26°	.0039	.008
38°	.0054	.008	33°	.013	.020
47°	.0073	.008	42½°	.010	.011
55°	.0073	.006	50½°	.0073	.006
62°	.013	.008	58½°	.013	.008
68½°	.013	.006	65°	.013	.006
74°	.018	.006	73°	.013	.004
79°	.018	.004	77½°	.018	.004

TABLE 1

The design and usefulness of the readily adjustable slide on the single turning head actually adds another cross slide to the turret lathe. Where jobs ranging from five to ten pieces per run must be machined, a cutter held in the adjustable block can be used for quickly setting a turned diameter so that facing cuts taken from the regular cross slide can be combined with the turning cut with a minimum of setup time. This allows the use of the combined cut principle on the turret lathe even for small runs, and thus secures economy of operation for this kind of production which is normally restricted to larger quantities that permit longer setup time with conventional tooling.



TURRET SLIDE removed showing tapered gibs. Adjustment of gibs positions turret to maintain turret holes on center with the center line of the spindle.

Holding Threaded Work

Providing second operation holding devices for gripping parts on a threaded surface have always been a problem. Many systems have been evolved but basically, the one illustrated in Figure 8 seems to provide the elements of design necessary for work of this nature.

The part is screwed into a tapped hole in a square or hex-

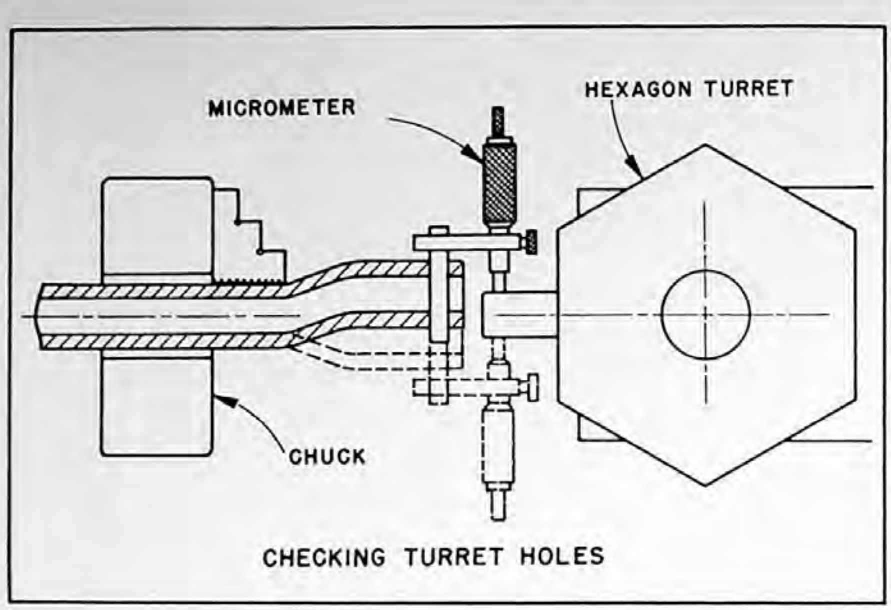
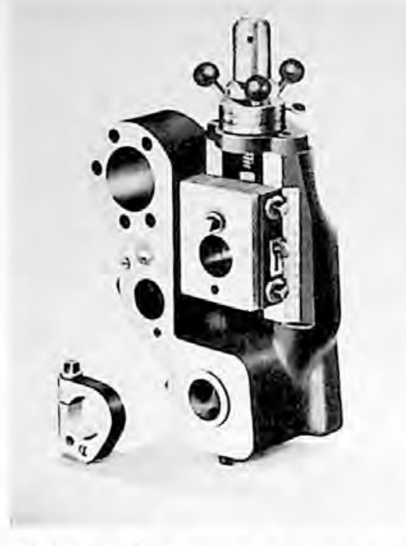


FIGURE 6



ADJUSTABLE single turning head used for combined turning and boring.

agonal plug which in turn is held in the master collet of the turret lathe. The plug provides a means of driving the work so that the threads cut in the first operation are not damaged. Fitted between the heel of the collet and the push tube of the collet mechanism is a stop which presses against the face of the part loaded in the plug with the collet closed.

Because of the design of conventional push-out collet mechanisms, the threaded stop plug is in a slightly forward or advance position. Due to the cutting torque while the part is being threaded, or while any other cutting operation is being performed, the part will wind up tightly in the arbor until it contacts the stop plug. This is the difficulty usually experienced with jobs of this kind. It is difficult to remove the threaded part from within the plug. With the arrangement shown in Figure 8, this torque is quickly released by opening the collet mechanism. This movement withdraws the back-up plug slightly, thus allowing the part to be unscrewed easily from within the holding plug.

Turret Lathe Alignment

Effects of proper gib adjustment on turret lathe accuracy have already been discussed in this article. However, another element which greatly affects accuracy is machine alignment. Straightness to which turning or boring cuts can be held is governed by the alignment of the square and hexagon turret travel in relation to the spindle. When the turret travels parallel with the center line of the spindle, accurate tolerances are maintained throughout turning and boring cuts. As a result, whenever close

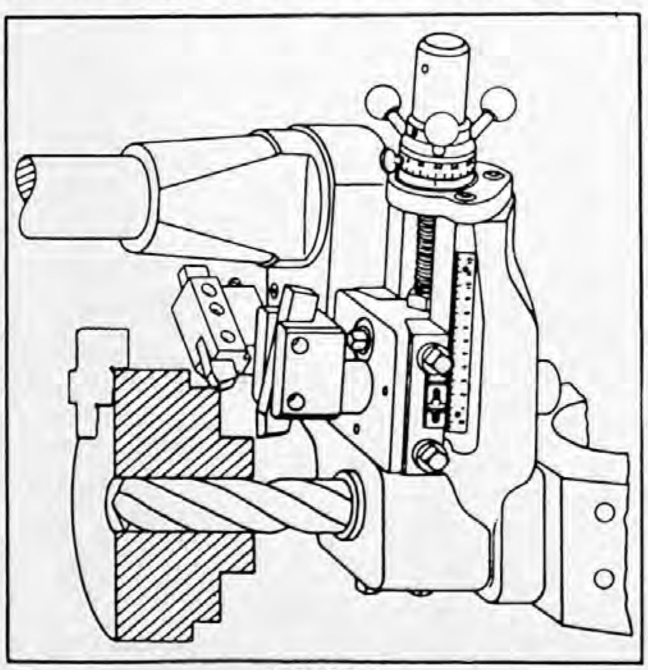


FIGURE 7

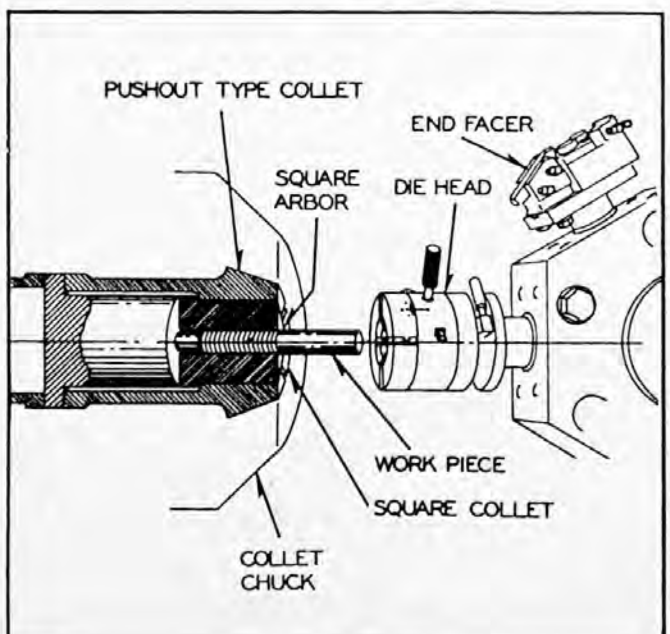


FIGURE 8

limits are required, it is necessary that alignment be established and maintained.

A turret lathe out of alignment or off level has developed a twist in the bed. Such a condition generally results from either settling of one of the foundation blocks or from a lowering of one of the legs which shifts the machine weight ordinarily supported by that leg onto the machine bed itself. This additional load twists the bed and throws both turret travels out of parallel with the spindle. The amount of twist is very often only a few thousandths, but it affects the precision turning of the machine when close limits must be held.

Most machine foundations settle in time. Therefore, it is good practice to check turret lathes frequently for alignment.

Checking the machine for alignment is a relatively simple matter requiring the use of a precision spirit level. On ram-type turret lathes, the level is set squarely across the ways of the bed beneath the spindle and the position of the bubble in the gage glass is noted. Moving the level to the outer end of the bed, again making certain that it is placed squarely across the ways, the position of the gage bubble is again checked. If the bubble registers at a different place in the gage, one of the legs of the machine has settled and caused a twist in the bed.

Comparing the relative positions of the bubble shows which leg of the bed must be raised or lowered with the adjusting or leveling screws. After each adjustment, it is advisable to recheck again by positioning the spirit level across the ways beneath the spindle and at the end of the bed, allowing the bubble to come to a complete rest during each check.

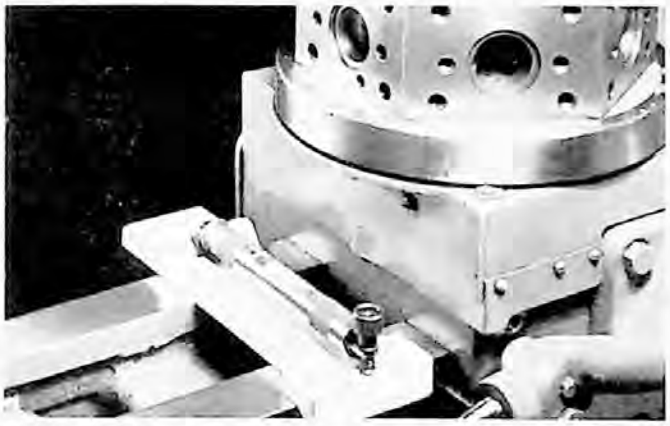
On saddle-type turret lathes, alignment is checked by placing the spirit level on the hexagon turret, noticing the position of bubble as the hexagon turret is moved from the head end of the machine to the outer end of the bed. A piece of paper placed between the level and turret prevents the level from moving as the hexagon turret is moved along the bed by means of the power rapid traverse. Leveling screws like those on ram-type machines are provided for this purpose.

Turning or boring taper does not always necessarily indicate that the machine has become worn. It is very often simply off level.

Whenever the machine begins to turn or bore tapers, the plant maintenance department should be notified. Immediate correction of an inaccurate, off level condition will result in machine accuracy for a longer period of time, and will eliminate undue strains that cause premature wear on finely finished bearings of the bed and hexagon turret slide and saddle.

Direction of the bubble indicates which way the bed is twisting. The off-level leg of the foot end pedestal is raised or lowered by means of leveling screws until the bubble reading in the spirit level is on center at both readings.

Direction of the taper showing up in a boring or turning operation also indicates the off level condition. If the machine turns large and bores small at the chuck end, the front foot leg is low. When the machine turns small and bores large at the chuck end, the front foot leg is high.



SPIRIT LEVEL in position on the bed ways of the lathe. Off level condition contributes to misalignment of turret.

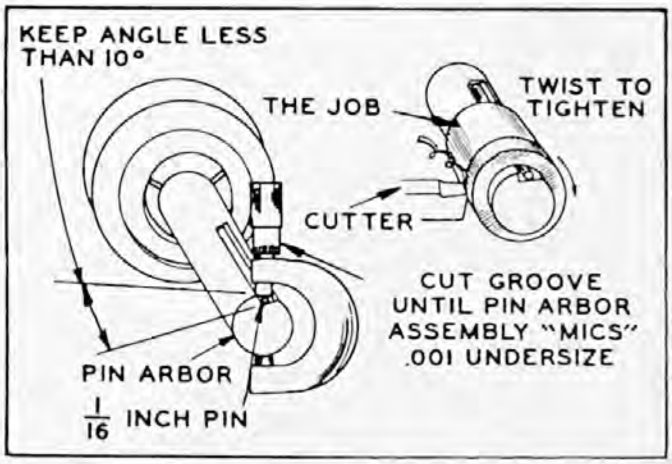


FIGURE 9

Holding Arbor

Second operation work on small parts requires a holding arbor which provides fast loading and unloading of the part, yet permits the operator to hold close tolerances from an internal surface previously machined in the first operation.

The simple arbor shown in Figure 9 is a quick and inexpensive holding method where only a few parts are to be machined. The arbor is turned up on the machine so that it runs concentric with the machine spindle. The only extra operation on the arbor involves milling a groove to a specified depth and angle in the arbor. The sketch shows how the groove is machined into the arbor with a 10-degree uphill angle and how a small piece of drill rod is laid in the groove to act as a lock. When a bushing or similar part is in position on the arbor, the part tends to turn under the cut, caus-

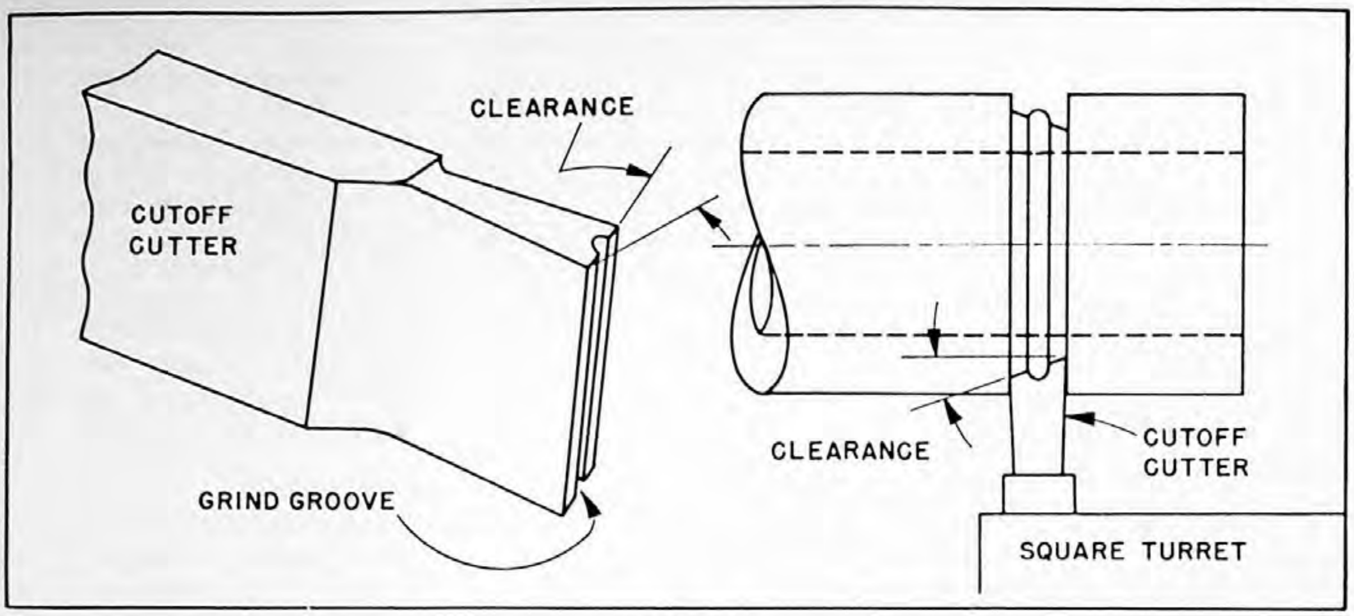


FIGURE 10

ing the drill rod to climb the 10-degree angle and hold the part tighter on the arbor as the load on the cut increases.

The measurement over the arbor and drill rod should be .001-inch less than the inside diameter of the part.

Setting Box Tool for Shallow Cuts

Most turning machines use some form of single bit turner or box tool for turning bar jobs. One turning operation which frequently causes trouble is that which involves very little stock removal.

In other words, when the depth of cut is shallow, difficulty is encountered in obtaining a burnished surface and close tolerance. The smooth finish produced on bar stock when using a single bit turning tool is obtained from the pressure caused by the tool bit forcing the work against the roller rests. As a result, the greater the pressure of the cut, the better the finish produced on the turned diameter.

When taking heavier cuts with bar turners, it is generally easy to produce a smooth finish. However, when light cuts must be taken it becomes a real problem for the machine operator. When depth of cut is shallow, a longer radius on the nose of the cutter creates greater pressure against the bar stock. For a longer radius the rolls must be set farther behind the cutter so they bear only on the turned diameter. It is also helpful to increase the feed since this also creates greater cutting pressure against the work and forces it over onto the roller rests.

Cutting Off Tubing

An ordinary cut-off tool produces a burr when it breaks through the wall of the tubing as it is being cut off. A tested method for eliminating such a condition is illustrated in Figure 10. A pilot groove ground into the tool tends to steady the long flexing cut-off tool during its travel through the work. If, on tubing work, the lead angle grind is incorporated into this type of cut-off tool, a smoother finish is assured and the finished piece will be cut off without a burr.

WORK HOLDING DEVICES

PART I

Description of collet chucks; various types of; how to select; accessories

AVAILABILITY of numerous standard work holding devices, and the ease with which special holding equipment may be applied to the horizontal turret lathe, are largely responsible for the popularity of this machine tool.

Work holding devices have been developed to accommodate every conceivable machining problem. As a result, a clear perspective of their respective capabilities must be understood and maintained if low cost tooling and production are to be assured. Generally speaking, work holding devices for turret lathes consist of collet chucks and bar feeds, jaw-type chucks, fixtures and arbors.

Units within each of these three main classifications may be hand or power operated, depending upon certain characteristics of the job and the nature of work flow. Hand operated units are less expensive than power units, and can be used on smaller job lots. In addition, hand operated units are simpler and consequently less likely to require as much maintenance as the more complex power units. By the same token, power holding devices reduce operator fatigue, operate faster, and grip heavy work more efficiently, which characteristics tend to balance increased cost through improved production returns.

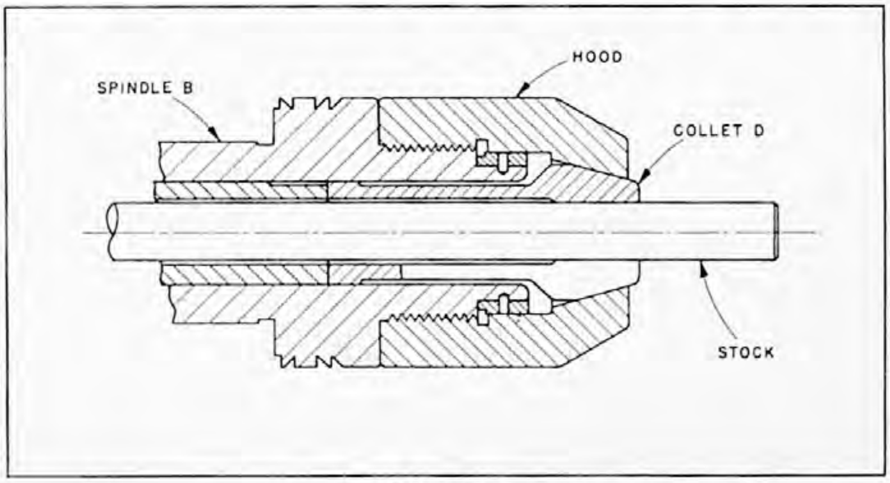


FIGURE 1

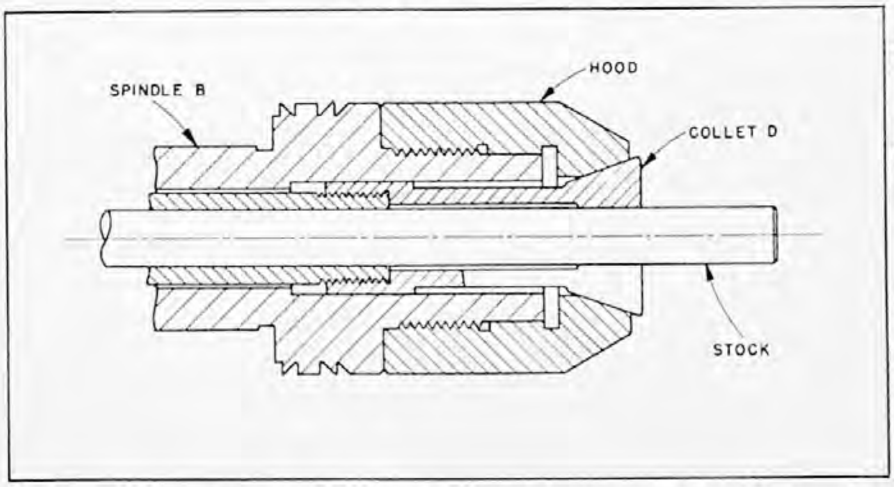


FIGURE 2

Collet Chucks

The collet chuck is a holding device ordinarily furnished with bar machines for gripping hot or cold finished bars or tubing. The collet is an integral part of the collet chuck mechanism. Two types are provided, either solid or master. The latter permits use of interchangeable pads to accommodate various stock sizes. Several style collet chucks are available.

Figure 1 illustrates a push-out collet chuck mechanism. This type is recommended for first operation bar work, particularly when a stock stop on the hexagon turret is used to control stock feed-out.

Forward closing action of the collet tends to carry the stock slightly forward, causing the stock to seat firmly against the stock stop. Ability of the push-out collet to position second operation work longitudinally depends upon the standard angle of the collet nose and the tolerance held on the chucking diameter of the part.

For instance, if the collet is ground with a 14-degree taper, then for every .001-inch variation in the part holding diameter, the longitudinal position of the part after gripping will vary about .002-inch. For most jobs of a commercial nature, this variation in locating is permissible.

A popular question among users of push-out collet chucks concerns the matter of concentricity. If the collet chuck mechanism is clean, and in "like new" condition, most collets will run true within .003-inch total indicator reading at a distance of 2 to 3 inches from the collet nose.

A drawback collet chuck is illustrated in Figure 2. This type collet carries over from the early days of turret lathes and permits the hood to be ground in place on the spindle nose in the interest of providing good concentricity. In other words, the tapered surface in the hood is quite accessible from outside the collet chuck mechanism. Some increase in gripping tension as a result of end thrust of the cut is obtained from the drawback design, although the collet is not in extensive use today. The principal objection to the drawback collet chuck for first operation bar work is that the closing action of the collet chuck mechanism draws the stock away from the turret stock stop so that facing cuts are usually required on the end of the work.

Figure 3 illustrates an extra capacity collet chuck of the drawback design. The drawback principle is used successfully with this type mechanism in a great many current turret lathe applications. Not only does this collet offer oversize gripping capacity for any given size turret lathe, but also permits stationary locating stops to be fixed in the hood of the collet mechanism so that as the collet draws the part back during the closing action, these locating stops accurately determine the longitudinal position of the work in the collet.

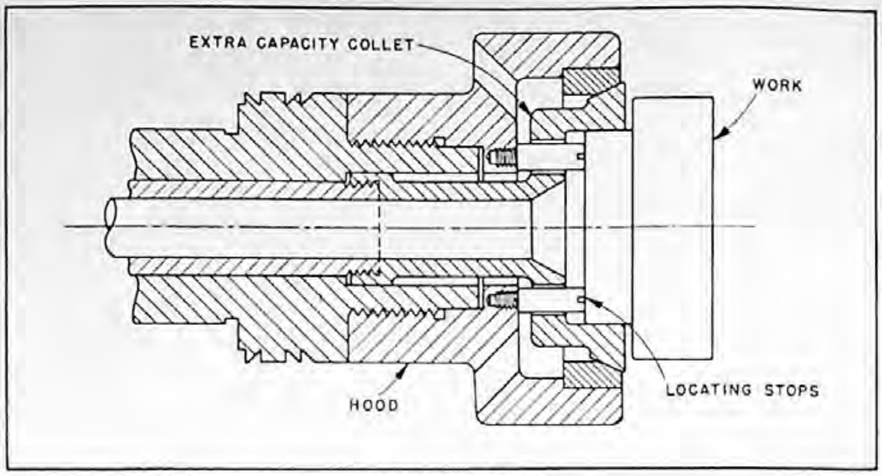


FIGURE 3

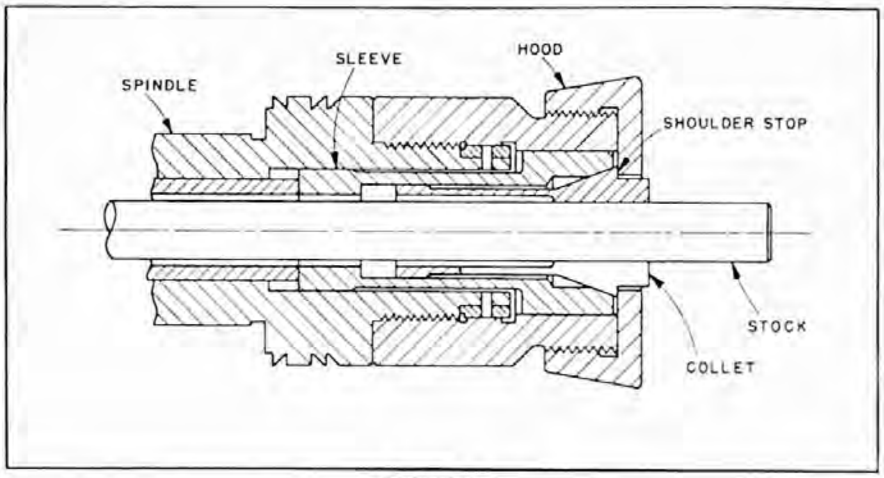


FIGURE 4

Figure 4 illustrates a variation of the push-out collet chuck mechanism for first or second operation work where longitudinal positioning must be accurately maintained. The collet itself does not move longitudinally during the closing action, but is actuated by a sleeve operating from the push-out closing mechanism of the unit.

Although this collet provides accurate longitudinal stopping, it has certain limitations. For example, it is most applicable to the smaller sizes of bar stock and, due to the relatively large number of sliding surfaces, it is not ideal where close concentricity between work gripping surfaces and work surfaces to be machined, is required. Frequent cleaning assists in maintaining the built-in accuracy of concentricity, but the manufacturing tolerances necessary between the sliding parts eliminate the possibility of obtaining or maintaining the same accuracy of concentricity that is possible with standard pushout and drawback collets.

Figure 5 illustrates the parallel closing type collet which, in one respect, is similar to the collet in Figure 4. While the parallel closing collet does not move longitudinally during the closing action, the primary basis of its design is to allow a quick adjustment for stock variations. For instance, in the larger sizes of hot rolled stock, considerable diametral variation may

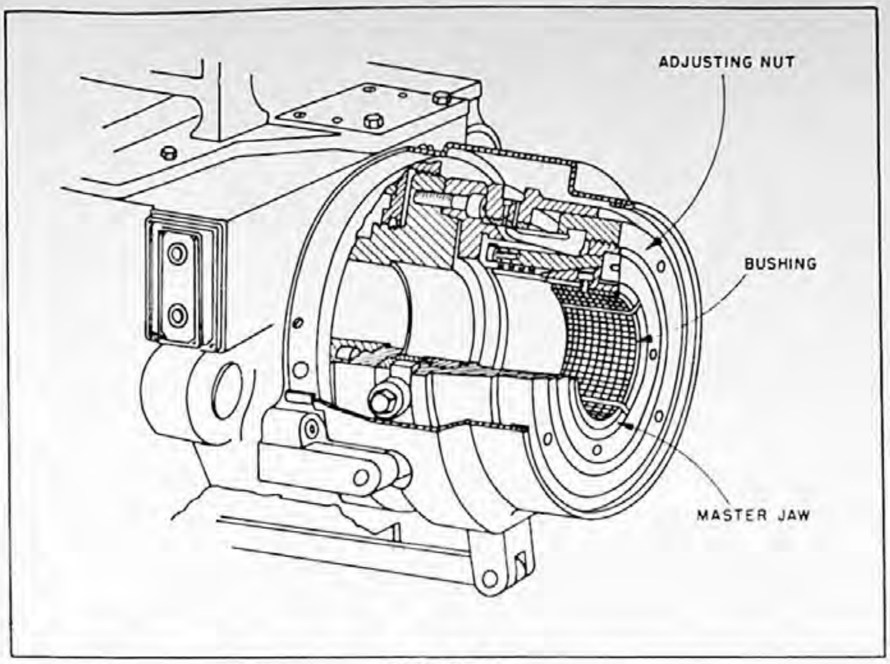


FIGURE 5

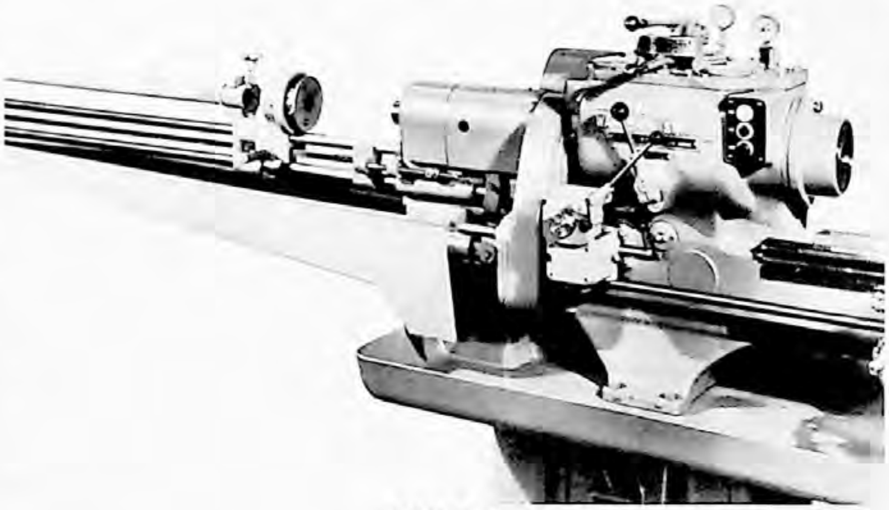


FIGURE 6

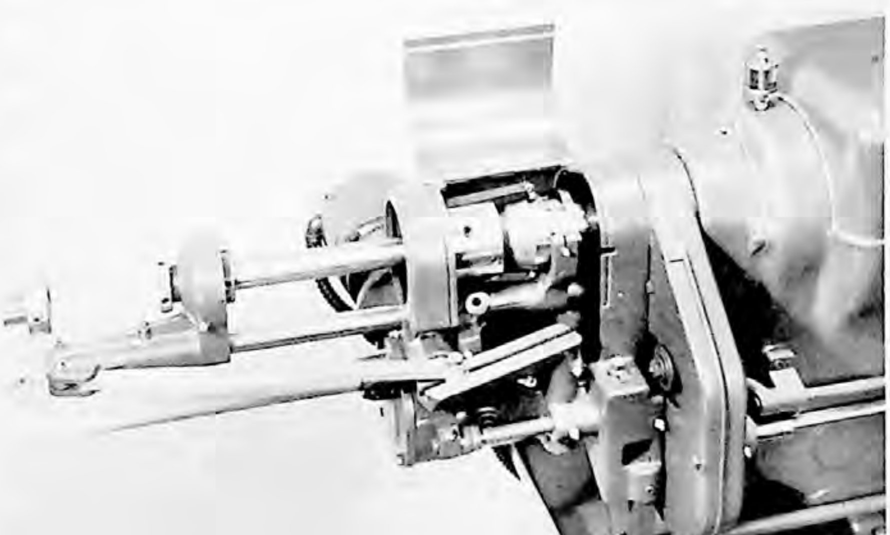


FIGURE 7

be expected and means must be provided to adjust the tension on the collet so that the work may be gripped with the proper pressure regardless of the change in stock size from one end of the bar to the other. When a bar is not in the collet, the collet bushings are held in place by spring clips. Thus the collet is properly applied to bar work where a full grip on the bar is possible. Second operation work where the parts are short in overall length, does not provide adequate support under the collet pads and, therefore, some collet run-out may occur.

With the exception of the parallel closing collet in Figure 5, all of the collets described are applied to ram type turret lathes. The parallel closing collet is primarily for use on saddle machines which have larger normal bar stock capacity. All collets may be either hand or power operated dependent upon conditions under which they are to operate. When the collets are designed for hand operation, the closing mechanism on the back end of the spindle may be readily removed so that a power cylinder can be mounted to operate a jaw-type chuck if necessary. In other words the hand operated collet chuck offers ease of installation and removal where the turret lathe must also be used for chucking work with power operated units.

It is, however, frequently advisable to equip the turret lathe with collet chucks which, in themselves, are power operated. Figure 6 is an example of such a collet. This is an hydraulically operated collet chuck and bar feed mechanism for a ram type turret lathe. The hydraulic control valve lever is shown just below the oil gage on the front of the machine headstock. This lever controls opening and closing action of the collet as well as feeding motion of the bar feed. Operator fatigue has been reduced as much as 15 percent by transferring manual effort to power control.

Figure 7 illustrates a mechanism used in an electrically operated collet chuck and bar feed. This is a standard motor driven unit available on the smaller sized ram type machines for operating the collet and bar feed. This mechanism is extremely fast but, by nature of its design, is best suited to smaller sized bar machines. The stock is fed by means of feed finger tubes operating in the cycle of opening and closing the collet.

Figure 8 illustrates an electric booster mechanism which may be applied to either ram or saddle turret lathes. This unit can be readily installed on existing equipment and reduces by about 80 percent the manual effort required to open and close the collet chuck. The collet chuck and its closing mechanism remain unchanged with the application of such a unit, thus making it possible to equip the machine with power operated air chucks and cylinders during other phases of its production use. When the electrically operated booster illustrated is in use, the bar is still fed forward manually by means of the lower lever.

Figure 9 illustrates a skeleton collet for use on ram or saddle turret lathes. It is operated by a power cylinder at the rear of the spindle. This is a drawback collet chuck with the body cored out for free chip disposal. Because of the drawback design, a fixed longitudinal stop can be used in the bore of the collet to locate work accurately. Since the collet is used with an air cylinder or some similar closing device, greater stroke is available. The collet may thus be used for gripping rough castings which vary in diameter much more than does bar stock. However, because of the overall construction, such a collet is not as accurate for concentric location as the collets previously described.

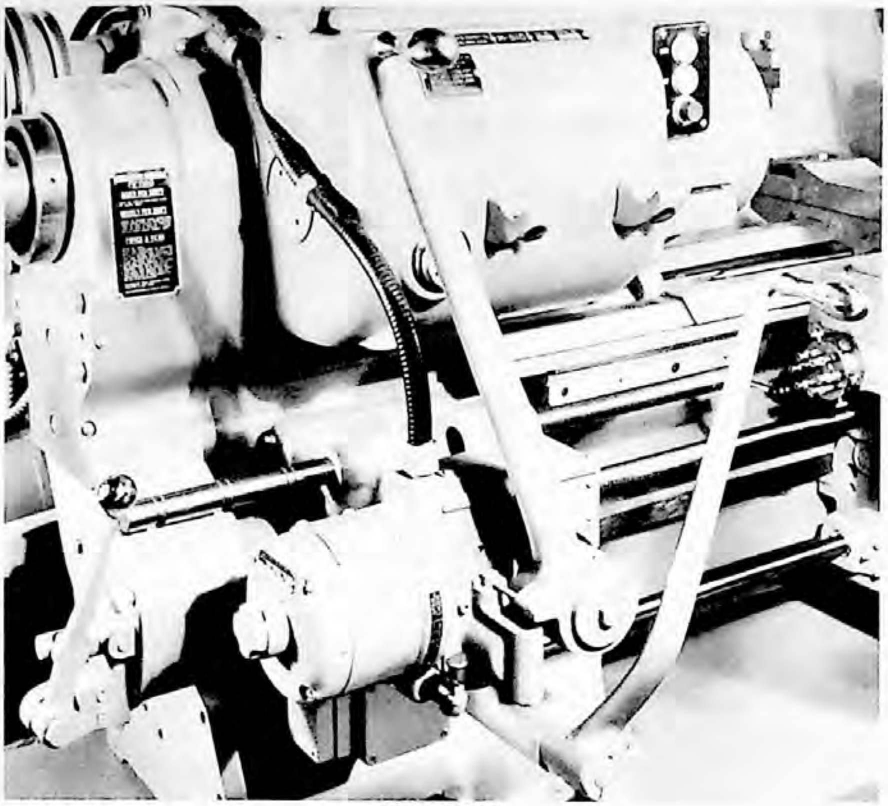


FIGURE 8

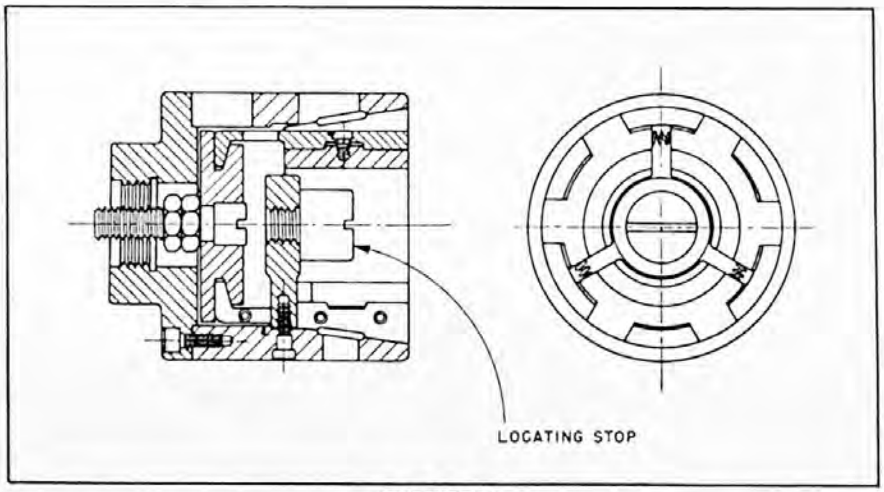


FIGURE 9

WORK HOLDING DEVICES

PART II Chucks of all kinds; fixtures and arbors

FIGURE 1

AMONG the most important work holding devices for turret lathes are hand and power operated jaw chucks. Whether a jaw chuck should be hand or power operated is determined by the same principles governing the selection of hand or power collets. The objectives of speed and relief from operating fatigue resulting from the use of power units must be balanced against the production return and additional equipment cost.

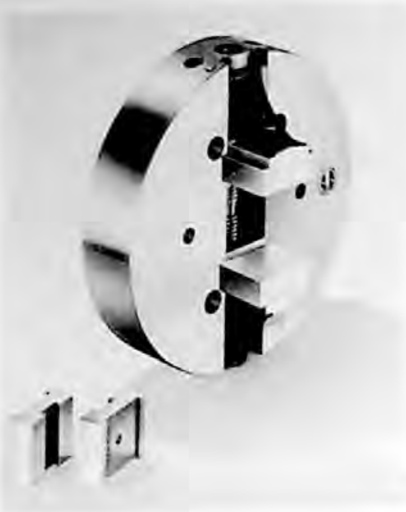
Several type hand operated chucks are used on turret lathes. Figure 1 illustrates a four-jaw independent chuck which is known to users of turning equipment as the preferred chuck when job lots are very small and expensive special jaws for irregularly shaped work are prohibitive. Each jaw is independently adjustable so that work may be trued up from one operation to the next or for distributing the stock allowance around the theoretical center line of the part. Four-jaw independent chucks grip 15 to 20 percent more powerfully than three-jaw universal chucks, because each jaw may be individually tightened on the work. In addition, with a four-jaw chuck, each jaw is spaced closer to its neighboring jaw, thus providing additional assurance that long overhanging work will not pull out of the chuck despite cutting stresses.

FIGURE 2

Figure 2 illustrates a three-jaw universal chuck which acts faster than the four-jaw independent chuck. From a cost standpoint, it means about the same investment and should be used in the production scheme somewhere between the four-jaw independent chuck and power operated device.

Standard jaws are used with the three-jaw universal chuck on regular work shapes which do not require adjustment of each jaw to compensate for stock runout, etc. Special jaws are used with the three-jaw universal chuck where lot sizes are large enough to absorb the extra cost of the jaws. Where advantages result from reduced chucking, better gripping, etc., special jaws can still be justified regardless of lot sizes to be machined.

Figure 3 illustrates a two-jaw universal box chuck designed so that both jaws move in and out by the action of a screw. A chuck of this type is used on small, irregularly shaped work where the subjaws may be formed, "V'd" or otherwise shaped to grip on unusual contours. Although a two-jaw chuck cannot split stock al-



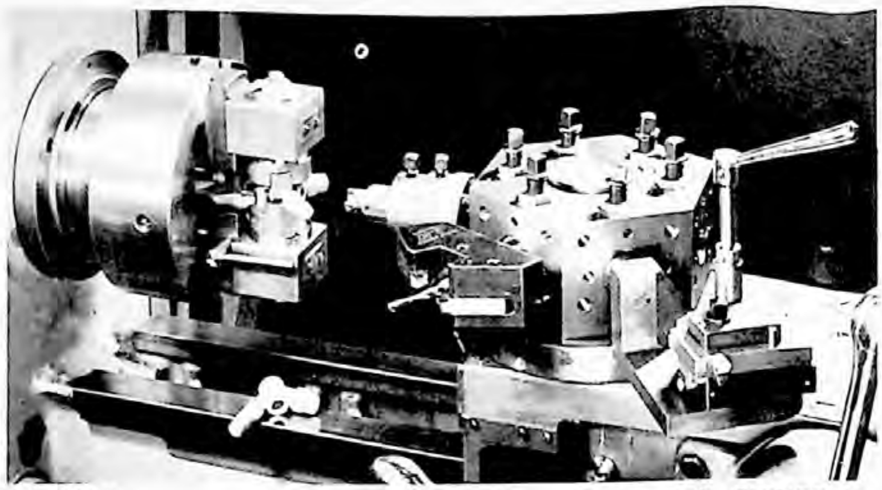


FIGURE 3

FIGURE 4

lowances as equitably as a three-jaw universal or four-jaw independent chuck, the ability of the two-jaw universal chuck to grip on some work shapes not suitable for three and four-jaw chuck balances its limitations.

Figures 4 and 5 illustrate two sizes of two-jaw indexing chucks. A two-jaw indexing chuck is meant to grip work, within the capacity of the chuck, which has several faces to be machined. Ordinary commercial limits of accuracy of index are easily met with chucks of this nature. They are not, however, meant to fulfill the exacting requirements of specially designed indexing fixtures.

Another type hand chuck is the three or four-jaw combination chuck shown in Figure 6. These chucks are fitted with master jaws of two-piece construction with an independent jaw screw between the sections. The master, or bottom part of the jaw, is moved by the scroll and the top part is moved by the independent jaw screw. Top jaws are ordinarily removable and reversible in order that they may be used for external or internal gripping and so that they can be removed and special jaws substituted.

Combination chucks are furnished with either three or four jaws. These chucks are used for holding irregularly shaped parts and when a jaw needs to be offset from a true circle. They are also of value when chucking castings having a characteristic runout requiring the same amount of offset for each part.

The independent adjustment is used to make a correction for this runout, and the universal feature for operating the jaws in production. The combination chuck also provides a means of truing up the work on first chucking by using the independent movement of the jaws. Then the same chuck can be used for second operations, using a geared scroll to operate the jaws when gripping on a finished true diameter.

Power Operated Chucks

For the most part, chucks which are meant to be power operated are designed differently than hand operated chucks. The design of power operated chucks makes it possible to open and close the jaws through wedges, spools, linkages, etc., by means of a draw rod running through the spindle to a power cylinder attached to the end of the spindle.

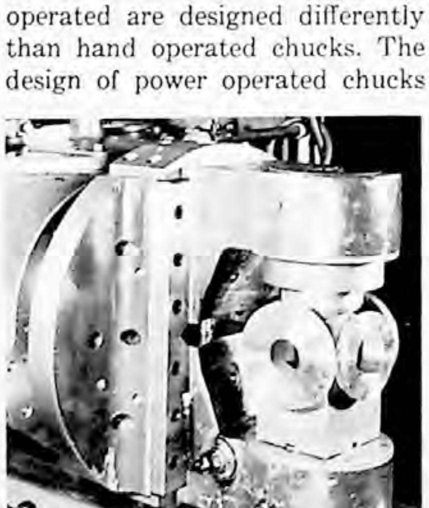


FIGURE 5

The chucks themselves may be two or three-jaw, combination, or two-jaw indexing, as with hand operated chucks. In addition, some manufacturers offer chucks which are locked in gripping position against accidental opening through centrifugal force if the power supply fails.

Air and hydraulic cylinders are used most commonly for operating power chucks. A power device of this kind applies constant pressure while the cut is in progress. This, in effect, prevents the work from slipping under an intermittent or heavy cut and thus being torn from the chuck jaws. Hydraulic power may be more expensive than air, but it eliminates the need for a shop air line, if such is not available. The hydraulic system may be more subject to temperature changes, which cause irregularities in the chucking operation.

Use of air for operating the cylinder costs less to install if the shop air line is available, but, by the same token, is subject to any troubles or failures of the main air line. An air operated system is relatively insensitive to temperature and is easily and quickly adjustable to required pressure. It is not possible to recommend one system over the other, as the choice depends entirely upon conditions in the shop and the job itself.

Another system of operating a three-jaw chuck by power is also shown in Figure 2. This illustration shows a three-jaw universal chuck which is opened and closed by an electrical power chuck wrench. The power chuck wrench consists of a torque motor driving through a worm gear box to a wrench shaft, which in turn engages the chuck pinion. The wrench shaft may be engaged or disengaged with the lugs on the outside of the chuck pinion at will. Current can be applied to the motor in either direction for opening or closing, simply by turning the handle. This handle also controls engagement.

The pressure with which the chuck comes to bear on the part is governed by the rheostat on the headstock of the machine. A device of this kind provides for use of a scroll chuck, thus permitting the hole in the spindle to remain clear. Frequently, bar stock sizes will pass through the spindle of the machine, even though it exceeds the machine's collet capacity. Machine capacity may thus be extended by gripping the bar with the chuck and power chuck wrench, yet retain the advantages of power gripping.

Rheostat control enables the machine operator to grip each part according to a pre-set degree—

FIGURE 6

whether tightly or delicately—without variation. In addition, for heavy gripping, the fatigue or labor involved in handling heavy work is, to a large degree, eliminated through use of this type equipment. All of the chucks discussed are available in the familiar tongue and groove jaw base, and some with step-along jaw bases. The latter master jaws are useful where one set of false jaws is used for a series of different size hexagons, squares, etc. This reduces over-all investment in jaws for numerous size parts with similar shapes.

Of all of the chucks described above, the three-jaw universal chuck is most likely to provide the ultimate in accuracy. If the chuck is kept clean and top jaws carefully bored out in place, end-to-end part concentricity of .002-inch t.i.r. is possible.

Fixtures and Arbors

The third main class of holding devices used on horizontal turret lathes is composed of fixtures and arbors. These may be hand or power operated, according to job requirements. If hand operated, the work is ordinarily held to the fixture by nuts, screws, toe clamps, etc. If power operated, air or hydraulically operated cylinders are the customary source of power.

Arbors may be of the expanding, nut, or threaded type. Expanding arbors, in turn, may be of the bushing, plug, or pin type. Figure 7 illustrates a bushing type expanding arbor. Part "A" fits over bushing "D" and, when the drawbar "C" is retracted either by the hand closing mechanism or a power cylinder, bushing "D" expands, gripping the part rigidly. This design allows for variation in the bore of the part, since the bushing expands equally along the entire length of bore. It is best for semi-finishing work where a reasonable amount of stock is to be removed from the part.

One expanding arbor now commercially available differs slightly from other standard models. This type arbor employs an expanding bushing with a two-step taper ground very accurately so that the plug which expands the bushing does so evenly across the entire diameter to assure concentricity.

Another expanding arbor known

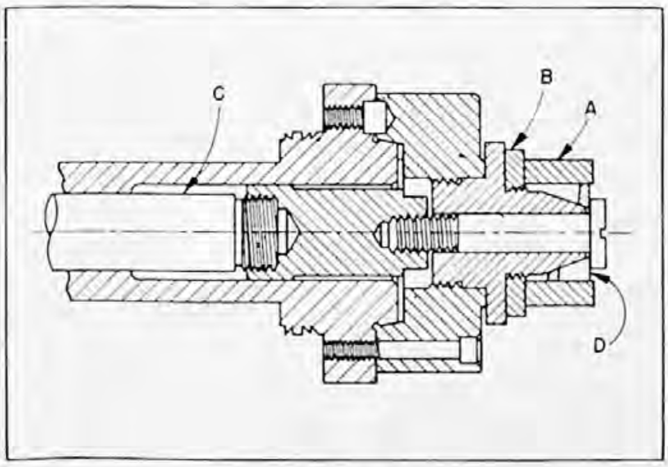


FIGURE 7

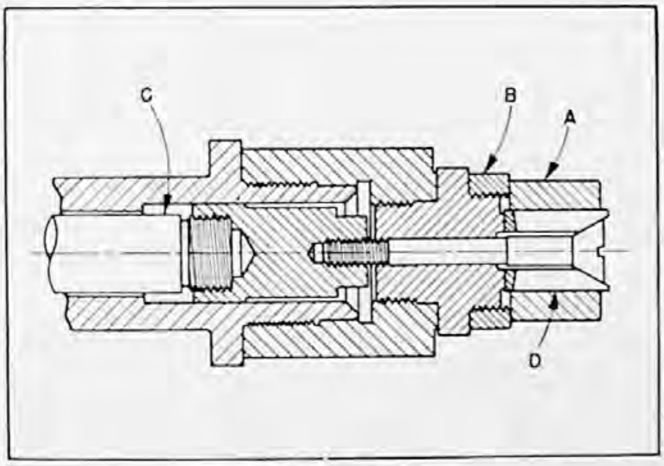


FIGURE 8

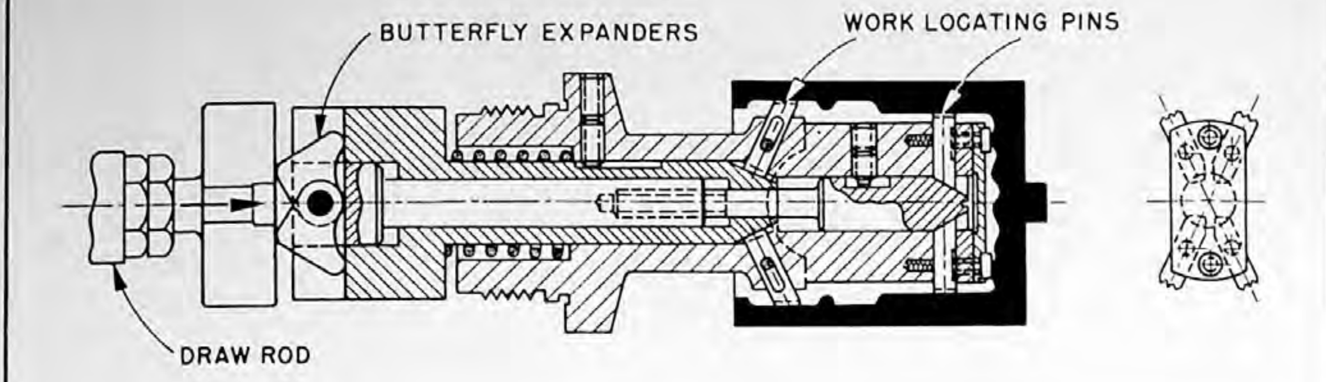


FIGURE 9

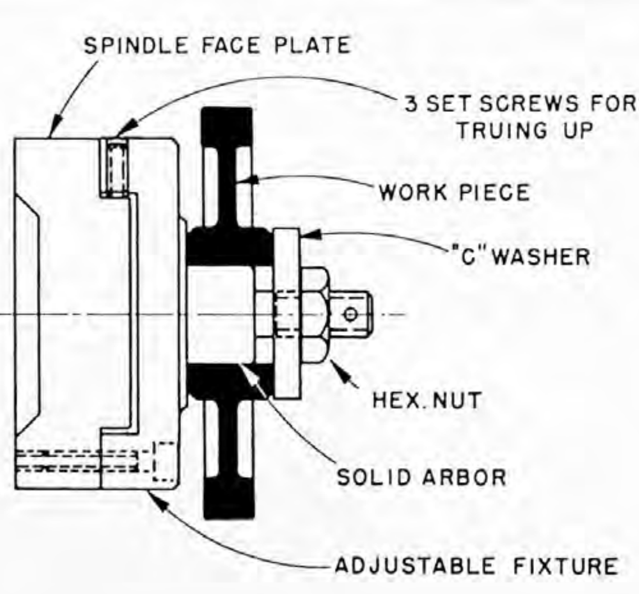


FIGURE 10

as the plug type is shown in Figure 8. This arbor employs an adapter which fits into the hood on the spindle. The adapter is split three or four times along its length at "D." For a certain portion of diameter "D," the arbor is not split but is ground to a definite size as determined by the bore in the part. This allows less variation in bore size. However, the arbor will hold work more true than that shown in Figure 7. Finishing cuts are recommended for this design.

Figure 9 illustrates a typical pin type arbor usually comprised of two sets of pins which act simultaneously to expand within the internal bores of parts. For example, this type arbor is used to locate within the bore of a cast piston so that stock may be distributed properly from the inside. Thus, when the outside diameter of the piston is machined, a uniform wall thickness is assured. One feature provided by this arbor is the independent expansion of the front and rear pins by virtue of the butterfly expanders. These expanders assist in compensating for irregularities within the length and diameter of the cast bore. This type arbor is not ordinarily used for gripping in finished bores, unless the cut is very light. The serrated surfaces of the pins—necessary to chuck under heavy cuts—tend to mar the finish of the bore.

A nut type arbor is illustrated in Figure 10. The part is slipped over the solid arbor and gripped in place by friction as the "C" washer and hexagon nut are drawn up tight. Frequently, these arbors are mounted on face plates which are trued up by adjusting screws on the spindle face plate so that the arbor runs true.

A large variety of threaded arbors is available. In general, they may be the fixed work stop or releasing work stop types.

Figure 11 shows three releasing work stop arbors. The main feature of this type arbor is its ability to release the work for quick removal. With threaded arbors, the part continues to tighten up against the stopping surface, due to the torque created during the cutting operation. With a moving plug "D," the part is threaded loosely onto the arbor and pulled back against stopping surface "B" by the drawing plug "D." Upon completion of the machining operation, plug "D" is released to break the contact between the part and surface "B," and the part is then spun off the threaded arbor.

A fixed work stop arbor is designed in a comparable manner without the complexities involving the moving plug "D." After a part is machined on a solid threaded arbor, a wrench or bumper on the cross slide of the machine is ordinarily used to break the work loose from the arbor. This is not considered good practice, as it may mar the part.

Two general type face plate clamping fixtures are commonly used. Figure 12 illustrates a fixture which employs "V" blocks and pins, as well as toe clamps for gripping. This fixture is used where there are no finished surfaces on the part for locating purposes.

Figure 13 illustrates 2 face plate fixtures in this case, power operated, which locate from previously machined diameters and surfaces. The three clamps shown in each fixture are attached to a spider which swivels around a conical unit attached to the drawrod of the power cylinder. The spider is pulled back by the draw rod and adjusts itself by means of the conical unit to the particular plane on the part against which the fixture fingers contact. The fingers are ordinarily designed with cams so they open automatically outward as the power cylinder is put in open position. This allows the part to be loaded and unloaded without interference with the fingers.

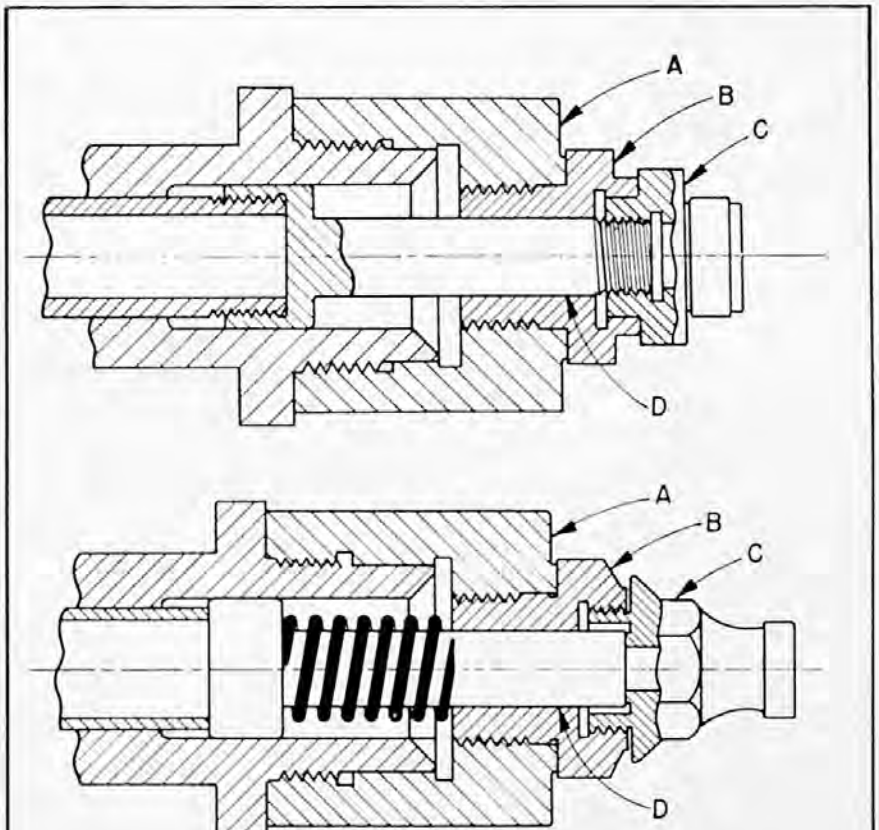


FIGURE 11

Another face plate fixture is shown in Figure 14. Here a piston is held by a locating plug in the previously machined skirt of the piston. A rod is dropped through the wrist-pin hole and through a hole in the drawbar of the fixture. As the drawbar retracts, it pulls the pin back and clamps the piston in place on the locating diameter. The tool shown in the cross slide block crowns the head of the piston as controlled by the contour of the cam plate mounted on the hexagon turret face.

Knee or angle fixtures are also commonly used on turret lathes, an example of which is shown in Figure 15. A fixture of this type is used where it is necessary to machine a diameter in exact relation to a previously machined flat surface. The parts are clamped against hardened and ground locating rails or plates. Location of the part may also be accomplished by means of pins, set in the locating plates and projecting into previously machined holes in the casting.

The illustration shows a compressor mount housing held in such a fixture. Both ends of the housing are to be machined in the same fixture in two different chuckings. The part has been previously machined on its bottom face and this surface rests on the rails of the fixture. In the first chucking, the part is located entirely by means of adjusting screws. After it is adjusted to center, it is held in place by clamps, and both crankshaft bores are finish machined. In the second chucking, the part is turned end-for-end and aligned by a bar extending from the hexagon turret through the machined bore of the crankshaft hole into a pilot bushing in the fixture. The bar is flat on top and bottom to permit it to bear on the sides of the bore only.

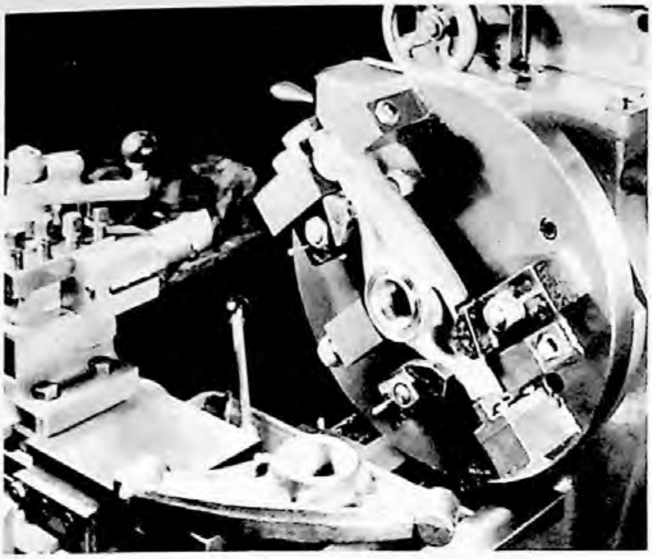


FIGURE 12

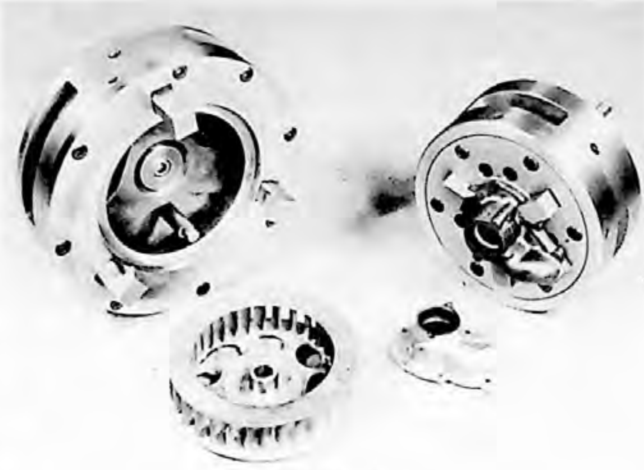


FIGURE 13

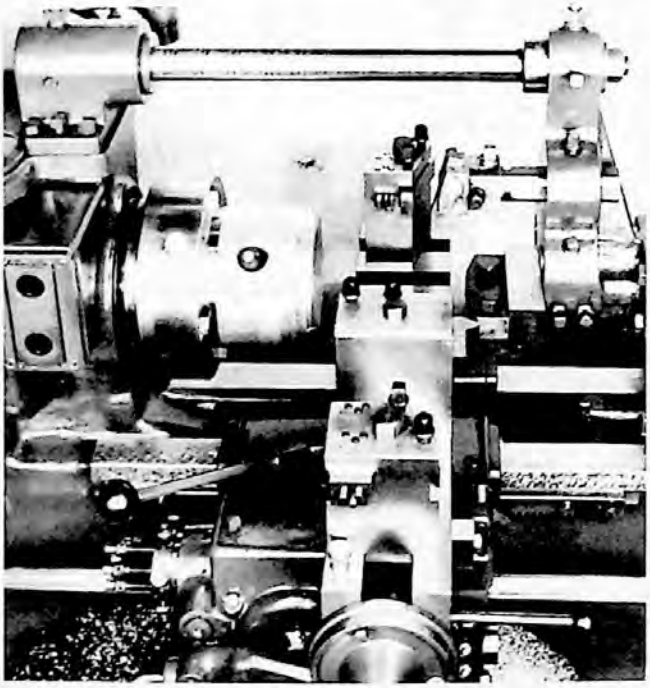


FIGURE 14

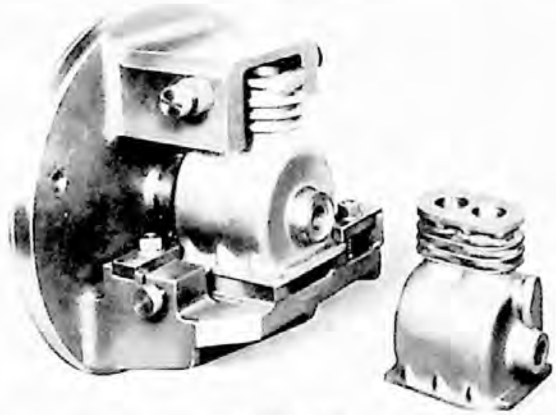


FIGURE 15

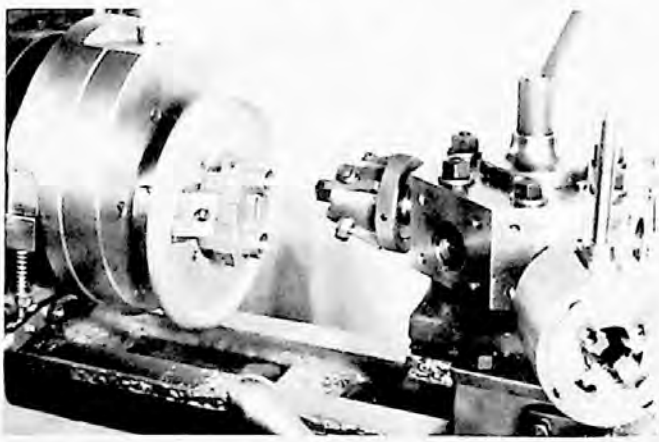


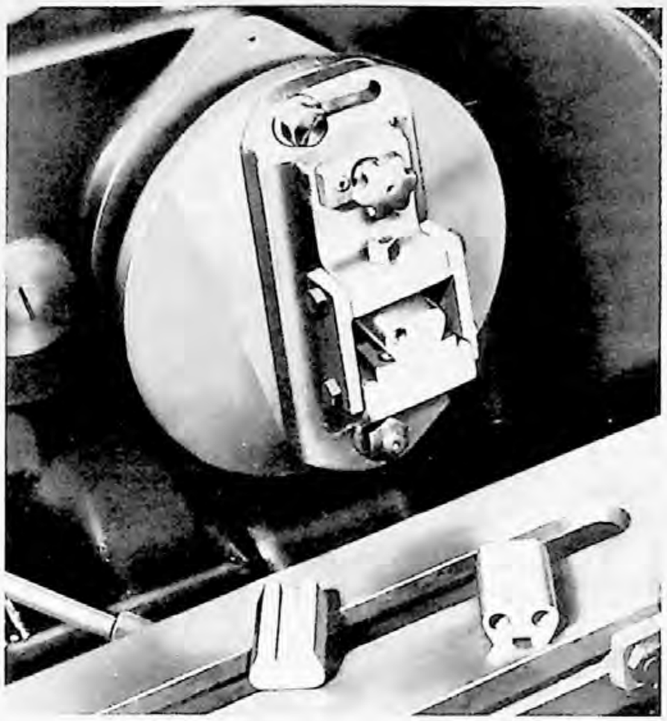
FIGURE 16

This method of locating the work is sufficiently accurate for machining surfaces in the second chucking, but if close concentricity between the first and second chuckings must be maintained, the work should be held on an accurately located plug extending into the previously finished crankshaft bore.

This fixture is well designed for small lot production. However, for larger runs, a faster handling method would be employed. To insure accuracy, the fixture is fastened to a standard face plate and is trued up by means of a recess on the outside diameter of the face plate.

A final important group in this classification are indexing fixtures which may be rotary, sliding or swinging. Figure 16 illustrates a rotary indexing fixture. This fixture allows both holes in the part to be machined successively by indexing the work around a theoretical center, between the holes.

One advantage of this type fixture is that, regardless of the position into which it is indexed, it is always in balance. Ordinarily, it is the most costly of all indexing types and is limited somewhat in the minimum spacing between the holes in the part. The design includes a hand-



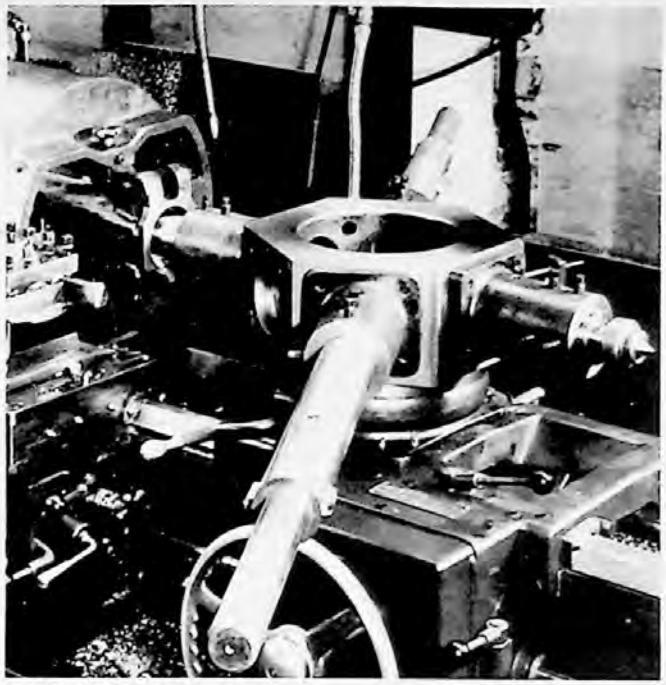


FIGURE 17   FIGURE 18

wheel grip around the fixture for ease in indexing from one side of the work to the other.

Another indexing fixture is shown in Figure 17. The part is mounted in a box attached to a face plate. The box swivels around a center, as indicated by the arrows.

From visual inspection of this fixture it is obvious that it is better suited to more closely spaced holes, that it costs less, yet, by the same token, requires slower speeds because it is not constantly in balance regardless of which side of the part is being machined. Such a fixture may also be designed as a knee type, where the work lies in a vertical, rather than a horizontal plane.

Pot fixtures are useful when long, overhanging work is gripped tightly enough on both ends to permit heavy feeds and maximum speeds. A typical pot fixture is illustrated in Figure 18. One end of the part is held in a standard three-jaw universal chuck, and the outer end supported by screws mounted in the fixture body.

On this particular job, a taper plug with a centered hole is first pressed into the front end. The part is then loaded into the pot fixture and gripped loosely in the three-jaw chuck. Next, the revolving center on the turret is brought into support position in the plug and the three-jaw chuck tightened down on the work. With the outer end of the part supported by the revolving center, the screws in the pot fixture are brought to bear on the work. Then, with the center and plug removed, the machining cuts are taken.

Many pot fixtures are designed with special characteristics that are determined by the job itself. It is possible to use tandem power operated gripping units in such fixtures, but the over-all cost of any design selected is determined by the number of parts to be made and other job characteristics.

JOB PLANNING ON THE TURRET LATHE

Description of the factors encountered in the systematic planning of setups for low cost operation

Good turret lathe practice produces parts at the lowest cost consistent with the number of pieces to be made by combining proper machine handling, basic tooling principles and systematic job planning.

Another chapter in this book on turret lathe practice outlines the elements of machine handling and tooling principles. It is the purpose of this chapter to expand on "Job Planning on the Turret Lathe".

Relation of Turret Lathe to Other Operations

The turret lathe is flexible enough to handle work of many kinds. Therefore, it is of prime importance to determine first which operations in the total routing must occur before and after the turret lathe operation. This reveals the physical characteristics of the part at the moment of processing on the turret lathe and the condition to which it must be processed for succeeding operations. Frequently, sub-operations such as tapping, threading, reaming, lapping or polishing, are economically routed to specialized equipment.

Heavy forgings or castings may be rough machined before shipment to the machine shop for purposes of material savings, stress relief or machine time savings.

The relation of heat treating operations to the turret lathe operation should also be determined. Work parts may be annealed and/or normalized or otherwise treated to improve machinability prior to any machine operation. Stock allowances may be required for grinding after hardening or to protect soft surfaces so that carburized stock may be machined off before hardening.

Heat treatment to establish physical characteristics may occur prior to the turret lathe operation and thus affect machinability. One prominent manufacturer of cemented carbide cutting tools has developed a practical formula for calculating cutting speed from values of depth of cut, tool feed, and Brinell hardness of steel materials.

The work itself may next be inspected in detail. Bar stock, castings, forgings, stampings, tubing, and extrusions in all forms may be machined on a turret lathe. Chemical compositions are important. Cast iron, all steels, common non-ferrous alloys, plastics, the valuable metals and rubber are among those materials machined on a turret lathe. Therefore, a knowledge of the metallurgy of material specifications is valuable as a guide to machinability, tool life, horsepower required for removal of metal, cutting speeds and feeds, tool design and selection, and fixture construction.

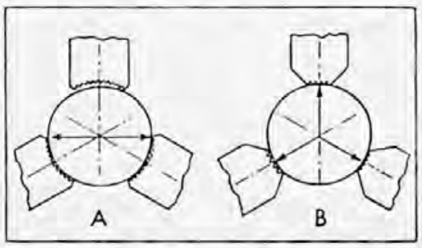
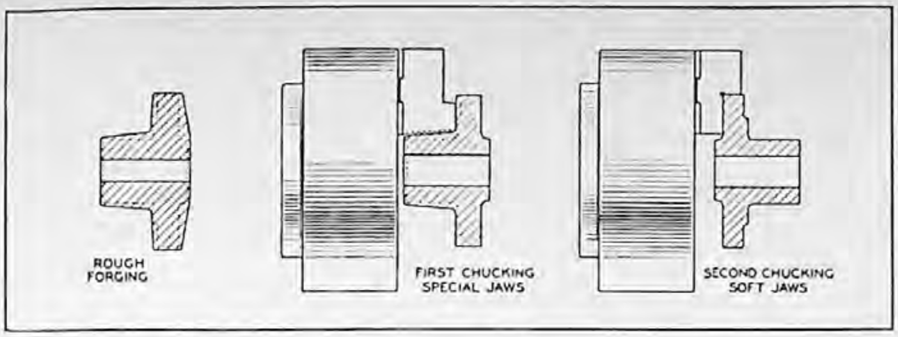


FIGURE 1—Chuck jaw widths at (A) are excessive. Part hangs across jaw corners preventing free centering action. Wide jaws do not grip work tightly. Narrower jaws, as shown in (B) are preferred to the wider jaws.

For instance, certain materials are known to be abrasive when machined. Oxides may appear in certain aluminum alloy castings and not in forgings. Cast iron, rubber, and some plastics are also abrasive. Recognition of this is a clue to tool design and selection of feeds and speeds. For machining abrasive materials, it is particularly necessary that H.S.S. tools have the property of high red hardness.

In machining some steels, notably those with low carbon content, nickel alloys or high chrome alloys, there is a tendency to "build up" on the cutting edges of tools. Certain aluminum alloys, copper and zinc machine in a similar manner. This is also a clue to tool design, selection of type and speeds and feeds. The hard, polished face of a diamond-lapped cemented carbide tool, together with increased top-rake angle and maximum speeds help overcome the "built up" edge and simplify control of surface finish on the part.

The shape of the part is another important factor in job planning. Castings or forgings with heavy sections can usually be held rigidly enough to permit maximum feeds and speeds with standard or semi-



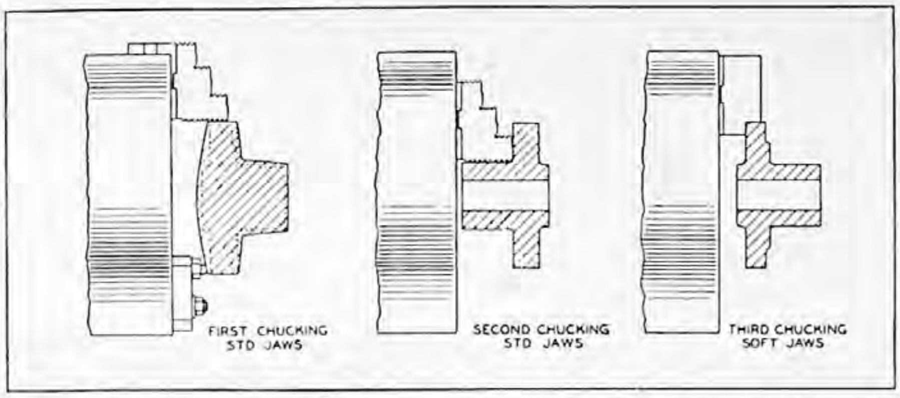


FIGURE 2A—(Above) Special jaws fit draft angle on forging, permitting job to be done in two chuckings. Soft jaws are used in second chucking and grip on flange which is almost twice the diameter of the hub, thus maintaining desirable relationship between grip and cutting torque. FIGURE 2B—(Below) Standard jaws require additional chucking. A rough cut is taken on the hub in first chucking to prepare a straight gripping diameter. This chucking method is more suitable for small lot production jobs than those illustrated in Figure 2A.

standard holding devices. However, where excessive metal must be removed from frail parts having close tolerances, finishing operations must usually be preceded by separate roughing operations to overcome distortion through stress relief and heat dispersion. Conversely, frail parts with minimum stock allowance may not require roughing cuts for the purpose just outlined, but may require special work holding devices and limited speeds and feeds to minimize distortion.

Stock allowance also determines types of holding devices, number of machining cuts required over any one surface to hold a required tolerance and finish, and the rate of metal removal.

The relation of surplus stock to finish part contours should also be considered. For example, draft angles and their direction with respect to mold and die split planes, as well as presence of core shift, may determine types of holding devices and order of operations on any given part.

Axle shafts and the like, whose lengths are many times their diameter, if machined from bar stock under conditions of maximum metal removal, may distort from stress relief and end pressure of machine cuts. Reduced speeds and feeds and use of self-supporting roll-type tool holders usually overcome the effect of this distortion.

With these facts about the part itself in mind, the details of a job plan may be further considered in terms of basic machining theories and types of tooling.

Work Holding Devices

The theory of holding a part for machine cuts is important, for it affects the efficiency of the whole producing unit. The function of a holding device, such as a chuck, fixture or arbor, is to grip a part as rigidly, accurately and quickly as demanded by the requirements of the job. Whether the device can be standard or must be special is determined from the job characteristics.

For initial operations from the rough, self-centering three-jaw chucks may be used, provided the part is round, nearly so, or has a contour conveniently reached at three equally spaced points. This type chuck is capable of gripping quickly and distributing stock allowances in relation to the holding surfaces. In addition, chucking pressures within the chuck tend to oppose and are distributed within the master jaw bearings equally, thus compensating to some extent for manufacturing tolerances and wear in the chuck.

Serrated false chuck jaws with compromise radii on the gripping areas may be used interchangeably on a large variety of jobs for reasons of economy, but special jaws should be used for unusual contours, increased gripping pressure, or to hold frail parts.

When used for increased grip, special jaws should not be so wide that a line extended from the corner of one jaw through the axis of the chuck will intersect any part of the opposing jaw. Unless this rule is followed, the part will hang between these points and will not center properly. (*See Figure 1*) Correspondingly, it should not be assumed that a great length of grip under a special jaw is required for increased gripping power. Higher specific pressure will develop under a reasonably short grip.

Chuck jaws, where possible, should hold where the greatest grip is possible when the area of the part containing the greatest stock allowance is to be machined. It is also advisable that jaws grip upon a diameter nearly equal to or greater than the maximum diameter being machined, so that cutting torque will not pull the work from under the jaws when gripped with reasonable pressure. (*See Figures 2A and 2B.*)

The four-jaw chuck, though slower in operation than self-centering three or two-jaw chucks, is useful for many purposes. It is most economical for the greatest variety of jobs where chucking time is a minor consideration. Also, it may grip many jobs not easily held in other chucks. Irregularly shaped work and long overhanging work require great gripping pressures and are easily handled in the four-jaw chuck. Difficult problems in stock distribution are also best resolved with the four-jaw chuck.

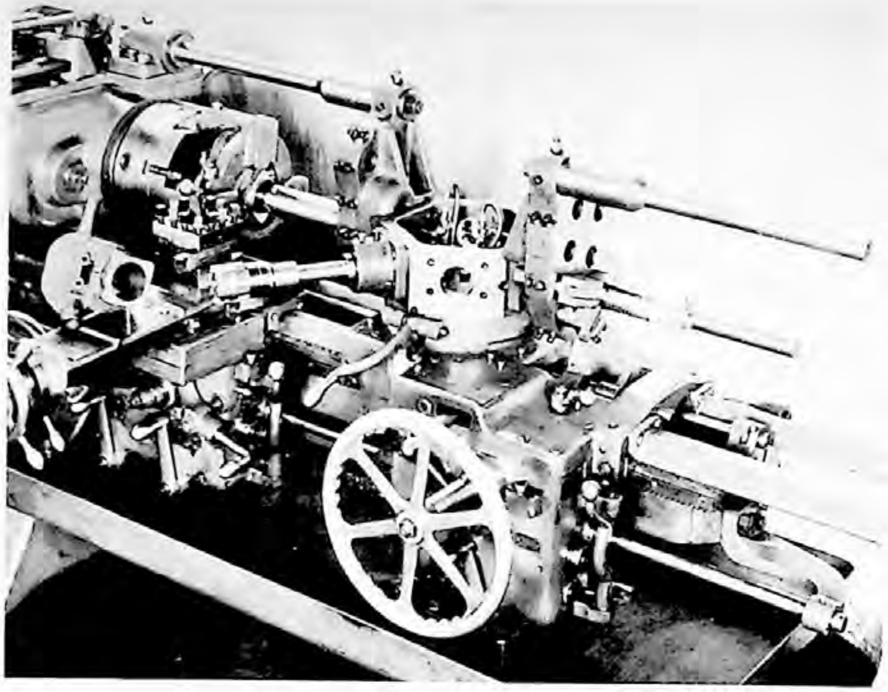


FIGURE 3

The two-jaw universal chuck is designed to handle irregular parts where three equally spaced chucking areas are not available to permit the use of a three-jaw chuck, or where excess opening and closing of the jaws in a three-jaw chuck would be required for loading and unloading the part. The two-jaw chuck will not equalize stock allowances as efficiently as the three-jaw chuck, but for some types of work, two-way equalization is acceptable. Valve bodies and miscellaneous hardware goods are typical of the jobs generally suited to a two-jaw chuck.

This chuck may also have jaws which index 360 degrees around their axis at predetermined increments.

Elbows, tees, crosses, some valve bodies and other similar parts may be machined to advantage in a two-jaw indexing chuck where the intersecting axes of the work must be held to close angular tolerances. Unless this latter condition is true, the value of the indexing feature may be somewhat fictitious, since experience shows that separate handling of machined ends in a non-indexing chuck are usually faster and less likely to overload tool station space, particularly where the part is small, the machine cycle time short, and variety of cuts large.

For long, overhanging work, a pot fixture, such as shown in Figure 3, may be used in conjunction with three and four-jaw chucks. A pot fixture is a fabricated or cast housing extended beyond the face of the chuck and in which two or more adjustable screws are placed so they may be brought to bear against the overhanging part to provide additional rigidity under cut.

They are particularly valuable where the only available surfaces on the part, against which support can be applied, are rough and irregular in shape. Should it be possible to support or locate on a round, smooth, or machined diameter in the extended area of the part, a steady rest would be faster acting.

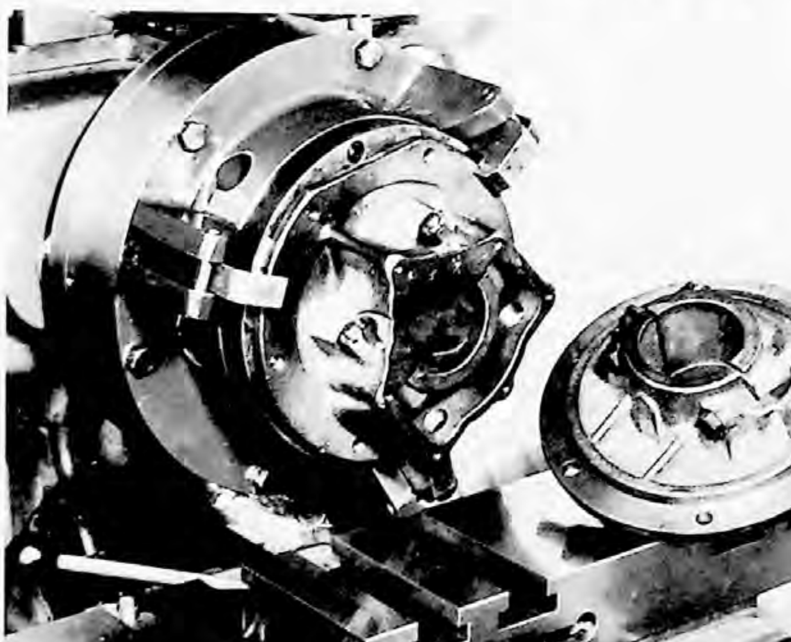
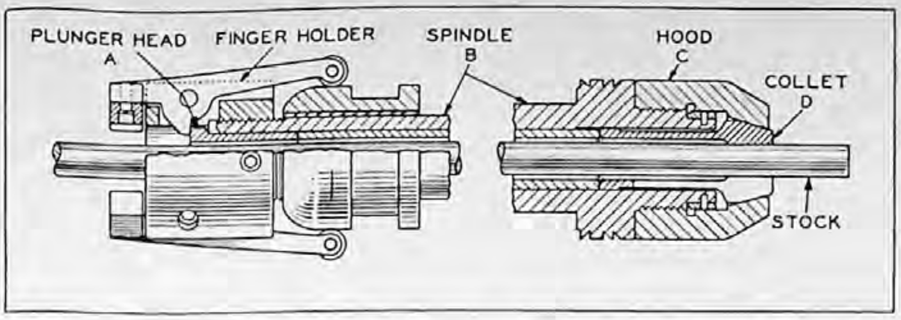


FIGURE 4

Holding Devices for Second Operation Work

The holding devices previously described are commonly used in first operations or holding in the rough. Second operation holding devices, though not usually re-



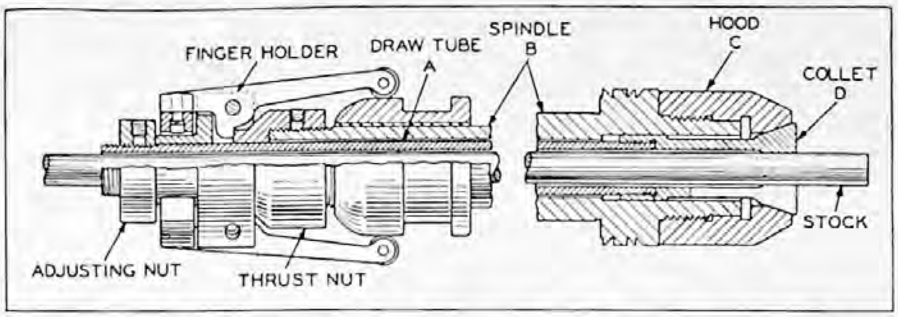


FIGURE 5A—(Above) Standard pushout collet chuck. FIGURE 5B—(Below) Standard drawback collet chuck. Both eliminate need for fitted sleeves, permitting maximum radial accuracy in locating for both first and second operations.

quired to distribute stock, must nevertheless grip tightly and frequently concentrically with respect to the surfaces to be machined in the second operation. The four-jaw chuck, used in this respect, though slow, is economical and offers both the means of gripping tightly and truing up surfaces on both sides of the part.

Where no special concentricity is required between sides, the three-jaw chuck with standard top jaws is faster than the four-jaw chuck. Concentricity can be improved with the three-jaw chuck, if soft top jaws are true bored with the chuck under pressure, to suit the diameter being gripped.

This will provide concentricity of .002 to .004-inch total indicator reading between sides, depending on the condition of the chuck, care that use is made of the same scroll pinion in loading and unloading, and skill in boring the jaws. Soft jaws, so used, may last for a lot of 25 to 50 pieces before reboring. Note that once soft jaws are removed from the chuck, reboring will be necessary to restore their accuracy.

If less concentricity is acceptable between ends, special top jaws may be hardened and then ground in place. Such jaws may grip several hundred parts before regrinding is necessary. They are not ordinarily reground after each removal from the chuck, and are generally considered less desirable than soft jaws where accuracy is preferred to wearing ability.

If second operation accuracy of a greater degree is required, or if the surfaces machined in the first operation are unsuited to holding in a chuck for the next operation, then clamping fixtures can be used. These are usually designed specially for the individual job, though some flexibility can be had by using interchangeable locating plates and clamping fingers.

A clamping fixture usually consists of a spindle face plate on which is fixed a locating ring or arbor to suit the locating area on the part. One or more fingers, or a washer and nut combination, clamp the workpiece against the locating ring or arbor. (*See Figure 4*) Note that clamping should be arranged, if possible, to grip through a solid section of the part.

This eliminates spring or distortion in the part under clamping pressure which might reflect to the surfaces to be machined. Accuracy in terms of total indicator run-out obtainable from a fixture of this type is never closer than twice the difference in size between the part locating surface and the locating plate or arbor.

If a hole which has been machined in a first operation on the center line of a part must run true or square with the second operation surfaces, solid taper arbors or expanding straight arbors may be used. If the hole is *under* one inch in diameter, then a solid arbor is preferred. If the hole is *over* one inch in diameter, then expanding arbors are practicable. Either type arbor can equalize, one through expansion and the other by the taper, the difference in size between locator and part, thus providing very accurate registration.

Occasionally a part is encountered where all diameters must run dead true to the bore and all faces must be square with each other and the bore. This is not a turret lathe job. The bore may be finished on the turret lathe and finishing stock allowed on the remaining surfaces. The part should then be mounted through the bore on an arbor and held between centers either on an engine lathe or production lathe, and all critical surfaces finished on one setting or chucking.

Bar Stock Holding Devices

Methods of holding described up to this point are applicable to cast, forged, or fabricated parts. However, an equal volume of work is machined on turret lathes from bar stock in its various forms. Standard holding devices developed for this class of work are known as collets, and several types are available to meet different job requirements.

For use in gripping bar stock approximately three inches or less in diameter, where materials in cold finished sizes are ordinarily available and where hot finished sizes within this range do not vary appreciably, the simplest and most accurate collet is the spring or heel-type collet. (*See Figures 5A and 5B*)

This is a single piece collet with a taper nose which is closed by being pressed against a mating taper in a hood or chuck nut affixed to the spindle nose. This type collet is usually split partially from the nose to the heel to assist in springing the collet to a closed position for holding. Splits may number three or more but rarely two, since a two-split collet is stiff, would require considerable force to close it, and would not register accurately.

Although the spring collet is unable to accommodate work whose diameters vary more than several thousandths of an inch, thereby eliminating most castings, forgings, and larger sizes of hot finished bar stock, it is by inherent design and method of manufacture most able to hold parts concentric to the spindle center line. Since the collet is made in one piece, the tapered collet nose, bore, heel diameter, and heel face can be ground in accurate relation to one another. Holding accuracy may thus be repeated from part to part, and the absence of fitted sleeves helps maintain accuracy. Spring collets may be pushout or drawback for mill length bars, or extra capacity in either form for short part lengths. (*See Figure 6*)

Since most turret lathe spring collets have 28-degree nose tapers, the longitudinal or stopping position of parts held by the collet may be expected to vary from part to part in ratio of two units longitudinally to each unit change radially

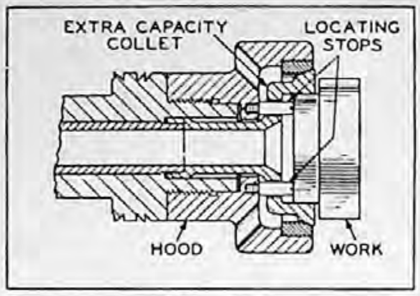


FIGURE 6

on the part holding diameter.

A different collet—the stationary closing type—is useful where it is desired to grip parts so that no longitudinal variation occurs from part to part in the closed position. (*See Figure 7*) It, too, is a onepiece spring-type collet but depends for its closing action upon a moving sleeve which mates with the taper on the collet.

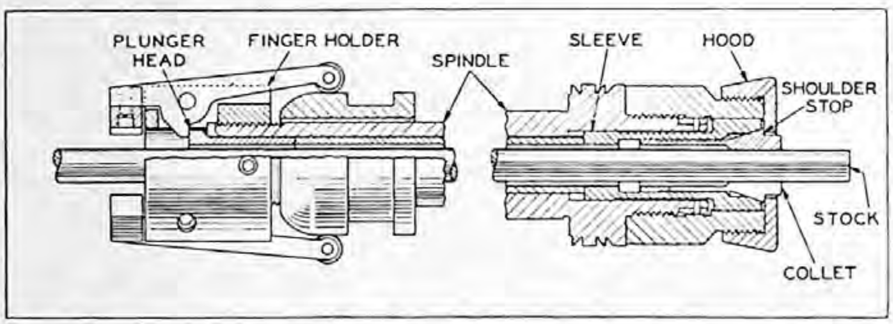


FIGURE 7—Stationary collet chuck grips successive parts with little variation in endwise location. Fitted sleeve introduces a sliding fit not used in collets (Figures 5A, 5B). This type chuck is not recommended for accurate radial location.

As the sleeve moves forward against the taper on the collet, it closes the collet. Any longitudinal variation in position of the collet in closed position is arrested by its contact with a flat surface at right angles to the direction of collet travel. This flat surface is integral with the chuck nut which, in turn, is integral with the spindle nose. This type collet offers less radial accuracy than the plain taper-nose spring collet since it incorporates sliding components.

A variation of the stationary closing type collet is used on larger turret lathes to accommodate hot finished bar stock in the larger sizes where diametral variation is allowed. (*See Figure 8*) With this type collet, eccentricity between operations of .006 to .015-inch t.i.r. may be expected depending on the condition of the collet. Therefore, it is rarely used for second operation work where surfaces must be machined concentric with those produced in the first operation.

Maintaining Close Tolerances

Once the chucking method is decided for a turret lathe job, it becomes possible to determine how the surplus stock may best be removed to establish the desired dimensional tolerances and surface finishes.

Depending to a large extent on the material, tolerances of .001-inch and micro-inch finishes of 40 or less can be produced on the turret lathe. Tooling must be rigid when holding size and finish to required limits. Tool cross sections should be ample, and tool holders should be designed to provide adequate support under the tool.

It is well to pilot roughing tools wherever possible, not only to permit increased feeds but to minimize tool holder deflection as well. This allows a uniform amount of stock to remain on the part for finishing cuts, which is a basic requirement for maintaining close tolerances.

It is not usually advisable to build finish boring or reaming tools with center pilots when these cuts are taken at high spindle speeds on a geared head turret lathe. Heat is generated in the lathe headstock when run for long periods at high speeds, and this heat may prevent the spindle from maintaining a constant position

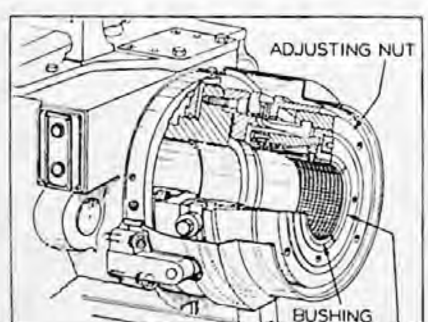


FIGURE 8

in relation to the axes of the cutting tools. This reflects on the work in terms of undersize holes, oversize holes, or taper holes. Spindle variation due to temperature rise affects turning cuts as well.

The job planner should determine whether the savings in cutting time obtained by operating at these extreme spindle speeds are great enough, when compared to the cutting time resulting from the use of slightly lower speeds, to offset the attendant loss in accuracy and efficiency. This is an important calculation to make and one which is often overlooked.

For normal conditions, however, center piloting or overhead piloting of finishing tools is usually helpful to overcome any misalignment between the hexagon turret and spindle axes due to wear or index error. The best way to produce a true, round hole with minimum taper—providing the machine is in good condition—is with the single point boring tool held in a stub bar. The deflection in such a bar is constant, whereas the distance between the pilot support and tool in a piloted bar diminishes as the cut progresses and thus changes the degree of deflection.

For turning most materials where tolerances are allowed in excess of .005-inch, two cuts, one roughing and one finishing, produce satisfactory control of size and finish. For tolerances less than .005-inch, three cuts may be required: One roughing, one semi-finishing, and one sizing. This is especially true under any of these conditions when:

1. Diameter is large.
2. Stock allowance is great.
3. Material is abrasive.
4. Gaging time is to be minimized.

Special Versus Standard Tooling

Both process and tool engineer must continually determine whether special tooling will pay for itself within the job limitations. Some jobs cannot be machined successfully without a few special tools, but average jobs offer a range in choice of setups comprising all combinations of standard and special tools.

Which choice is made must be left to the individual company, since recovery policies and job requirements vary widely. Generally speaking, however, special tooling should not be used where total time savings computed against job overhead does not permit paying for any particular tool within the life expectancy of that tool.

Standard tools such as chucks, multiple turning heads, tool holders of many kinds, boring bars, cross slide tool blocks, and bar turners, are available for turret lathes and should be considered for the average tooling job. These standard tools are produced by the manufacturer in production lots and are priced moderately. Universal and flexible, they are often used in place of special tooling with satisfactory results.

PRODUCTION ESTIMATING

How to analyze and figure production time on a turret lathe job

Total time for producing any machined part—exclusive of setup time—consists of cutting, machine handling, and work handling time. The manner in which machine and work handling time affect the time study is obvious, but the job planner must set quantitative values for them in the time study. To supplement the individual shop's experience, turret lathe manufacturers are able to provide average time standards for indexing and maneuvering the various machine elements, including holding devices.

The question of machinability arises which, in a sense, is the least definite of all principles of job planning. In a sense, all materials are machinable provided they may be attacked by the cutting medium. The rate of machining, then, should be a practical expression of the economic relation between work material and tool life. Rates of machining vary with the part, material, and types of tools.

For instance, assuming equal tool life is desired, S.A.E. 1020 steel should be machined at different rates with high speed steel tools than with cemented carbide tools. Brass would demand a new set of rates for each tool medium. Furthermore, for any one combination of material and tool medium, different rates would apply for cuts with single point tools, form tools, reamers or taps. In any event, a practical machining rate for the tool should be selected with a desired tool life in mind.

Cutting tool manufacturers, technical societies, and private investigators have made available to the job planner numerous tables of machining rates, feeds and machinability indexes for different materials. Such tables are deliberately omitted from this article to permit re-examination of the factors incident to the practical use of this published data.

Machining Rate Table Use

For instance, one table of machining rates suggests 250 s.f.p.m. for rough machining cast iron with cemented carbides and 400 s.f.p.m. for finishing. These rates are simply figures lying somewhere between the lower and upper limits of machinability of this material with the given cutting tool.

Life of the tool immediately enters consideration. If the job is simple and involves resetting few tools which are expected to machine the part to wide limits of tolerance and finish, it might be wiser to accept a relatively shorter tool life by raising the cutting rate and thus reducing the cutting time.

Conversely, if a job is complicated, involves resetting many tools, and requires maintenance of sharp cutting edges to protect surface finish and to hold fine limits of tolerance, a longer tool life is desirable and this means a reduction of cutting speed. The number of pieces in a lot or quantity to be machined during a setup has a great effect on whether rates must be related to life of the cutting edge between grinds.

Power available at the tool will also determine permissible cutting rates. The size of the drive motor and machine headstock efficiencies allow just so much work to be expended upon the part in the form of metal removal. Headstock efficiencies of turret lathes average about 70-85 percent, depending upon the condition of gears, shafts, bearings, method of lubrication, design, and speed. A 10 h.p. drive motor may thus deliver up to 8.5 h.p. at the cut under conditions of normal load.

Other factors contribute to the setting of cutting speeds. Among these are shape and form of the tool. Turning, drilling, counterboring, forming and cut-off tools may all be made of high speed steel and yet for the same material require different cutting rates. The shape of a turning tool itself may vary the permissible rate. Some such shapes require more power for metal removal, thus indirectly affecting the cutting rate.

If a tool must turn to a shoulder and blend with a sharp corner, the cutting tool being ground with this small radius may not be able to withstand maximum cutting rates. Tools with small cross sectional areas cannot carry heat from a cutting edge as rapidly as tools with large cross sections, and this lack of heat transfer may impair the ability of the cutting edge to withstand maximum cutting rates.

Another factor indirectly affecting cutting rate is the shape of the part. An irregular-shaped part may not be rotated beyond certain speeds if vibration is to be controlled, thus limiting cutting rates according to the size of the diameters to be machined. A part may also have interrupted surfaces to be machined which call for reduced cutting rates. Rigidity of the machine and tool holders also affect cutting speeds.

Factors Determining Ultimate H. P. Demand on Machine Motor

Much emphasis is currently placed on the importance of horsepower in cutting with carbides. In general, this is proper, yet there is evidence that the job planner will lose sight of other important factors in metal cutting if power, as such, continues to be overemphasized.

Machine shops want production. Power is only one factor in production and its influence on shortest production time may be minimized by other job factors:

Some of these factors are:

1. *Horsepower is directly proportional to speed, feed, depth of cut and cutting resistance of work material.*

Feed and depth of cut are usually fixed by part characteristics. The strength of the part, type of holding device and work finish required tend to govern both feed and depth. Tool life determines practical speeds, and to some extent feeds, for hard and soft materials. Most tables of recommended cutting speeds show a range from which a speed to give satisfactory tool life may be selected. The effect of speed on tool life is somewhat variable, depending on the type of material.

Ordinarily, heavy cuts in hard materials are not as likely to create maximum power demands because slower cutting speeds are used to obtain tool life. However, softer materials such as aluminum and bronze, may be run faster with acceptable tool life; thus power demands are likely to be higher.

2. *The amount of production gain must warrant the decrease in tool life even when speed is increased within a range of practical values.*

If a simple shaft is to be turned in one pass with a carbide tool, the job obviously can be operated at the highest possible speed (and horsepower) because it is a simple matter to change tools, thus securing high production.

However, another part machined from the same kind of material may be more complex in shape and require more tools. If this job is run at the same speed as the shaft, tool maintenance becomes a factor and the net production gain may not warrant the higher speed. Reduced speed (and reduced horsepower) may, in this case, put more finished pieces on the floor in a specified time than is possible at the higher speed.

Many jobs exist where the number of cuts which may be operated at higher speeds are a small total of the entire cycle. For example, if higher speed and horsepower applied to one or two cuts save .5 minutes out of a 12 minute cycle time, the reduced tool life at the higher speed hardly seems warranted, and the greater power demand loses significance.

3. *Possibility that an increase in cutting speed may eliminate available time for combined cuts, thus reducing apparent benefit gained by the higher speed.*

Consider that a long turning cut is taken on a shaft from the hexagon turret. Assume also, that during this time, a substantial amount of work on the shaft is accomplished by the cross slide.

If turning time is decreased by increasing the speed, some of the cross slide work may have to be done separately. When this is so, the *net* gain, if any, over the original production time, must be carefully considered against the loss in tool life resulting from the higher speed.

4. *Chip Control.*

Chip form and disposal varies with the type of cut, material, speed, feed and tool grind.

This factor is frequently overlooked when more speed and horsepower are considered.

From a practical operating standpoint, chip form and disposal is a very real problem and speed, feed and tool grind may have to be adjusted to suit. In this case, it is quite possible that maximum speeds and horsepower are *not* the controlling factors.

A typical example of job planning based on full consideration of the fundamentals of turret lathe practice is outlined in Figures 1, 2, and 3. Figure 1 illustrates a wheel used by a large

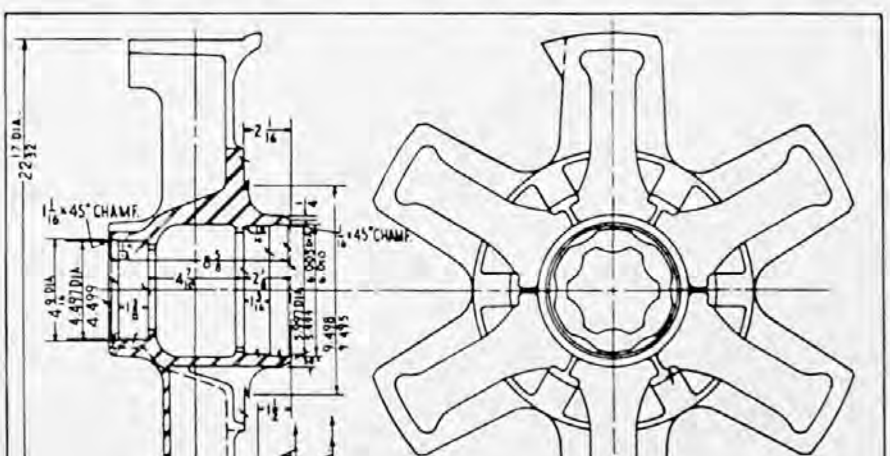


FIGURE 1

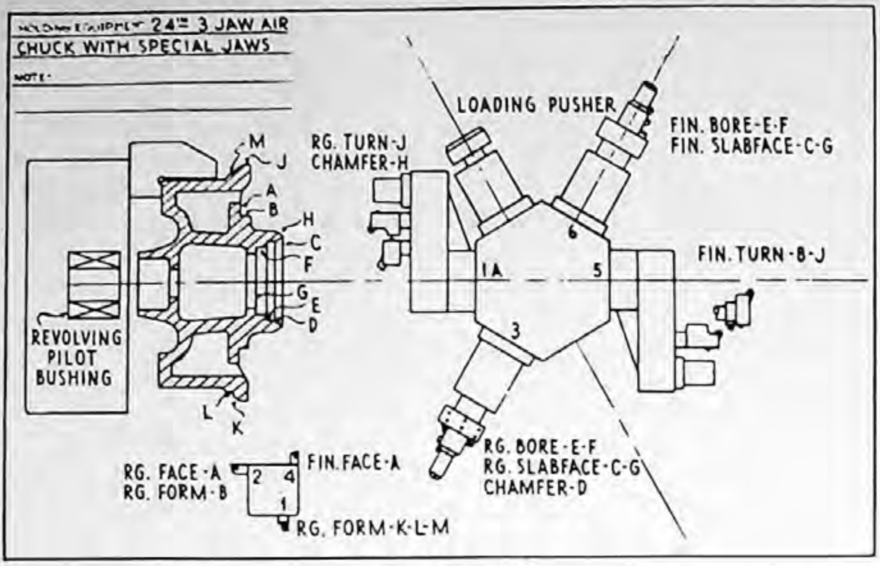


FIGURE 2

trailer manufacturer. Recommended turret lathe setups for machining these wheels in continuous production where it is worthwhile to minimize production costs through efficient machining methods are shown in Figures 2 and 3.

The wheel is machined from cast steel, and for purposes of this discussion it may be assumed that it will arrive at the turret lathe "as cast." It is further assumed that a minimum ¼-inch surplus stock on a side must be removed from each finished surface and that this material is normally abrasive due to sand inclusions, impurities, and other factors.

This chucking job requires a heavy duty turret lathe which is capable not only of removing metal under production conditions, but of reproducing the accurate dimensions indicated. Since the part finishes approximately 23⅜-inches across the rim, the turret lathe must swing at least a 25-inch diameter over the bed ways.

Furthermore, the swing over the cross slide horn must be at least a 25-inch diameter so that the indexing square turret may be positioned in front of the part for the rough and finish forming cuts on the rim. It is further required that the turret lathe selected for this job be powered with a minimum drive motor of 50 h.p. and that it be the sliding saddle type with sufficient bed length to accommodate use of piloted boring bars.

Inspection of the part contour indicates that it is symmetrical and that, under the conditions of this job, a fast acting three-jaw air-operated chuck with special jaws should be used. It would appear that a choice is possible regarding which end of this part should be machined as a first chucking, but in either event, special chuck jaws would be designed to grip on three of the spokes of the wheel, which are spaced at 120 degrees. This allows proper stock distribution around the rim surfaces and also permits the greatest mechanical advantage for gripping the part with respect to cutting torque for any of the machine cuts on the part in the initial chucking.

Correlation of First and Second Chuckings

When it is considered that this is a wheel with opposed axial bearing diameters which, in theory, must be held as concentric as possible to one another, the problem of second operation holding enters the picture and, in effect, solves the question of which end of the part should be done in the first chucking. That is, it appears advisable to machine that end of the part in the first chucking which includes the 9.495/9.498-inch rabbet diameter, so that this diameter may be used in the second chucking for locating in a clamping fixture.

Therefore, the first operation chuck jaws are shown gripping on the diameter which finishes to 22$^{17}/_{32}$ inches. This size chucking diameter requires the use of a 24-inch or larger air chuck in order to minimize radial overhang of the chuck jaws. To assist in loading this wheel into the chuck jaws, a "loading pusher" mounted on the hexagon turret would be helpful.

Sectional strength of this part will permit complete finishing of

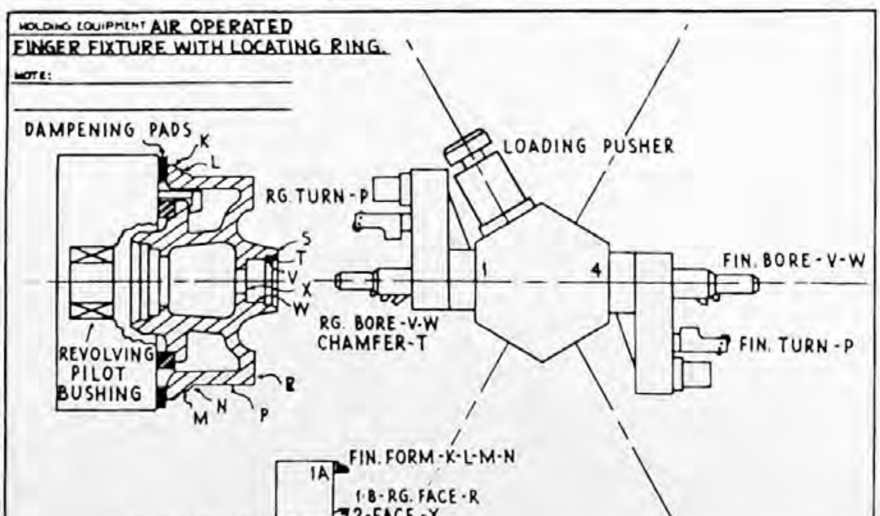


FIGURE 3

all surfaces on either side within the individual chucking. It is not necessary to rough this part all over and then return it to the turret lathe for finishing since heat dispersion and stress relief will not affect immediate control of dimensional tolerances.

In order to take advantage of multiple and combined cuts, standard overhead piloted multiple turning heads are used on opposing faces of the hexagon turret. These turning heads permit the use of tool holders arranged in multiple so that index time and cutting time are minimized. They are designed so that minimum interference exists between the body of the turning head and the square turret for combining cuts.

Planning Bar Stock Jobs

The toggle bolt illustrated in Figure 4 has been chosen as an example of a small high production bar stock job to contrast with the large chucking job previously described. This bolt is machined from SAE-X-1315 steel and it is planned to harden the bolt and grind the .749/.747-inch diameter. The job illustrates the basic functions of a small turret lathe used for bar work. Other types of bar jobs such as long axle shafts and multi-stepped studs are also machined from bar stock on turret lathes, and jobs of that nature require an advanced conception of the principles of tooling for efficient production.

However, the principal difference in the method of tooling the latter parts as compared to the toggle bolt described in this example, lies with the possibility of combining cuts on the longer parts which is not possible in the case of the toggle bolt shown in Figure 4. Analysis of tooling interferences becomes important when combining cuts on short bar work, yet it is important to study the possibility of combining cuts from the hexagon and square turrets in order to reduce total cutting time.

Figure 5 shows the recommended tooling setup for the first chucking on the toggle bolt. A pushout-type hand operated collet chuck and bar feed is used for holding the bar stock in this operation. The stock is fed to the stock stop on the hexagon turret while the collet is in open position.

The first operation in this chucking is shown in Station 1 of the hexagon turret and consists of turning diameter "E" and rough slab facing surface "H." The tool holder used for supporting this carbide-tipped tool is a roll turner, which is designed to support the bar with anti-friction rolls as the cut progresses.

Pressure built up between the rolls and the cutting edge during the cut serves to burnish the turned diameter. In this case, the rolls are adjusted to trail the cutting edge by 1/32 to 1/16-inch. This pressure and burnishing action assists in holding close tolerances when necessary although in the case of this example, diameter "E" is later ground and customary grinding stock tolerances are allowed.

In station 2 of the hexagon turret, a second roll turner is used for turning the thread diameter "C" and for rough slab facing surface "J." The rolls of the turner in Station 2 are allowed to pilot ahead of the tool on diameter "E," so that the thread diameter will be concentric with diameter "E," and the center drilling operation on surface "L" will also be concentric with the thread and ground diameter.

After these operations, the hexagon turret is next indexed to Position 3 and the roll-type end facing tool used to finish face "A" and chamfer surface "B." Following this operation, the part is center drilled in hexagon turret Station 4. This center drilling tool is a standard tool, and is designed with three rolls that can be operated universally as in a three-jaw universal chuck by means of a lever or knob. As these rolls

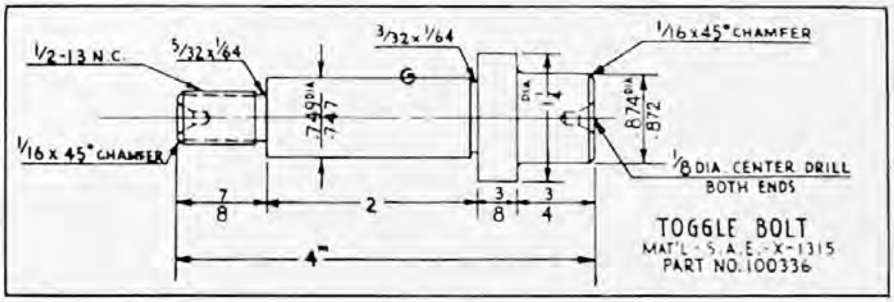


FIGURE 4

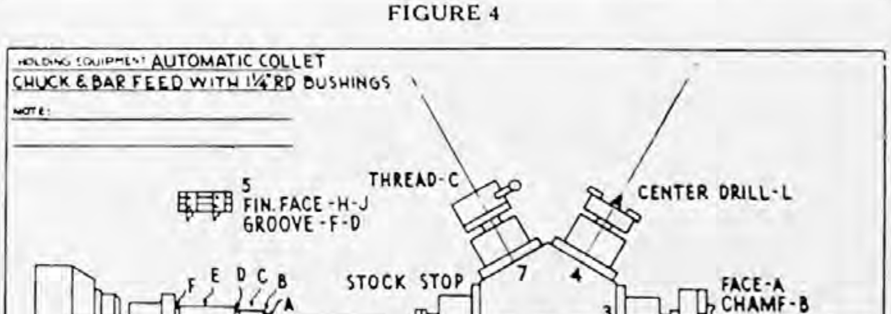


FIGURE 5

close onto the pilot diameter "C," the axis of the center drilling tool is aligned with the center line of the part diameters with which the center drilled hole must be concentric.

Upon completion of these cuts, the necking block shown on the rear of the universal cross slide is advanced to position, surfaces "H" and "J" faced, and undercuts "F" and "D" machined. The indexing square turret is then advanced to cutting position, and the rough forming tool in Station 6 reduces the stock diameter to "G" so that finish turning of "G" may be completed in the next or second chucking.

A self-opening die head is mounted in Station 7 of the hexagon turret to cut the thread on surface "C." After the part is cut off from the bar, the cut-off tool advances an additional distance to chamfer the stub end of the bar at "K" so when the stock is advanced to the stock stop for the next part, a starting chamfer is available to assist in leading on the roll turner from Station 1 of the hexagon turret.

Toggle Bolt Second Operation Tooling

In the second operation (*not illustrated*) the part is again held in the pushout collet chuck on the previously turned diameter "E," back stopping against face "H." The .872/.874-inch diameter is finish turned from the roll turner in Station 1 of the hexagon turret, and the shoulder faced with a tool on the rear of the cross slide. The end of the stud is then faced and chamfered by a roll tool in Station 3, after which center drilling occurs from Station 4 in the hexagon turret.

A cutting speed of 300 surface feet per minute has been selected for machining this material with cemented carbide. The heaviest cut is that in Station 1 of the first chucking where the long diameter "E" is machined. This is run at 920 spindle revolutions per minute or 300 surface feet per minute at a feed of .018 inches per revolution. Calculations show that this speed and feed are proper in order to balance the horsepower available at the cut with other factors in the setup such as tool life, distortion, etc.

The machine on which this example is based is a 1½-inch bar capacity universal ram-type turret lathe which has been selected for several reasons, aside from its proper collet capacity. The cross slide of the machine is universal in the sense that it has power feed in all directions and may be moved longitudinally to positive stops at will. These features are useful for performing the various operations indicated.

Furthermore, the indexing times for cross slide and hexagon turret units are fast enough to be consistent with the proportionate value of the cutting time. The turret ram suits the short work strokes which are necessary on a job of this type, thus minimizing handling time on the job. Progressive overhang of the ram as the cuts advance to completion is not harmful since the critical cutting tools are supported by self-supporting roll-type holders.

This particular turret lathe can be equipped with 10/5 h.p. two-speed motor which allows the feeds and speeds indicated for the material to be used. By virtue of being a two-speed motor, push-button shifts from high to low in a ratio of 2:1 are available and this feature has been used in selecting the spindle speeds to reduce over-all handling time. It so happens that this type turret lathe also has a mechanical high-low clutch, which together with the electrical high-low shift completely eliminates the necessity of shifting head gears during the production cycle of the part. Where the complete cycle time for machining parts is relatively short, it is always necessary to balance the elements properly in handling and cutting time.

MACHINE SELECTION BASED ON JOB ANALYSIS

How job factors such as tooling method, required power, ratio of cutting time to handling time, etc. affect the selection of the proper size turret lathe

It is not difficult to select the proper size and type of turret lathe for a job if the relative importance of certain factors affecting production is decided. Other chapters in this book on turret lathe practice have discussed the effect of machine handling, power, and tool selection on the designation of a proper machine for a job or class of work. Unfortunately, however, it is not possible to lay down universal rules which govern all cir-

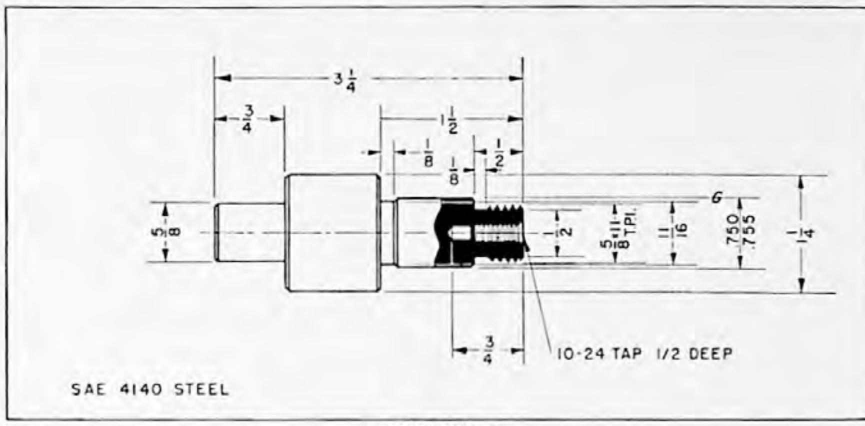


FIGURE 1

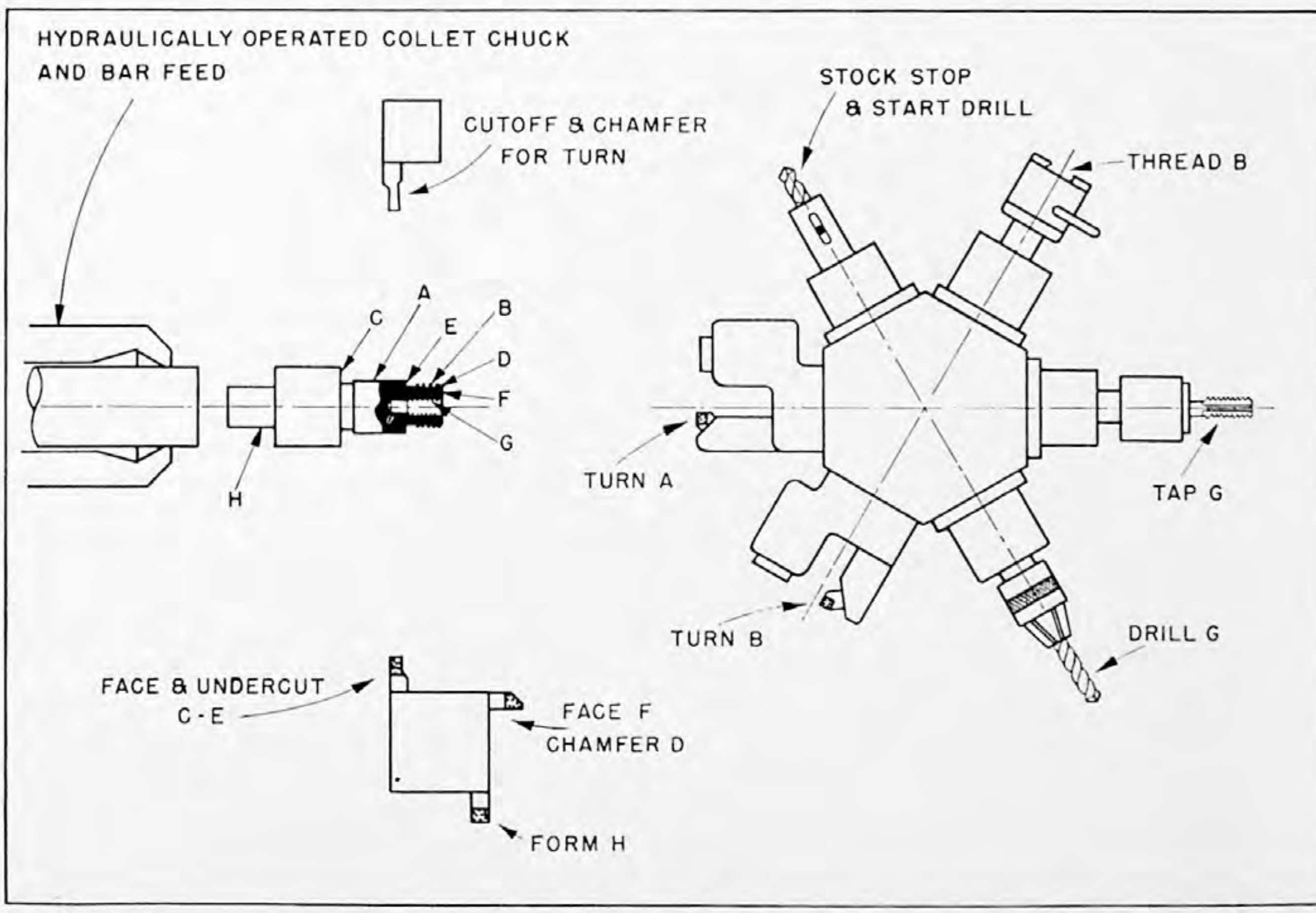


FIGURE 2

cumstances in the selection of a proper machine. The many types and sizes of available machines, and the variations in tooling arrangements and part characteristics permit only a general set of guiding principles to be expressed, any or all of which may be altered in specific cases. As a consequence, the logic underlying machine selection may be best demonstrated by a series of typical examples.

As a specific example of machine selection, the stud in Figure 1 represents a common class of shop work. This part has no unusual tolerances or concentricities and exhibits no unique features which would call it to attention in a shop as worthy of special handling. As such, therefore, work of this kind is often an important reservoir of potential cost savings in shops whose principal efforts are directed at the "hard to handle" job.

Since the part is 1¼ inches in diameter and fairly short in length, it is clear that a small or medium size ram-type turret lathe is the best machine for the job. Accordingly, a choice may be made between a standard 1½ inch No. 3 Geared Head Universal Turret Lathe equipped with either a 7½—3¾ h.p. motor or a 10—5 h.p. motor; a 1½ inch No. 3 Electro-Cycle Turret Lathe with a 7½—3¾ h.p. motor; or a two-inch capacity No. 4 Ram-Type Universal Turret Lathe powered by a 15—7½ h.p. motor.

The No. 3 Geared Head Turret Lathe is equipped with a high-low clutch in the headstock which, together with the push button shift for the two speed motor, provides four spindle speeds obtainable for any setup without shifting head gears.

The No. 3 Electro-Cycle is designed so that all functions of the spindle such as start, stop, change spindle speed, and direction, are obtained automatically by means of preset controls.

The No. 4 Geared Head Turret Lathe is slightly larger than the No. 3, and spindle speeds are obtained by shifting gears with a single lever headstock control.

FIGURE 1		
MACHINE	FLAT TIME	MAXIMUM PIECES IN 8 HOURS
#3 Geared Head (7-1/2—3-3/4 h.p.)	2.98	147
#3 Geared Head (10—5 h.p.)	2.78	157
#3 Electro-Cycle (7-1/2—3-3/4 h.p.)	2.59	182
#4 Geared Head (15—7-1/2 h.p.)	2.74	155

TABLE 1

It must be determined whether a choice exists between these machines for the job in Figure 1 and the class of work it represents, and if so, on what basis should that choice be made.

In order to minimize the effect of changes in the tooling method on the analysis, the same setup (*See Figure 2*) has been assumed to apply to each of the machines in question. This setup conforms to standard turret lathe practice for a job of this nature when produced in small to medium size lots.

Based on Figures 1 and 2, flat production times were calculated for each of the machines. These times are listed in Table 1. The flat production times were then corrected for fatigue for an eight hour run and the corresponding figures listed in the second column in Table 1.

Observe that if the machines were to be chosen in the order of the flat production times the following would apply:

Flat Time
No. 3 E-C
No. 4
10 hp No. 3
7½ hp No. 3

However, when the flat production times are corrected for the fatigue element, the order of choice would be as follows:

Daily Production	
No. 3 E-C	No. 3 E-C
No. 4	10 hp No. 3
10 hp No. 3	No. 4
7½ hp No. 3	7½ hp No. 3

Notice that the No. 3 Electro-Cycle, which has a minimum fatigue factor, still occupies the first position, but that the 10 h.p. No. 3 machine reverses its order with the No. 4 Turret Lathe. In other words, the cuts on the part in Figure 1 are not long enough to permit the power in the No. 4 machine to offset the gain in handling time or fatigue present in the smaller No. 3 machine with a 10 h.p. motor. However, as every business is operated on the basis of dollars earned, this important factor must be taken into consideration in selecting the proper machine for a job. For example, if the order of choice of the same four machines were expressed in terms of the annual savings in direct labor after full allowance for machine depreciation, the following order would apply:

Annual Dollars Saved
No. 3 E-C
10 hp No. 3
7½ hp No. 3
No. 4

The above listing of dollars saved allows for the difference in initial investment in the various machines spread over a period of 20,000 machine hours. It is assumed that it is desirable and proper to recover the investment in the respective machines by laying aside a proper amount annually so that the cost of the machine is set aside in 20,000 machine hours, or a 10-year period. This, after all, is the realistic approach to machine selection and points out that the No. 3 Geared Head Machine with the 7½ h.p. motor is a prior choice over the more heavily powered No. 4, even though the No. 4 machine can produce more parts per day. The point is, the more expensive No. 4

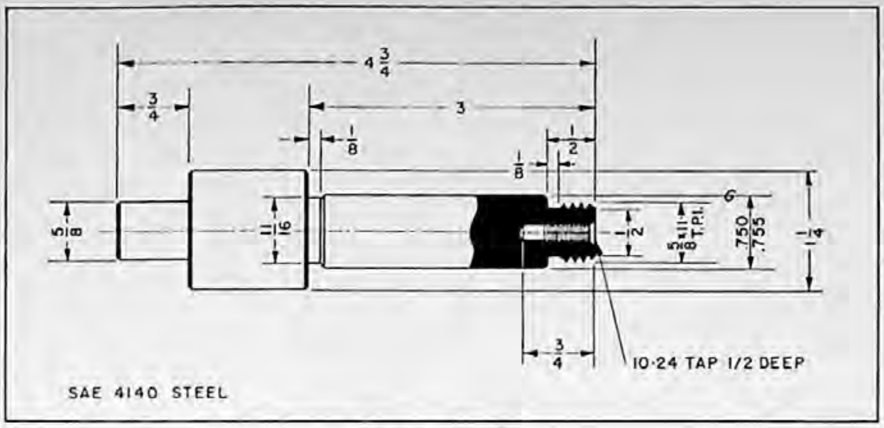


FIGURE 1A

FIGURE 1-A		
MACHINE	FLAT TIME	MAXIMUM PIECES IN 8 HOURS
#3 Geared Head (7-1/2—3-3/4 h.p.)	3.2	136
#3 Geared Head (10—5 h.p.)	2.92	149
#3 Electro-Cycle (7-1/2—3-3/4 h.p.)	2.79	168
#4 Geared Head (15—7-1/2 h.p.	2.8	151

TABLE 2

machine cannot produce enough more parts per day on the particular part shown in Figure 1 to compete cost-wise in terms of dollars saved with the smaller and slower machines.

Simply to show quantitatively the relation in terms of net dollars saved after allowance for depreciation, the figures in Table 4 have been calculated. These figures are based on hypothetical "present production" of 100 parts per day on an assumed turret lathe in the user's shop. An hourly labor rate plus fringe benefits of $1.80 per hour is further assumed.

Notice that there is a tangible difference in dollars saved between the No. 3 Electro-Cycle and the No. 4 machine with the 15 h.p. motor. As a matter of fact, since we are assuming in this part of the table that each of these four machines is limited to the present production rate of 100 parts per day, the full productive capacity of the No. 3 Electro-Cycle and 10 h.p. No. 3 machines cannot be fully realized over the slower machines, and, therefore, an extremely wide range in dollars saved does not appear.

What happens when production on the same part in Figure 1 must be increased 50 percent? The middle two columns in Table 4 show that the No. 3 Electro-Cycle and the 10 h.p. No. 3 are still first and second choices, respectively. The span in dollars saved between these two machines naturally increases because the greater productive capacity of the No. 3 Electro-Cycle over the manually controlled machine is allowed greater leeway. However, the No. 4 machine now assumes third position over the 7½ h.p. No. 3 by virtue of its greater capacity to take heavier feeds and speeds, and thus offsets, to some extent, the faster handling of the smaller 7½ h.p. Geared Head No. 3. In fact, this difference is negligible and it may be assumed that for the part in Figure 1, on the basis of the 50 percent increase in production, either the No. 4 or 7½ h.p. No. 3 would represent an acceptable third choice after the No. 3 Electro-Cycle and 10 h.p. No. 3.

What happens when the *full* productive capacity of the respective machines is allowed to determine the proper choice on the basis of dollars saved annually. These figures are listed in the last two columns of Table 4. Notice that the same order of machines applies as in the columns for the 50 percent increase in production with the difference that a larger span in dollars appears between the No. 3 Electro-Cycle and 10 h.p. No. 3, while the gap between the 10 h.p. No. 3 and the No. 4 machine closes in slightly. The No. 4 machine likewise increases its financial advantage over the 7½ h.p. No. 3.

From the above analysis, it may be concluded that for a part such as the one in Figure 1 where the cuts are relatively short and the opportunity for heavy feeds and speeds is limited, a machine with minimum fatigue factor is more likely to be a first choice over a similar size machine with a heavier motor or a larger machine with a heavier motor where the latter machines are manually controlled. This applies from relatively small lot production on through the maximum available production based on the fastest producer among the four machines. The analysis also shows that the amount of annual production has a tangible effect on the order in which the machines are selected and on the net dollars saved annually after allowing for depreciation.

What is the effect of our analysis if the part in Figure 1 is changed as in Figure 1-A? Notice that the general contour and shape of the work is the same except that the 1½ inch long power cut is increased to three inches. Obviously, this allows a greater proportion of the total cycle time to be devoted to the heavier feeds and speeds in the larger and more heavily powered machine.

Table 2 illustrates the flat time and daily production rate corrected for fatigue applying to the stud in Figure 1-A.

Notice that if the machine in this instance were selected according to the order of flat times only, this would be as follows:

Flat Time
No. 3 E-C
No. 4
10 hp No. 3
7½ hp No. 3

Notice that this is the same order of selection as applied to the stud in its original form in Figure 1.

When the flat times are corrected for fatigue and the daily production figures obtained, the order becomes as follows:

Flat Time	*Daily Production*
No. 3 E-C	No. 3 E-C
No. 4	No. 4
10 hp No. 3	10 hp No. 3
7½ hp No. 3	7½ hp No. 3

Note that the order of choice now remains the same, which is not true of the stud in Figure 1.

Reverting once again, however, to the realistic basis for comparing machine sizes, that of dollars saved, we can list the comparison in the following order:

Flat Time	*Daily Production*	*Dollars Saved*
No. 3 E-C	No. 3 E-C	No. 3 E-C
No. 4	No. 4	10 hp No. 3
10 hp No. 3	10 hp No. 3	No. 4
7½ hp No. 3	7½ hp No. 3	7½ hp No. 3

The order of machine selection now changes when going from the basis of daily production to net dollars saved annually. Referring to the previous discussion in this article, it will be noted that the order for selection of the part in Figure 1 was quite unlike that determined for Figure 1-A. Comparison is as follows:

Dollars Saved

Figure 1	*Figure 1-A*
No. 3 E-C	No. 3 E-C
10 hp No. 3	10 hp No. 3
7½ hp No. 3	No. 4
No. 4	7½ hp No. 3

Assuming that, on the present equipment in the user's shop, production of the part in Figure 1-A is 85 pieces per day, the relative net dollars saved, after depreciation per year, is listed in Table 4. Note that there has been a general contraction in the maximum and minimum dollars saved by the four machines when competing on the limited basis of 85 parts per day.

However, if production is increased 50 percent, and then when production is figured on the maximum available production based on the fastest machine as listed in the right hand column in Table 4, it will be noted that while this contracted range still generally applies, the same order of machines also applies across the table. In other words, the increased horsepower available on the No. 3 Geared Head Machine and the No. 4 machine still cannot offset the handling time-fatigue factor advantage of the automatically controlled No. 3 in spite of the fact that that machine is the most expensive in the group. It is true that the net financial advantage decreases for the No. 3 Electro-Cycle as the length of the power cut increases, although that machine is still clearly indicated on the basis of dollars saved annually.

As a final test of how much an increased length in the power cut affects the choice of the machine, the stud in Figure 1 has been changed to conform to that in Figure 1-B. Notice that the power cut has been increased from 1½ inches to six inches.

The flat time and daily production applying to this stud for the respective machines is listed in Table 3.

Notice that if the machines were again selected on the basis of flat time, the order would be as follows:

Flat Time
No. 4
10 hp No. 3
No. 3 E-C
7½ hp No. 3

However, when the daily production figures are utilized as a basis of machine selection, the order becomes as follows:

Flat Time	*Daily Production*
No. 4	No. 3 E-C
10 hp No. 3	No. 4
No. 3 E-C	10 hp No. 3
7½ hp No. 3	7½ hp No. 3

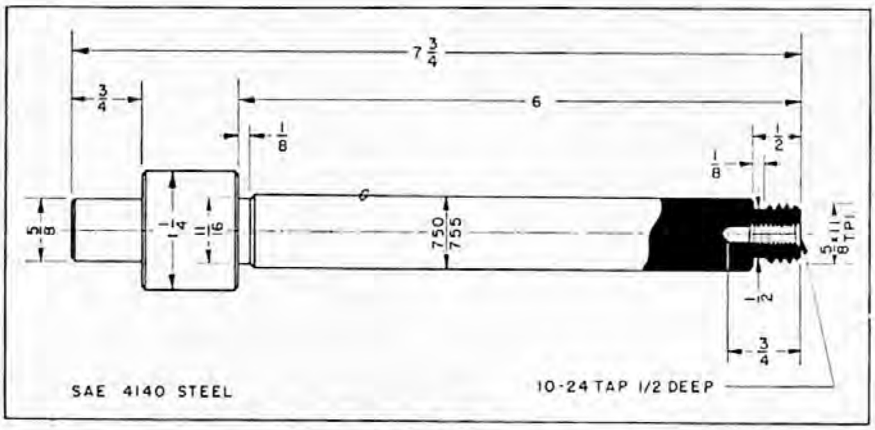


FIGURE 1-B

FIGURE 1-B		
MACHINE	FLAT TIME	MAXIMUM PIECES IN 8 HOURS
#3 Geared Head (7-1/2—3-3/4 h.p.)	3.67	119
#3 Geared Head (10—5 h.p.)	3.18	137
#3 Electro-Cycle (7-1/2—3-3/4 h.p.)	3.2	147
#4 Geared Head (15—7-1/2 h.p.)	2.96	143

TABLE 3

FIGURE 1					
Based on Production from Present Shop Equipment of 100 Pieces Per Day		50 Percent Increase in Production		Maximum Available Production (Based on Fastest Producer)	
Machine	*Net Dollars Saved/Yr.	Machine	*Net Dollars Saved/Yr.	Machine	*Net Dollars Saved/Yr.
#3 E-C	$447	#3 E-C	$1,267	#3 E-C	$1,767
10 h.p. #3	304	10 h.p. #3	954	10 h.p. #3	1,284
7-1/2 h.p. #3	159	#4	736	#4	1,166
#4	106	7-1/2 h.p. #3	734	7-1/2 h.p. #3	1,089
Present Production 85 Pieces Per Day		FIGURE 1-A			
#3 E-C	$592	#3 E-C	$1,587	#3 E-C	$2,377
10 h.p. #3	554	10 h.p. #3	1,404	10 h.p. #3	2,104
#4	411	#4	1,286	#4	1,986
7-1/2 h.p. #3	359	7-1/2 h.p. #3	1,089	7-1/2 h.p. #3	1,669
Present Production 70 Pieces Per Day		FIGURE 1-B			
10 h.p. #3	$769	10 h.p. #3	$1,544	#3 E-C	$2,767
#3 E-C	702	#3 E-C	1,517	10 h.p. #3	2,704
#4	676	#4	1,476	#4	2,686
7-1/2 h.p. #3	499	7-1/2 h.p. #3	1,124	7-1/2 h.p. #3	2,139

**Direct Labor Only (After Full Allowance for Depreciation Based on 20,000 Machine Hours)*

TABLE 4

Notice how the order of machines has been revised.

Again referring to the use of net dollars saved annually as a basis for machine selection, our columns indicating machine choices would become as follows:

Flat Time	*Daily Production*	*Dollars Saved*
No. 4	No. 3 E-C	10 hp No. 3
10 hp No. 3	No. 4	No. 3 E-C
No. 3 E-C	10 hp No. 3	No. 4
7½ hp No. 3	7½ hp No. 3	7½ hp No. 3

Note again what a substantial effect the difference in approach has on the order of machine selection.

Table 4 indicates in the two left hand columns the order of machines as previously mentioned on the basis of the user's present production of 70 pieces per day together with the net dollars saved. Notice again how compactly the net dollars saved relate to one another for the respective machine.

As before, the figures in Table 4 which apply to the part in Figure 1-B have been calculated for a 50 percent increase in production and on the basis of maximum available production for the fastest machine. For the 50 percent increase in production, the same order of machines applies as with the present production of 70 pieces per day, although the second choice machine, the No. 3 Electro-Cycle, has narrowed the gap between itself and the first choice No. 3 with the 10 h.p. motor.

Correspondingly, when the maximum available production based on the fastest machine is allowed to apply, the No. 3 Electro-Cycle overcomes the advantage of the 10 h.p. No. 3 machine and actually shows a slight net financial gain at the end of the year over the No. 3 machine with the larger motor. Here again is tangible evidence of the relative effect on dollars saved annually of a machine with fully controlled handling compared to other machines of the same general size with larger capacity to remove metal by virtue of increased feeds and speeds.

By way of concluding this analysis, it may be observed that the No. 3 Geared Head Machine with 7½ h.p. motor consistently occupies a low position in the order of machine selection. This should not be construed as a relative inability of this machine and motor combination to produce efficiently. It so happens that for the class of work on which this analysis is based, the No. 3 machine should at least be powered with a 10 h.p. motor.

Surely, many other types of jobs occur in shops where power requirements are much simpler than those indicated in the samples cited, in which case the 7½ h.p. machine would consistently show to better advantage, particularly if the jobs are simple and the advantages of fatigue elimination are not so prevalent.

In such cases, the smaller motor would exert an advantageous effect on the shop power factor with the resulting reduction in power costs, which, in turn, reflect in terms of dollars saved at the end of the year.

Entire purpose of this article may be well served if it emphasizes the need for users of turret lathe equipment to expand their analysis of machine selection beyond the more obvious element of flat production time or daily production figures. There is no simple continuity in reasoning between the relationship of power, handling time and tooling arrangement which allows snap judgment in machine selection for different classes of work.

In the last analysis, machine selection must always be placed on the basis of net financial gain to the user and frequently surprising choices are indicated on the basis of that reasoning.

PRODUCTION TOOLING ON THE TURRET LATHE

Review of tooling principles with full description of a typical bar and chucking job showing good application of these principles

In many respects, the five basic factors of good turret lathe practice are inseparable from several principles of tooling. In fact, the complete subject of good turret lathe practice is a complicated combination of teamwork between the turret lathe manufacturer, the machine operator, the tool engineer, and the machine maintenance engineer. However, these tooling principles are a good yardstick with which to measure the efficiency of any turret lathe setup.

These principles are:

1. Do not be complacently satisfied with the setup previously used.

2. Total time for the job should be kept at a minimum by balancing setup time, work handling time, machine handling time and cutting time.

3. Reduce setup time by using universal tooling equipment and by arranging the heavier flange-type tools in a logical order and keeping them in a permanent setup.

4. Keep work handling and chucking costs down by selecting proper standard equipment and by using special equipment when it is justified by large lot quantities and possible savings.

5. Reduce machine handling time by using the right size machine for the job and by taking as many multiple cuts as possible.

6. Reduce cutting time by using: multiple cuts, combined cuts, increased feeds for rigid tooling, increased speeds by proper tooling.

Planning Bar Stock Jobs

The toggle bolt illustrated in Figure 1 has been chosen as an example of a small high production bar stock job. This bolt is machined from SAE-X-1315 steel, and it is planned to harden the bolt and grind the .749/.747-inch diameter.

The job illustrates the basic functions of a small turret lathe used for bar work. Other types of bar jobs, such as long axle shafts and multi-stepped studs, are also machined from bar stock on turret lathes, and jobs of that nature require an advanced conception of the principles of tooling for efficient production.

However, the principal difference in the method of tooling the latter parts as compared to the toggle bolt described in this example, lies with the possibility of combining cuts on the longer parts which is not possible in the case of the toggle bolt shown in Figure 1.

Analysis of tooling interferences becomes important when combining cuts on short bar work, yet it is important to study the possibility of combining cuts from the hexagon and square turrets in order to reduce total cutting time.

Figure 2 shows the recommended tooling setup for the first chucking on the toggle bolt. A pushout-type hand operated collet chuck and bar feed is used for holding the bar stock in this operation. The stock is fed to the stock stop on the hexagon turret while the collet is in open position.

The first operation in this chucking is shown in Station 1 of the hexagon turret and consists of turning diameter E and rough slab facing surface H. The tool

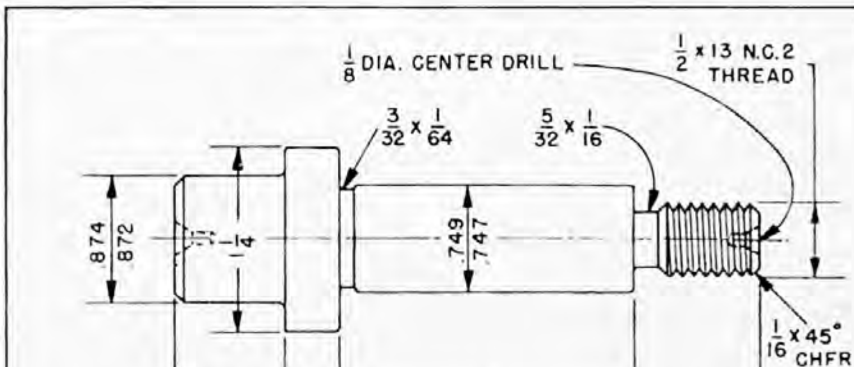


FIGURE 1

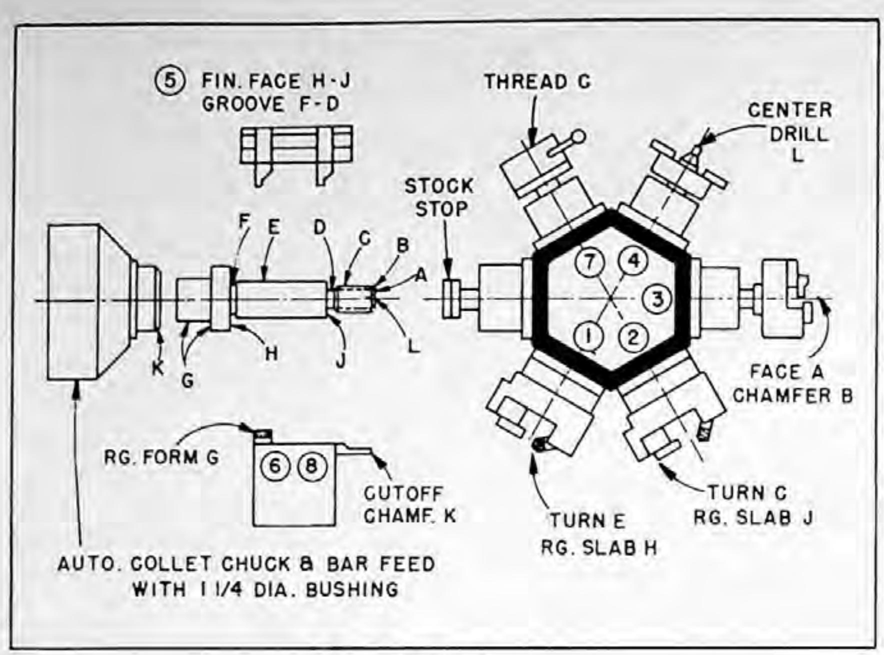


FIGURE 2

holder used for supporting this carbide-tipped tool is a roll turner, which is designed to support the bar with anti-friction rolls as the cut progresses.

Pressure built up between the rolls and the cutting edge during the cut serves to burnish the turned diameter. In this case, the rolls are adjusted to trail the cutting edge by $\frac{1}{32}$ to $\frac{1}{16}$-inch. This pressure and burnishing action assists in holding close tolerances when necessary, although in the case of this example, diameter E is later ground and customary grinding stock tolerances are allowed.

In Station 2 of the hexagon turret, a second roll turner is used for turning the thread diameter C and for rough slab facing surface J. The rolls of the turner in Station 2 are allowed to pilot ahead of the tool on diameter E, so the thread diameter will be concentric with diameter E, and the center drilling operation on surface L will also be concentric with the thread and ground diameter.

After these operations, the hexagon turret is next indexed to Station 3 and the roll-type end facing tool used to finish face A and chamfer surface B. Following this operation, the part is center drilled in hexagon turret Station 4. This center drilling tool is a standard tool, and is designed with three rolls that can be operated universally as in a three-jaw universal chuck by means of a lever or knob. As these rolls close onto the pilot diameter C, the axis of the center drilling tool is aligned with the center line of the part diameters with which the center drilled hole must be concentric.

Upon completion of these cuts, the necking tool block shown on the rear of the universal cross slide is advanced to position, surfaces H and J are faced, and undercuts F and D machined. The indexing square turret is then advanced to cutting position, and the rough forming tool in Station 6 reduces the stock diameter to G so finish turning of G may be completed in the next, or second, chucking.

A self-opening die head is mounted in Station 7 of the hexagon turret to cut the thread on surface C. After the part is cut off from the bar, the cut-off tool advances an additional distance to chamfer the stub end of the bar at K so when the stock is advanced to the stock stop for the next part, a starting chamfer is available to assist in leading on the roll turner from Station 1 of the hexagon turret.

Second Operation Tooling

In a second operation, the part is again held in the pushout collet chuck on the previously turned diameter E, back stopping against face H. The .872/.874-inch diameter is finish turned from the roll turner in Station 1 of the hexagon turret, and the shoulder faced with a tool on the rear of the cross slide. The end of the stud is then faced and chamfered by a roll tool in Station 3, after which center drilling occurs from Station 4 in the hexagon turret.

A cutting speed of 300 surface feet per minute has been selected for machining this material with cemented carbide tools. The heaviest cut is in Station 1 of the first chucking where the long diameter E is machined. This is run at 920 spindle revolutions per minute or 300 surface feet per minute at a feed of .018-inch per revolution. Calculations show this speed and feed are proper, in order to balance the horsepower available at the cut with other factors in the setup such as tool life, distortion, etc.

Figure 3 illustrates a typical bar or shaft job which can be tooled efficiently. This bar job is intended only to illustrate the method and application of a basic tooling arrangement to a general class of work.

This particular bar job is one where the length of the finished part is many times the diameter of the bar. Note that all machining cuts are taken on the bar in Position 1. The part is extended to Position 2 for cutting off.

The sequence of cuts on this bar job follows the numerical listing of the stations on both the cross slide and hexagon turret. For example, Position 1 is a start turning operation with a tool held in the square turret on the cross slide. This start turned diameter is equal in size to surface C, and the starting cut is taken while the stub end of the bar is projecting from the collet. A true turned diameter can, in this manner, be obtained quickly with a small projection of bar stock.

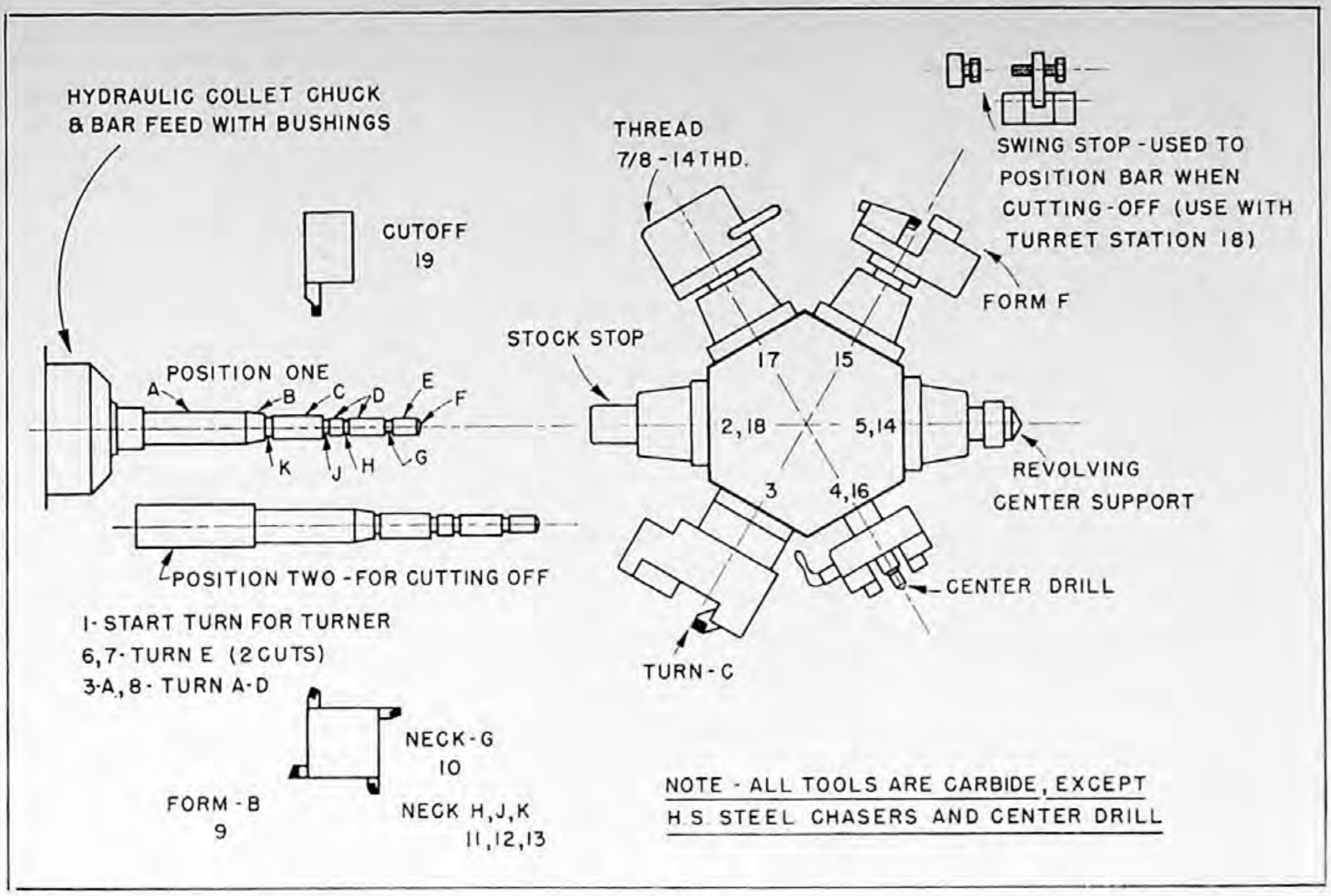


FIGURE 3

Deflection would occur if the stock were extended to full length prior to this starting operation.

Following the start turning operation, the stock is extended to stock stop Position 2 on the hexagon turret. This determines overhang of the bar from the collet while the remaining cutting operations are performed.

Next, the roller turner in Station 3 of the hexagon turret is advanced to the work and the rolls of this tool pick up and guide on the previously start turned diameter so that the tool may receive an adequate start to complete turning diameter C.

Note that some loss in concentricity will result on the work after the preturned diameter is machined, due to opening and closing the collet to feed out this part. Thus the roller turner may not secure a concentric start after the stock is extended.

However, the preturned diameter extends only a short distance along the end of the bar and since diameter C is larger than diameters D and E, any irregularity in finish, obtained in the initial stages of the turning cut taken from Station 3, will disappear when the tool cuts into full bar diameter in the area of diameter C. Ordinarily, a bar pointed on the end, rather than having a start turned diameter, will not provide a good start for the turning cut in Station 3, especially when bar overhang is many times greater than its diameter.

The next cut is a center drilling operation in Station 4, after which the end of the part is supported by the revolving center in Station 5. With the bar supported at the front end by the revolving center, cuts six through 13, inclusive, are performed from the square turret on the cross slide. The center support is then removed from the end of the bar.

In Station 15 of the hexagon turret, the end of the bar is formed and, after this forming operation, the part is recentered from Station 16 so that any burr thrown into the center by means of the end forming operation can be removed. Threading the 7/8-inch 14-pitch thread is accomplished with the die head in Station 17.

After the thread is cut, the part is ready to be cut off and, in order to reposition the bar stock for the cutting off operation, the stock stop in Station 18 is again indexed into position and used in conjunction with a swing stop mounted on the turret ram.

Because the positive ram stop is adjusted to suit the forward position of the ram when the stock stop in Station 2 is used, an auxiliary stop is necessary for stock stop Position 18. This requirement is met by the semi-standard swing stop mounted between the turret ram and saddle of the Warner & Swasey turret lathe. This stop is simply swung into position for stock stop Operation 18, and raised out of place to allow further forward motion of the ram when Station 2 is required.

Note that the turning cut in Station 3 of the hexagon turret is accomplished in combination with the tool in Position 3-A on the square turret used for turning surface A.

The shaft in Figure 3 can be tooled completely with carbide, and with the tool holders illustrated, may be produced efficiently in lots as low as five to 10 pieces.

Depending upon the material specification, it would be possible to hold surface C to a tolerance of at least .0005-inch with a micro-inch finish as low as 15.

The flywheel presents the opportunity of successfully combining both standard and special tools and holders. Tooled as shown in Figure 4, the part is produced complete in one operation in 3.6 minutes.

This setup provides special chuck jaws which allow the outside diameter to be machined completely in one pass and also allows flange G to be back faced in the same chucking. Hub G is either machined as a second operation on a drill press or blind faced from the hexagon turret in the turret lathe setup by means of a quick acting slide tool and stub boring bar.

The first step in this operation is to use a heavy duty multiple turning head with overhead pilot and angle turning holder for rough machining outside diameter A in one pass. Arranged in combination with this turning tool is a piloted boring bar containing a tool for machining hole clearance E, rough boring hole D and rough slab facing hub C. This piloted boring bar is supported by an anti-friction pilot bushing in the bore of the chuck.

The bar is specially designed for this job. Arrangement of the single bit tools in the piloted bar permits combination or simultaneous cutting on bores E and D, thus eliminating a separate operation for machining clearance hole E as would be required in a setup using completely standard tools. The slab facing cutter for hub C combined in the finishing piloted bar eliminates the necessity of positioning the cross slide for the facing cut and also saves cutting time, as it can be combined with machining the bores.

Operations performed by this first hexagon turret station are combined with a special tool block mounted on the front of the cross slide which is used to straddle face flanges G and B. The tool block is special, and is an improvement over the standard cross slide tool block as it combines the cutting time for machining face G with that required for machining face B.

The second hexagon turret station holds another standard multiple turning head with overhead pilot and an adjustable angle tool holder for finish turning outside diameter A in one pass. Another special piloted boring bar is used with tools to size and chamfer hole D, and finish slab face C. These cuts are taken in combination with the special straddle facing block on the rear of the cross slide used to finish cut faces B and G. It is not considered necessary in this

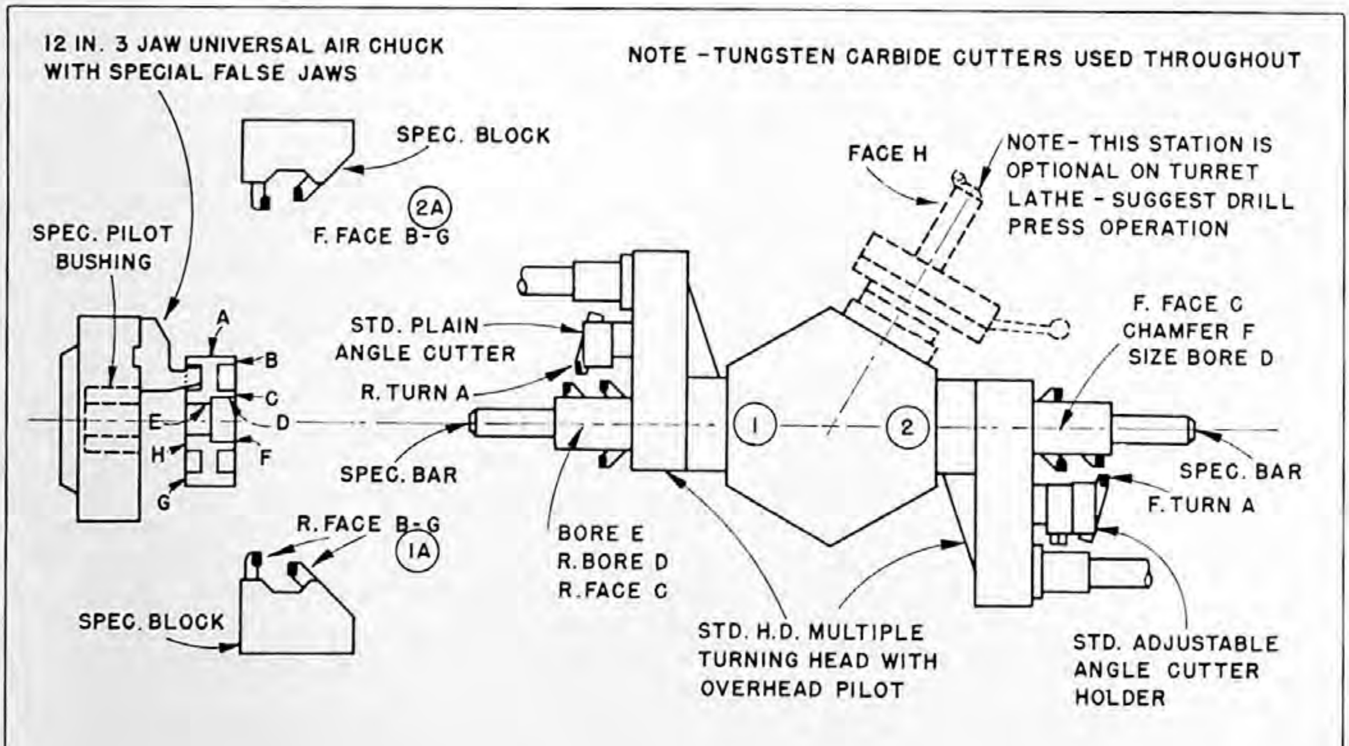


FIGURE 4

special tooling setup to take a separate size boring cut on hole D, because piloting the bar in Station 2 of the hexagon turret permits the tolerance to be held without an additional and separate sizing cut.

The increase in production with a job similarly tooled, which includes both standard and special tools, should not be allowed to prevent the economical use of completely standard tooling arrangements where lot sizes are low and variable in nature.

Admittedly, many concerns differ in their accounting approach in establishing production costs. However, a typical example should serve as a guide for individual investigations. The advisability of making comparisons is borne out by the vast differences in production. Many shops fail to organize their tool planning and engineering with sufficient detail to allow these savings to be made.

Both process and tool engineer must continually determine whether special tooling will pay for itself within the job limitations. Some jobs cannot be machined successfully without a few special tools, but average jobs offer a range in choice of setups comprising all combinations of standard and special tools.

STANDARD TOOLS and the PERMANENT SETUP

Explanation with typical job applications of how standard tools can be arranged in permanent setups to reduce setup time

AN IMPRESSIVE characteristic of the modern turret lathe is its ability to produce efficiently an extremely wide range of work shapes and job lots to requirements of size and finish which border on the field of specialized equipment. To accomplish this, the machine itself is supplemented by a complete array of standard tooling and attachments, the effective use of which depends upon an understanding of their relation to the principles of turret lathe practice. For example, consider the subject of tooling for producing small to medium size job lots.

Figure 1 illustrates how the hexagon turret of a bar machine may be arranged in skeleton fashion so that setup time can be held to a minimum in changing from one job to another. Station A, an almost universal station in bar tooling, consists of a flanged tool holder with a combination stock stop and center drill. Station C houses an easily set roller turning tool for reducing bar diameters to close limits of size and finish. Station B holds a short flanged tool holder in which a self-opening die head is mounted for use over a range of thread sizes.

These three stations contain tools which are commonly encountered in general bar work and may, therefore, be left in place on the turret to good advantage. Stations D, E and F are equipped with any of the twelve standard tools listed in Figure 1 which fill out the requirements for any particular setup. Centering, drilling, reaming, tapping, supplementary turning, knurling, recessing, etc., may be performed in these stations.

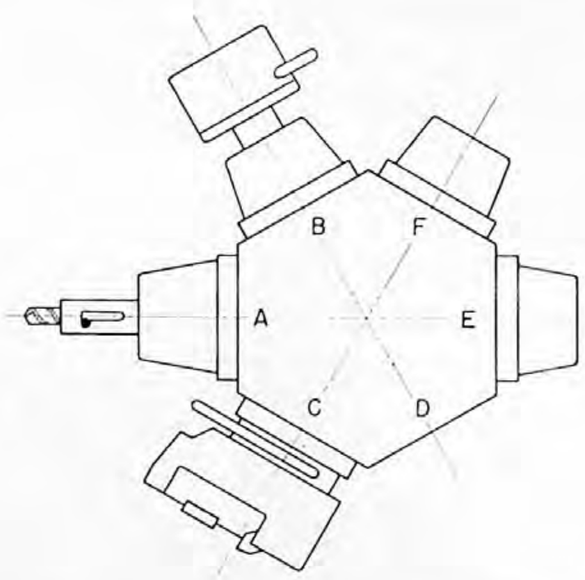
A comparable arrangement of tools may be established for chucking work. Figure 2 illustrates a hexagon turret with basic tools in

A SHORT FLANGED TOOL HOLDER & COMB. STOCK STOP & START DRILL

B SHORT FLANGED TOOL HOLDER & DIE HEAD

C SINGLE CUTTER BAR TURNER

D-E-F 2 SHORT FLANGED TOOL HOLDERS
CLUTCH TAP & DIE HOLDER
DRILL CHUCK OR SOCKETS
FLOATING REAMER HOLDER
SHANK TYPE SLIDE TOOL FOR BORING
COMBINATION TURNING OR END FACING TOOL
REVOLVING CENTER SUPPORT
ADJUSTABLE CENTER SUPPORT
ADJUSTABLE KNEE TURNER
KNURLING TOOL
QUICK ACTING SLIDE TOOL
PLAIN TOOL HOLDER
ADJUSTABLE TOOL HOLDER



RECOMMENDED UNIVERSAL TOOLING ARRANGEMENT FOR GENERAL SMALL TO MEDIUM SIZE LOTS OF BAR WORK.
TOOLS LISTED FOR STATIONS D-E-F ARE OPTIONAL AND DEPENDING ON THE JOB, MAY BE INTERCHANGED IN STATION D-E-F.

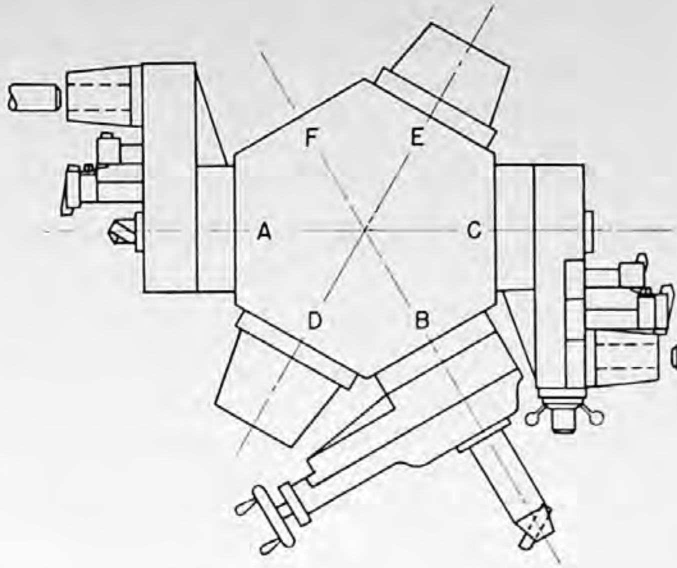
FIGURE 1

A MULTIPLE TURNING HEAD WITH OVERHEAD PILOT BAR AND ONE PLAIN & ONE ADJUSTABLE ANGLE CUTTER HOLDERS.
NOTE - START DRILL, DRILL, OR BORING BAR ETC. MAY BE USED IN CENTERLINE HOLE AS REQUIRED.

B VERTICAL SLIDE TOOL WITH VARIETY OF STUB BORING BARS

C SINGLE ADJUSTABLE TURNING HEAD WITH OVERHEAD PILOT AND ONE ADJUSTABLE AND ONE PLAIN ANGLE CUTTER HOLDERS.
NOTE - SAME CENTERLINE TOOLS AS WITH STATION A MAY BE USED

D-E-F I LONG &
I SHORT FLANGED TOOL HOLDER
QUICK ACTING SLIDE TOOL
MISC. SIZES & TYPES OF BORING BARS
PLAIN TOOL HOLDER
ADJUSTABLE TOOL HOLDER
DRILL SOCKETS OR CHUCK
FLOATING REAMER HOLDER
CLUTCH TAP AND DIE HOLDER
ADJUSTABLE KNEE TURNER



RECOMMENDED UNIVERSAL TOOLING ARRANGEMENT FOR GENERAL SMALL TO MEDIUM SIZE LOTS OF CHUCKING WORK.
TOOLS LISTED FOR STATIONS D-E-F ARE OPTIONAL AND DEPENDING ON THE JOB, MAY BE INTERCHANGED IN STATION D-E-F

FIGURE 2

place in stations A, B and C. Station A contains a heavy duty multiple turning head with overhead piloting for rapid metal removal. The turning head is designed with holes spaced so that shank-type tool holders can be set to cut diameters up to the capacity of the machine. The multiple turning head is equipped with a center hole so that centering, drilling, boring, counterboring, and like operations can be accomplished in combination with overhead tooling.

Station B is reserved for an adjustable slide boring tool in which various size stub boring bars are mounted. By virtue of the easy adjustment, this tool may be used for single point roughing or finishing operations where surface generation is desirable. Ordinarily, a tool of this type is fitted with positive adjustable stops so that the boring tool may be used in two positions during any one setup.

Station C houses an adjustable single turning head with overhead pilot in which tool holders are mounted in a manner similar to the plain turning head in Station A. One of the tool holders in the single turning head is mounted in a rugged slide which is adjusted for range and size control.

In effect, the adjustable slide provides a second cross slide in that the tool and its holder may be left in place in the turning head from job-to-job. A turning cut from the hexagon turret may, therefore, be set up in combination with a cut from the standard cross slide carriage with no appreciable increase in setup time.

This principle of combining cuts between the hexagon turret and cross slides on a turret lathe has often been repeated in this series of articles because it is probably the one basic principle of turret lathe practice—resulting in low cost production—which is most often overlooked.

As with the turret arranged for bar tools, the turret used for chucking work also has three blank stations, D, E and F, in which the miscellaneous standard tools listed in Figure 2 can be mounted. Tools in these stations may be used for additional turning cuts, drilling, reaming, tapping or threading, recessing, etc.

Figure 3 illustrates a typical bar or shaft job which can be tooled efficiently in accordance with the discussion on basic turret arrangement for bar tools. No part sketch is furnished for this bar job since it is intended only to illustrate the method and application of a basic tooling arrangement to a general class of work.

This particular type of bar job is one where the length of the finished part is many times the diameter of the bar. Note that all machining cuts are taken on the bar in Position 1. The part is extended to Position 2 for cutting off.

Stations 2, 18, 3 and 17 are identical with the skeleton tooling arrangement in Figure 1. The tools in Stations 4, 5, 14, 15 and 16 are set up from the list of tools in Figure 1 for use in stations D, E and F.

The sequence of cuts on this bar job follows the numerical listing of the stations on both the cross slide and hexagon turret. For example, Position 1 is a start turning operation with a tool held in the square turret on the cross slide. This start turned diameter is equal in size to surface "C," and the starting cut is taken while the stub end of the bar is projecting from the collet. A true turned diameter can, in this manner, be quickly obtained with a small projection of bar stock. Deflection would occur if the stock were extended to full length prior to this starting operation.

Following the start turning operation, the stock is extended to stock stop Position 2 on the hexagon turret. This determines overhang of the bar from the collet while the remaining cutting operations are performed. Next, the roller turner in Station 3 of the hexagon turret is advanced to the work and the rolls of this tool pick up and guide on the previously start turned diameter so that the tool may receive an adequate start to complete turning diameter "C." Note that some loss in concentricity will result on the work after the preturned diameter is machined, due to opening and closing the collet to feed out this part. Thus the roller turner may not secure a concentric start after the stock is extended.

However, the preturned diameter extends only a short distance along the end of the bar and since diameter "C" is larger than diameters "D" and "E," any irregularity in finish, obtained in the initial stages of the turning cut taken from Station 3, will disappear when the tool cuts into full bar diameter in the area of diameter "C." Ordinarily, a bar pointed on the end, rather than having a start turned diameter, will not provide a good start for the turning cut in Station 3, especially when bar overhang is many times greater than its diameter.

The next cut is a center drilling operation in Station 4, after which the end of the part is supported by the revolving center in Station 5. With the bar supported at the front end by the revolving center, cuts six through 13, inclusive, are performed from the square turret on the cross slide. The center support is then removed from the end of the bar.

In Station 15 of the hexagon turret, the end of the bar is formed and, after this forming operation, the part is recentered from Station 16 so that any burr thrown into the center by means of the end forming operation can be removed. Threading the $\frac{7}{8}$-inch 14-pitch thread is accomplished with the

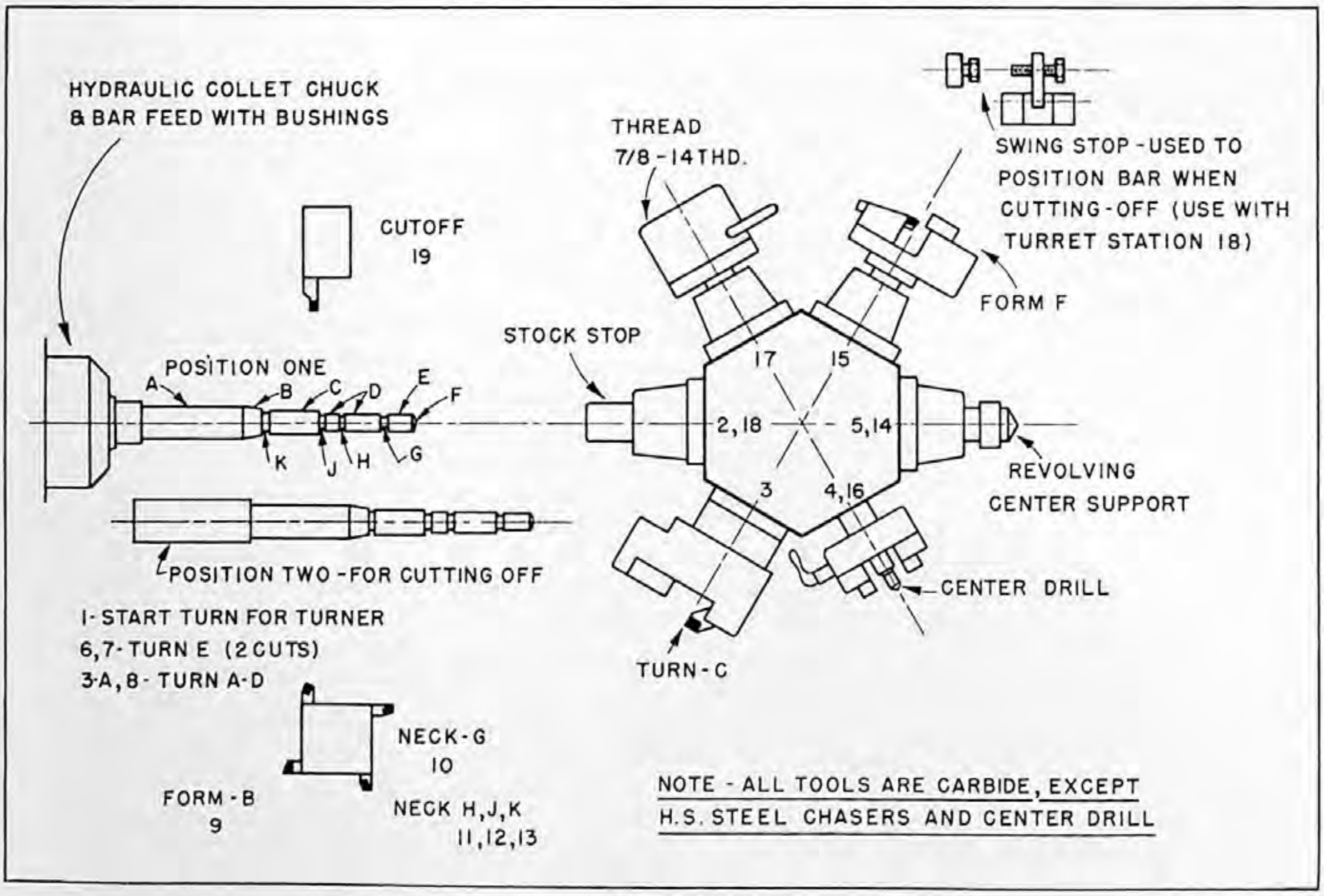


FIGURE 3

die head in Station 17.

After the thread is cut, the part is ready to be cut off and, in order to reposition the bar stock for the cutting off operation, the stock stop in Station 18 is again indexed to position and used in conjunction with a swing stop mounted on the turret ram.

Because the positive ram stop is adjusted to suit the forward position of the ram when stock stop Station 2 is used, an auxiliary stop is necessary for stock stop Position 18. This requirement is met by the semi-standard swing stop mounted between the turret ram and saddle of the machine. This stop is simply swung into position for stock stop Operation 18, and raised out of place to allow further forward motion of the ram when Station 2 is required.

Note that the turning cut in Station 3 of the hexagon turret is accomplished in combination with the tool in Position 3-A on the square turret used for turning surface "A."

The shaft in Figure 3 can be tooled completely with carbide, and with the tool holders illustrated, may be produced efficiently in lots as low as five to 10 pieces.

Depending upon the material specification, it would be possible to hold surface "C" to a tolerance of at least .0005-inch with a microinch finish as low as 15.

A job of this nature is ideal for a hydraulically operated collet chuck and bar feed mechanism because the ratio of stock extension to the mill length of the rough bar is unfavorable to hand-operated bar feed units. These units must be frequently adjusted during the course of cutting up the bar, due to stroke limitations of the bar feed head. The hydraulic mechanism feeds the bar continuously for its full length, without adjustment of the bar feed head.

Figure 4 is a photograph of the tooling used to machine a cast steel axle housing 34 inches in length and 12⅝ inches in diameter. Because of the deep internal and long external cuts, this job presents great opportunity for combining inside boring operations with turning cuts on the outside of the work. This reduces machining time.

It is also apparent that this is an ideal job for a cross sliding turret machine, which simplifies the turret tooling design by permitting numerous surfaces to be machined with each tool.

The cross sliding turret also permits the use of a very heavy duty double-end boring bar to be mounted rigidly in the turret for deep hole boring. The presence of internal facing cuts, as well as the lengthy undercut in the midsection of the bore, are also well adapted to the characteristics of the cross sliding machine.

The first problem involved in machining the axle housing is that of gripping. The axis of the internal surfaces of the part must be aligned with the axis of the machine spindle so that these surfaces will run as true as possible in order to reduce the stock eccentricity for boring. It is self-evident that, on any heavy duty metal removing job, it is preferable to split stock allowances in favor of boring cuts so the amount of stock removed by a boring tool is as even as possible to produce a constant deflection on the boring apparatus.

For cast or forged parts, this throws maximum eccentricity of stock allowance to the outside surfaces. This has less effect on turning tools held in cross slide carriages, due to their increased rigidity.

Therefore, on the job illustrated, special chuck jaws mounted in the scroll chuck on the spindle of the machine are used to locate inside the counterbore. The outer end of the part is supported by an auxiliary rotating chuck mounted on one face of the hexagon turret, again locating in the counterbore of the part.

With the part suspended between these two holding devices, a rough turning cut is taken across the work diameter on which the steady rest rolls are to bear. Upon completion of this cut, the rolls of the steady rest are adjusted around the turned diameter, the jaws on the revolving chuck mounted in the turret are relieved, and the turret indexed for machining the subsequent cuts.

Design of the open-type roller steady rest is unique in that, being open on the front, the cross slide carriage may pass freely from the turret end of the part to the spindle end of the part without interference. This means that turning outside surfaces need not be broken down into individual chuckings, but may be combined in one chucking with the various boring

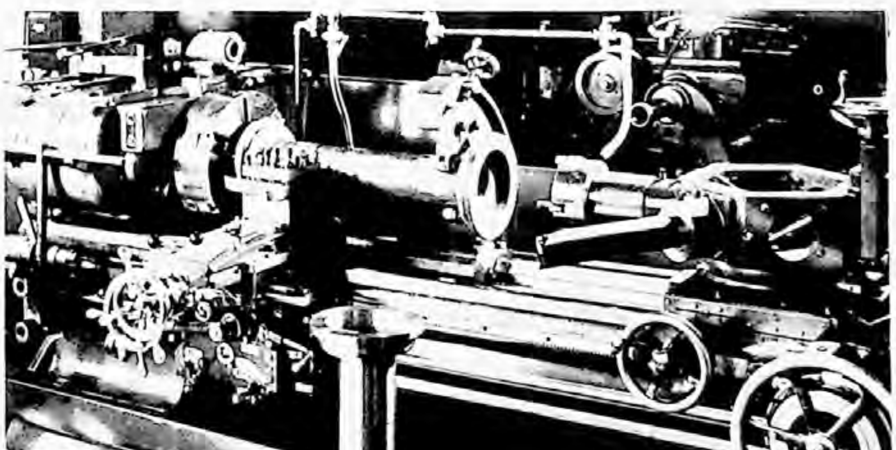
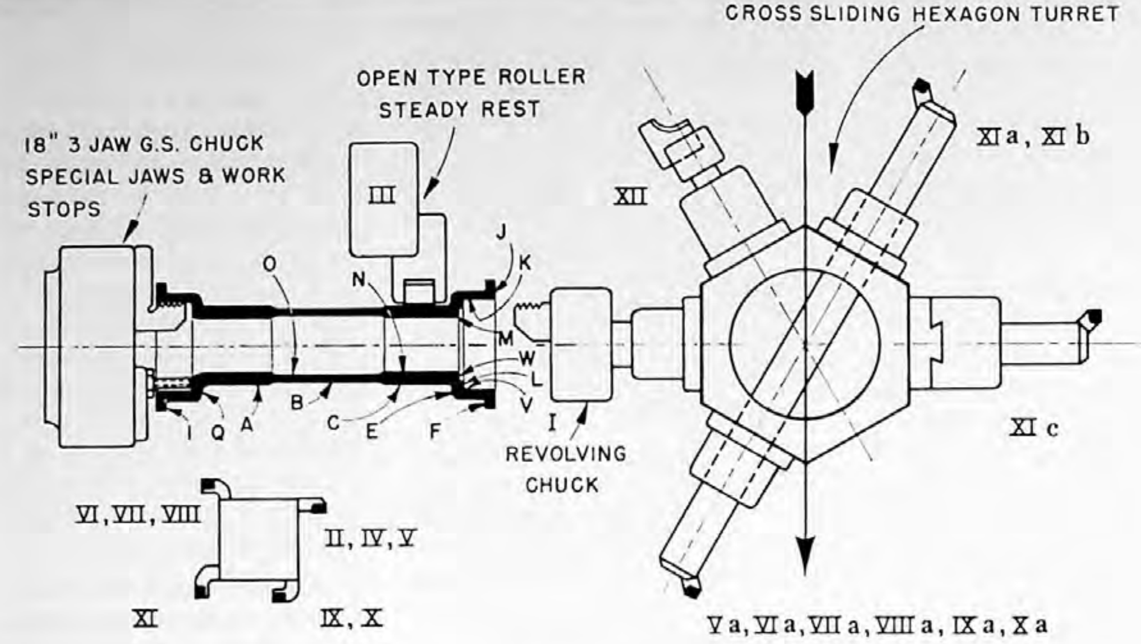


FIGURE 4



OPERATION ONE
ALL CARBIDE TIPPED CUTTERS EXCEPT STATION XII

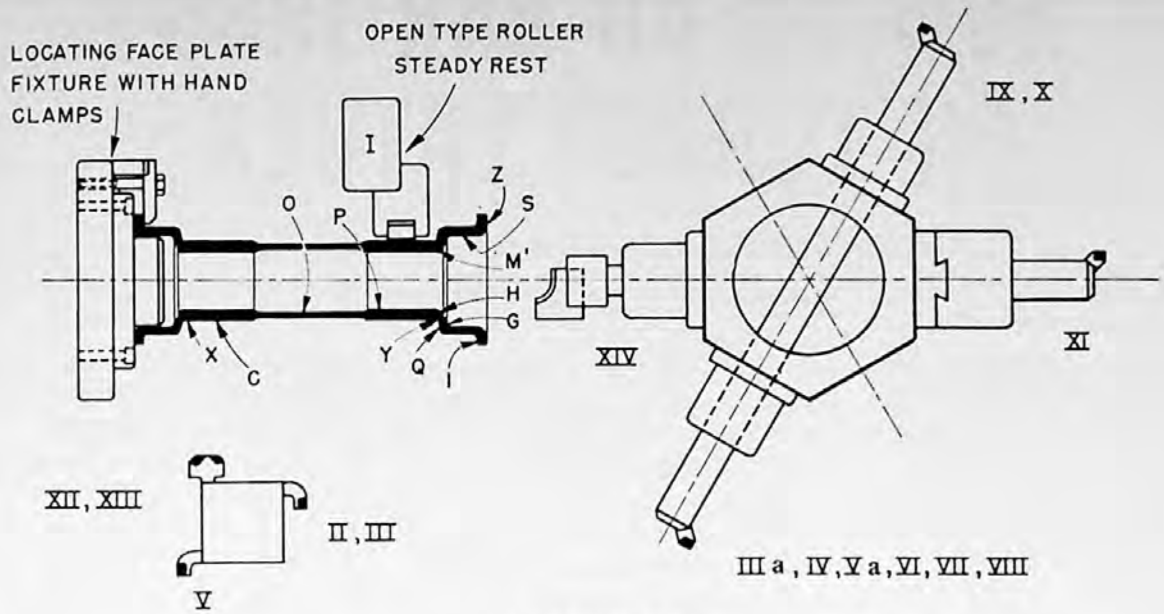
CROSS SLIDE		HEXAGON TURRET	
OPERATION	STATION	STATION	OPERATION
		I	SUPPORT PIECE IN CHUCK
ROUGH TURN C	II		
III APPLY STEADY REST ROLLS AND REMOVE CHUCK IN STATION I			
ROUGH FACE E	IV		
ROUGH FACE F	V	V a	ROUGH FACE J
ROUGH FACE I, Q	VI	VI a	ROUGH BORE K
ROUGH TURN A	VII	VII a	ROUGH BORE N
ROUGH TURN B	VIII	VIII a	ROUGH BORE 1/2 OF O
FINISH FACE E	IX	IX a	ROUGH FACE W
FINISH FACE F	X	X a	ROUGH FACE L
FINISH TURN A	XI	XI a	SEMI-FINISH BORE K
		XI b	FINISH FACE L (FORM V)
		XI c	SIZE BORE K
		XII	FORM M

FIGURE 5

and inside facing cuts so that overall machining time is held to a minimum.

The table of operations in Figure 5 indicates the various operations which are performed on the axle housing. The cuts are taken in accordance with numerical sequence, and whenever a cut is combined with another cut, it is designated by a letter. That is, Rough Facing Cut F, No. 5, is combined with Rough Facing Cut J, No. 5-A. Note that the amount of cutting time, which is obtained as combined or free time, almost balances that which is chargeable directly to production.

Figure 6 illustrates tooling for the second operation on the axle housing. In this operation, the work is mounted on the spindle on a locating face plate fixture with hand clamps. This fixture suspends the work in the previously machined counterbore, and the outer end of the work is supported by



OPERATION TWO
ALL CARBIDE TIPPED CUTTERS EXCEPT STATION XIV

CROSS SLIDE		HEXAGON TURRET	
OPERATION	STATION	STATION	OPERATION
I-APPLY STEADY REST ROLLS TO PREVIOUSLY FINISHED DIAMETER			
FINISH FACE I	II		
FINISH FACE Q	III	IIIa	ROUGH FACE Z
		IV	ROUGH BORE S
FINISH TURN C	V	Va	ROUGH BORE P
		VI	ROUGH BORE 1/2 OF O
		VII	ROUGH FACE G
		VIII	ROUGH FACE H
		IX	SEMI-FINISH BORE S
		X	FINISH FACE H
		XI	SIZE BORE S
FORM X	XII		
FORM Y	XIII		
		XIV	FORM M'

FIGURE 6

the steady rest rolls which bear on a diameter which has been machined in the first operation. This means that location in the second operation is taken from two surfaces which, by virtue of being machined together, are completely concentric, thus providing ideal locating conditions for the second operation.

A chart of operations accompanies Figure 6 and indicates the surfaces produced in this chucking. Note again that combining cuts is possible, although to a lesser extent than in the first operation.

Among the many interesting facts brought out in machining this axle housing job is the complete adaptability of the cross sliding turret lathe to work with characteristics as illustrated. There is, perhaps, no better machine for producing a part of this kind, than the horizontal cross sliding turret lathe. Though the type of tooling works with equal facility on lots ranging from five parts on up, it is difficult to conceive of many ways in which greatly increased lot sizes could justify any improvement in the method of tooling over that illustrated.

HOW TO DO BAR JOBS ON TURRET LATHES

Fully illustrated explanation of the special technique needed to set up bar jobs efficiently

PARTS made from bar stock may be produced on turret lathes with less variety in tooling arrangements than is necessary with typical chucking work. Despite this, experience shows that in many shops bar set-ups are very much neglected as far as tooling improvements are concerned. Unless the basic rules of turret lathe operation are kept constantly in mind, the relative simplicity of bar work often engenders a false complacency about tooling setups.

It is well to remember that opportunities for multiple and combined cutting are more difficult to distinguish in the average bar job of medium size than on an equivalent chucking job. However, recognition of these possibilities is one of the first principles of turret lathe practice applying to any kind of work. Furthermore, turret lathe users must recognize that cycle times on bar jobs are frequently the sum of many short cuts involving a large amount of manual handling or "maneuvering" of machine components. Consequently, greater care must be taken that the job will "suit" the size and type of machine and arrangement of tools, so that the important element of handling time will be in proper relation to the basic cutting time.

In general, selecting a turret lathe for bar work involves consideration of these factors:

1. Type and capacity of collet chuck.
2. Working strokes of cutting slides.
3. Power and speed.
4. Maneuverability of machine components.
5. Degree of automaticity.

These factors are not necessarily listed in order of importance but must be considered as a whole when selecting a machine.

Collet Chuck Type, Capacity

In another chapter of this book, a detailed discussion of collet chucks and bar feeds and their application to various types of bar work is presented. While selection of the proper collet chuck is a prerequisite of a successfully tooled bar job, the reader is cautioned against over-dependence upon collet capacity as a means of measuring the proper machine for the job.

Cutting Slide Work Strokes

A ram-type turret lathe is equipped with a relatively light, easily maneuverable, hexagon turret slide which operates in a saddle that is clamped in various positions along the bed, depending upon the length of the job. As the turret tools feed across the work, overhang of the ram slide from its saddle becomes progressively greater, thus limiting, to some extent, the type of cut feasible with the slide at its extreme extension. Turret ram slides are available with feeding strokes from four inches to approximately 20 inches, depending upon machine size.

The ram-type turret lathe is, therefore best applied to relatively short bar work where multiplicity of cuts and demand for rapid handling of tool slides may be best satisfied with this design machine.

Roller supported turret tools have been standardized and are universally accepted by users of ram-type turret lathes for supporting the end of the work and guiding the path of travel of the ram along the axis of the work.

By comparison, the hexagon turret of a saddle-type lathe is mounted on a saddle which slides along the bed of the machine. Tooling overhang in this instance is constant and independent of the length of the work.

By the same token, sliding saddle turret lathes are larger and more heavily constructed than ram-type machines and, therefore, cannot be maneuvered at the same rate.

As a consequence, the saddle-type machine is well suited to bar jobs where the cuts are long, exceptionally heavy, or where the collet chuck requirements for gripping hot rolled bar stock must be satisfied by the parallel closing collet chuck mechanism.

Power and Speeds

Due to the variety of horizontal turret lathes, bar jobs may be classified, then assigned to the size and type machine to which the bar job's over-all characteristics are best suited.

Increasing use of carbide tools on turret lathes has spotlighted the subject of power. In some cases, this has caused certain bar jobs to be shifted to larger size lathes than were formerly considered acceptable. However, power requirements for any bar job must be carefully balanced against the maneuverability of the machine components so that the gains secured from having greater power available on the machine will not be offset by a subtractive rise in machine handling time. Only on very simple jobs may power be considered to the exclusion of other important factors in the total cycle time.

Furthermore, speed and power are inevitably tied in with tool life, whose acceptable value must be determined by the turret lathe user prior to calculating power requirements and, as a consequence, selecting the size machine which meets those power requirements.

Most bar jobs have only one major "peak load" cut, and, if this is determined in advance, the proper machine may be selected with greater care. It is important to use the "mean" diameter of the cut to determine power requirements because most jobs of this nature are relatively small in diameter and the mean diameter of the cut thus assumes a greater significance in determining over-all power requirements than does chucking the work. Errors up to 10 percent may result from using the outside bar diameter when calculating required horsepower for a given cut. In any event, peak loads for the bar job at hand should be calculated since power demands for cuts of this nature are apt to be deceptive. A bar cut running at high speed, heavy feed and relatively light depth of cut cannot be gaged accurately by the eye and some system should be employed to determine the horsepower required.

Because of the variety of ram-type turret lathes available, some consideration must also be given to cutting torque requirements. Previous chapters of this book have reviewed turret lathe headstock constructions, and it is sufficient to emphasize that, in addition to the usual six or 12-speed geared headstock, medium size turret lathes are also available with direct motor drive to the spindle, with the drive motor integral with the spindle, and with a combination of direct drive and back gearing. Each turret head construction is superior for a given class of bar work and must be properly evaluated in selecting the size and type machine for the job at hand.

Machine Component Maneuverability

As a factor in machine selection for bar work, the maneuverability of machine components cannot be ignored.

Experience shows that handling time on the average bar job runs as high as 30 percent of the total cycle time. Thus a machine whose maneuverability is ideally suited to handling requirements of the job may show a greater over-all return than a larger machine with less maneuverability but heavier motor. In other words, the 30 percent handling time segment of the total cycle must not be penalized to obtain a 20 percent increase in power (or decrease' in cutting time) for one or two peak loads which, in themselves, may only comprise a small percentage of the total cutting time.

Depending upon the size of the ram-type machine, cross slides may be either plain or universal. In the smaller size machines, plain cross slides which do not feed under power in any direction, are customarily used. In other words, on a one-inch bar machine, forming or facing cuts are normally taken from the front of the hand-operated cross slide, and cut-off operations from the rear. Most turning and end working cuts are, as a consequence, taken from the hexagon turret under power feed. The plain cross slide for work within this classification is clamped in a given position on the bedways of the machine and simply operated either by lever or screw feed with respect to the work.

Universal cross slides are obtainable on 1½-inch capacity or larger ram-type turret lathes. The universal cross slide may be positioned at various points along the bedways of the machine for cutting at different areas of the part. Power feed in all directions is available with this type cross slide. Therefore, in spite of the slightly longer maneuverability factor of the heavier cross slides, this type machine may be selected for a one-inch job, even though a smaller non-universal machine of adequate collet capacity may be available to grip the stock.

Another factor affecting the choice of turret lathe from the standpoint of maneuverability of machine components, is "degree of automaticity." For example, power-operated collet chucks and bar feeds of various types are available, depending upon the size machine. In addition, headstock control may be obtained by preset automatic cycling, high-low headstock clutches, two-speed motors with three-station pushbutton, or by rheostat control.

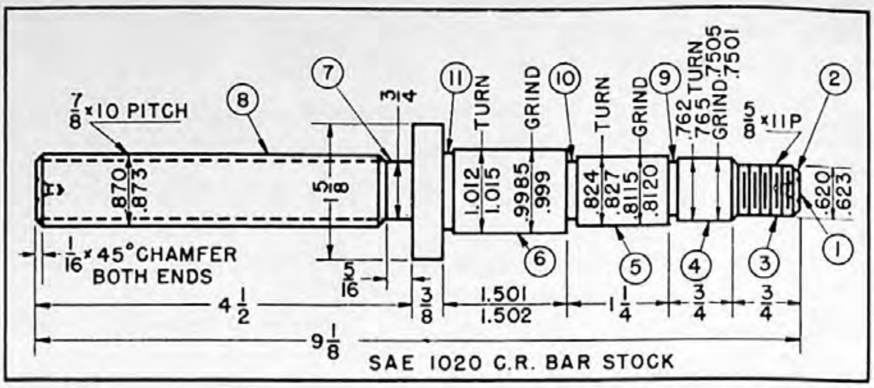
The variety of cutting operations and the corresponding number of headstock speed changes and changes in direction of the spindle for threading, etc., must be properly evaluated for the class of bar work planned for a machine so that its effect on the choice of a headstock can be determined.

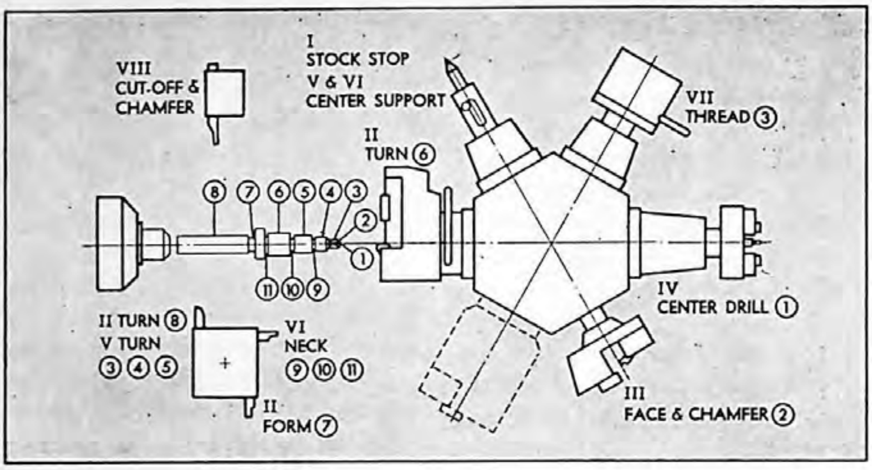
Tool Arrangement Economics

Easily amortized, standard bar tools exact a powerful influence on cutting costs of bar jobs in all ranges of lot sizes. With the exception of tools, special holders are rarely substituted for standard equipment; hence, the over-all investment in bar tooling is almost insensitive to variations in production quantities. However, the tooling arrangement and total set-up time are dependent upon lot sizes. The point is, standard bar tooling allows quick attainment of maximum production with minimum increase in set-up time and tooling investment.

For example, Figure 1 illustrates an adjusting screw which may be produced on a two-inch ram-type bar turret lathe. Figures 2, 3 and 4 illustrate proper tooling arrangements for small lot, quantity, and high production lots. Except for tools, standard holders are used throughout.

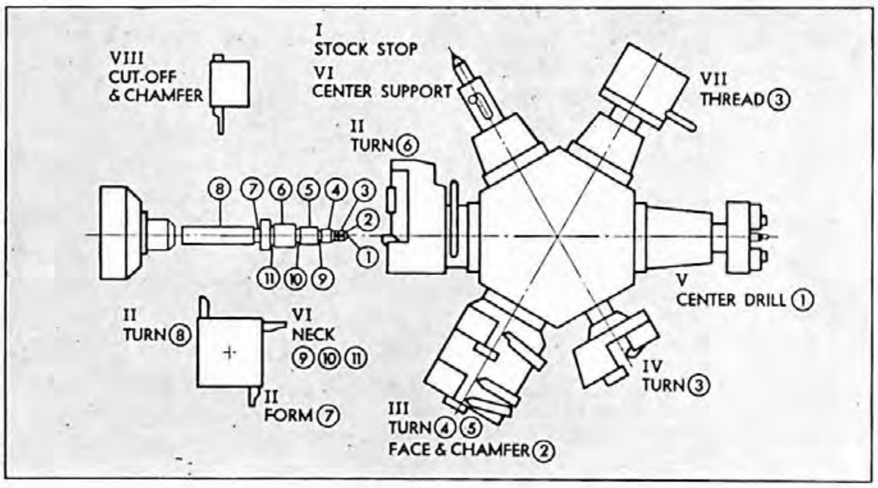
FIGURE 1 →

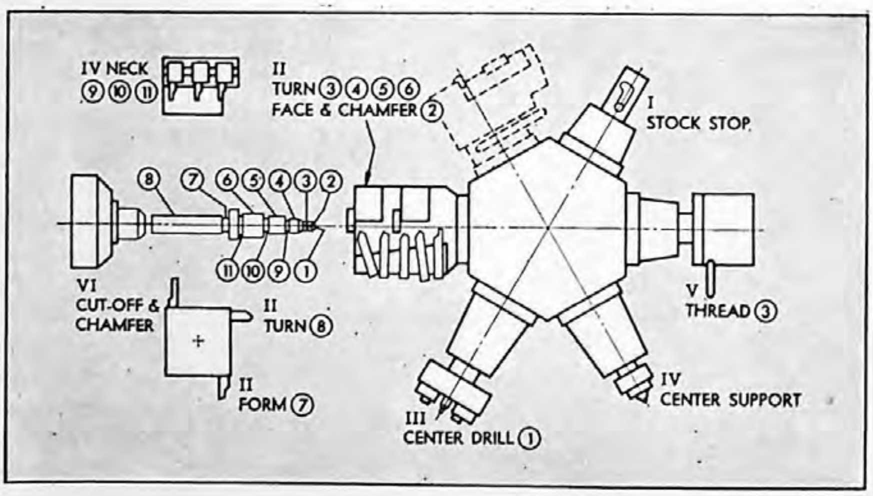




← FIGURE 2

FIGURE 3 →





← FIGURE 4

Table I illustrates how the number of tool slide settings and floor-to-floor time is reduced by only a slight increase in setup time and virtually no increase in tooling investment.

PRODUCTION	SETTINGS		SETUP TIME (HOURS)	PRODUCTION TIME (MINUTES)
	CROSS SLIDE	HEXAGON TURRET		
Figure 1 Small Lot	9	7	1.75	5.3
Figure 2 Quantity	6	7	2.30	5.0
Figure 3 High Production	4	5	2.60	3.8

TABLE 1

Basic Cutting Operations

Certain basic cutting operations are common to almost all bar stock jobs. This justifies a short review of some of the more important of these operations. See Figure 5 for a detailed layout of a typical bar tooling setup which illustrates several basic operations.

Starting Roller Turning Tool

Three basic methods of starting the box tool or roller turning tool are in common use. All of these methods involve preparing the end of the bar so that the edge of the turning tool engages the work slightly in advance of the rolls of the holder. If cold rolled bar stock is being machined and the job is relatively short, a chamfering edge may be ground on the cut-off tool so that the tool feeds into the stock end to form the lead chamfer on the end of the bar for the next part, after the previous piece has been parted off. When the bar stock is extended for the succeeding part, this chamfer serves as a relief on the end of the bar, thus permitting the cutting edge of the roller turning tool to engage the bar progressively in advance of the rolls.

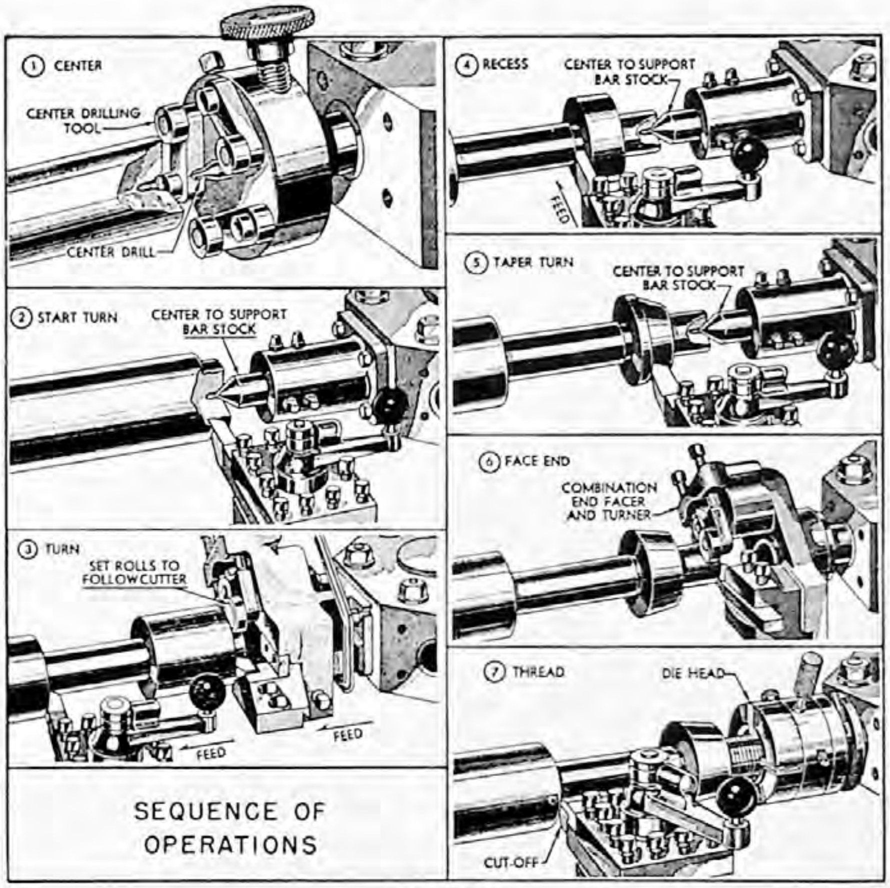


FIGURE 5

Pointing tools, which ordinarily consist of a hardened steel cone and a chamfering tool, are sometimes mounted in the hexagon turret. As the bar stock is advanced and set to length, the pointing tool is brought against the end of the bar and the end of the part is chamfered.

Where the stock extends from the collet many times its diameter, it is frequently desirable to center drill the end of the bar first. Then a center support is positioned so that a turning cut can be taken from the cross slide for a short length along the bar. The diameter so turned should be the same size as the diameter which the roller turner is to cut. This preturned diameter facilitates engaging the box tool with the work without producing chatter or deformity in the bar. The risk of tool breakage is also minimized.

Diameter Concentricity

Most bar jobs require some degree of concentricity between various diameters. If diameters on both ends must be concentric, the problem is further aggravated.

There is no better way of establishing concentricity between diameters on one or both ends of any part than to machine them in the same operation. This eliminates the eccentricity introduced by regripping in a subsequent operation. For example, see Figures 6, 7 and 8.

To produce Diameter 9 concentric with Diameters 6 and 7, it should be finish turned in the same chucking and part of this operation can be done while Diameters 6 and 7 are being produced. In any event Diameter 9 should be turned while the bar is supported against the rolls of one of the bar turners. The same tool used to form the short length of Diameter 7 is used to form a short portion of Diameter 9, which is then turned with a turning tool held in the square turret.

In the second chucking (*Figure 8*) Diameter 10 is produced concentric with Diameters 6, 7 and 9 by turning it with the rolls of the single turning tool set ahead of the cutting tool and bearing on Diameter 9, which was produced concentric with Diameters 6 and 7 in the first chucking.

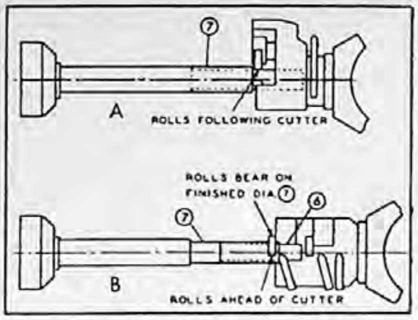


FIGURE 6

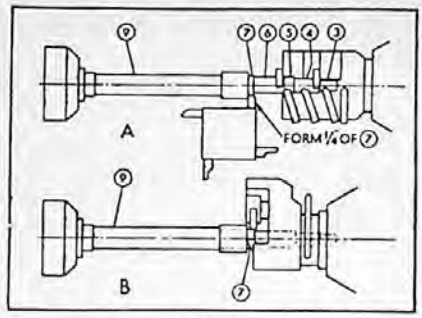


FIGURE 7

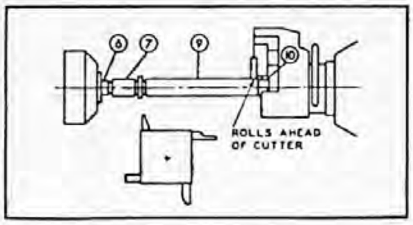


FIGURE 8

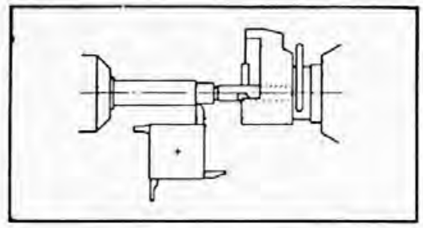


FIGURE 9

Cutting-Off

Many shops are using carbide-tipped cut-off tools successfully on both tubing and solid bar stock. It is not the purpose of this article to list the arguments for and against the use of carbide cut-off tools, but rather to encourage experimentation with them on solid bars of all specifications, particularly in the smaller diameters.

When long cut-off strokes are required, the thickness of the carbide tip and the steel shank supporting it may become so wide that excess stock waste in the cut-off area may become objectionable. If so, the extra heavy carbide cut-off tool may be discarded in favor of high speed steel. For cutting off bars up to and including two inches in diameter, a carbide-tipped tool measuring ¼ or 5/16-inch in width should be satisfactory if run at high speed and medium feed.

Combined Cuts on Bar Work

Combined cuts are desirable on bar work because they help support the work against the tools, thus avoiding spring and chatter. Such cutting operations on bar work consist mainly of turning, grooving and chamfering from the square turret, while a roller turner is turning a diameter from the hexagon turret. The roller turning tool acts as a steady rest to support the bar stock against tools mounted in the square turret.

Another means of combining cuts on bar work is to perform square turret turning, facing and grooving operations while drilling from the hexagon turret. In this case, the drill helps support the work against the square turret tools, avoiding spring and chatter.

On long bar work, combined turning from both hexagon and square turrets is often desirable for an additional reason. Long shafts having a single turned diameter allow the turning cut to be split up by simultaneously taking duplicate cuts from both square and hexagon turrets. The square turret turning tool starts near the middle of the bar and machines the diameter at the same feed selected for the hexagon turret roller turner. Figure 9 illustrates a method of setting a turning tool in a square turret to allow combining with a roller turner cut from the hexagon turret.

THE IMPORTANCE OF CONTROLLING MACHINE HANDLING TIME

Discussion of the relation of cutting time vs machine handling time ratios to production efficiency and how certain turret lathe designs effect the solution

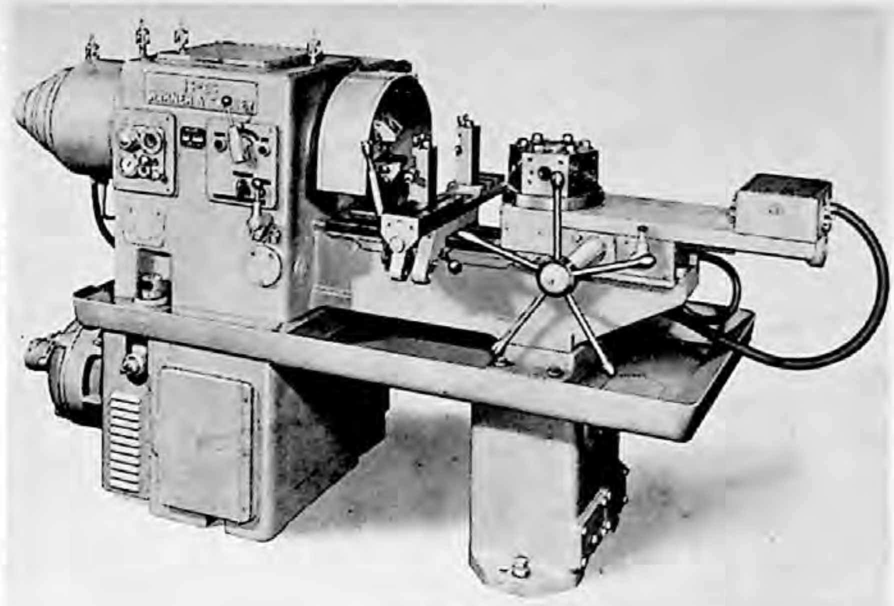


FIGURE 1

EQUALLY as important as reducing the cutting cycle of a given job or jobs, is the necessity of effecting reductions in handling time. This factor is often overlooked as a means of reducing cost.

A survey of work produced in machine shops on geared head turret lathes indicates that, on smaller size lathes, machine handling time may average 80 percent of the total cycle time for brass goods, and about 30 percent of the total cycle for cast iron and steel parts.

It is evident that such non-productive time, in relation to the total job cycle, is expensive, and therefore, of particular concern to producers of brass goods. Within this industry, competitive factors have already led to advanced conceptions of cutting practice and tool design, and further economies of manufacture appear possible only through increased cutting speed and reduced handling time.

If handling time is to be reduced, it is necessary to minimize operator fatigue and increase the maneuverability of hand-controlled machine components.

One way of reducing the fatigue element in short cycle work is offered by a new, fast-handling turret lathe which also transfers many of the operator's functions to automatic control. These lathes are known as Electro-Cycle Machines, and can accommodate both bar and chucking work.

Figure 1 illustrates the new 16-inch Electro-Cycle Turret Lathe used for machining non-ferrous work materials. It is a high speed, gearless head machine, with the spindle driven by "V" belts from a specially designed two-speed motor mounted in the base. The drive motor is built for a rated reversing cycle and changes speed and direction automatically. Torque characteristics of the motor enable it to reverse quickly so that maxi-

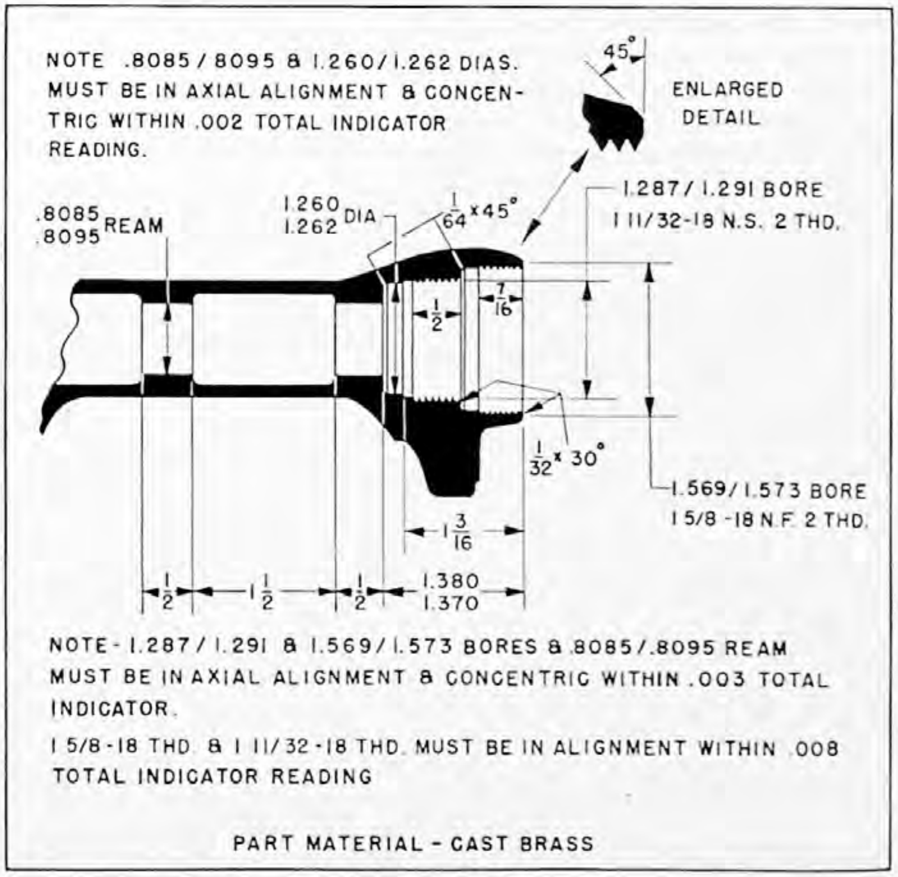


FIGURE 2

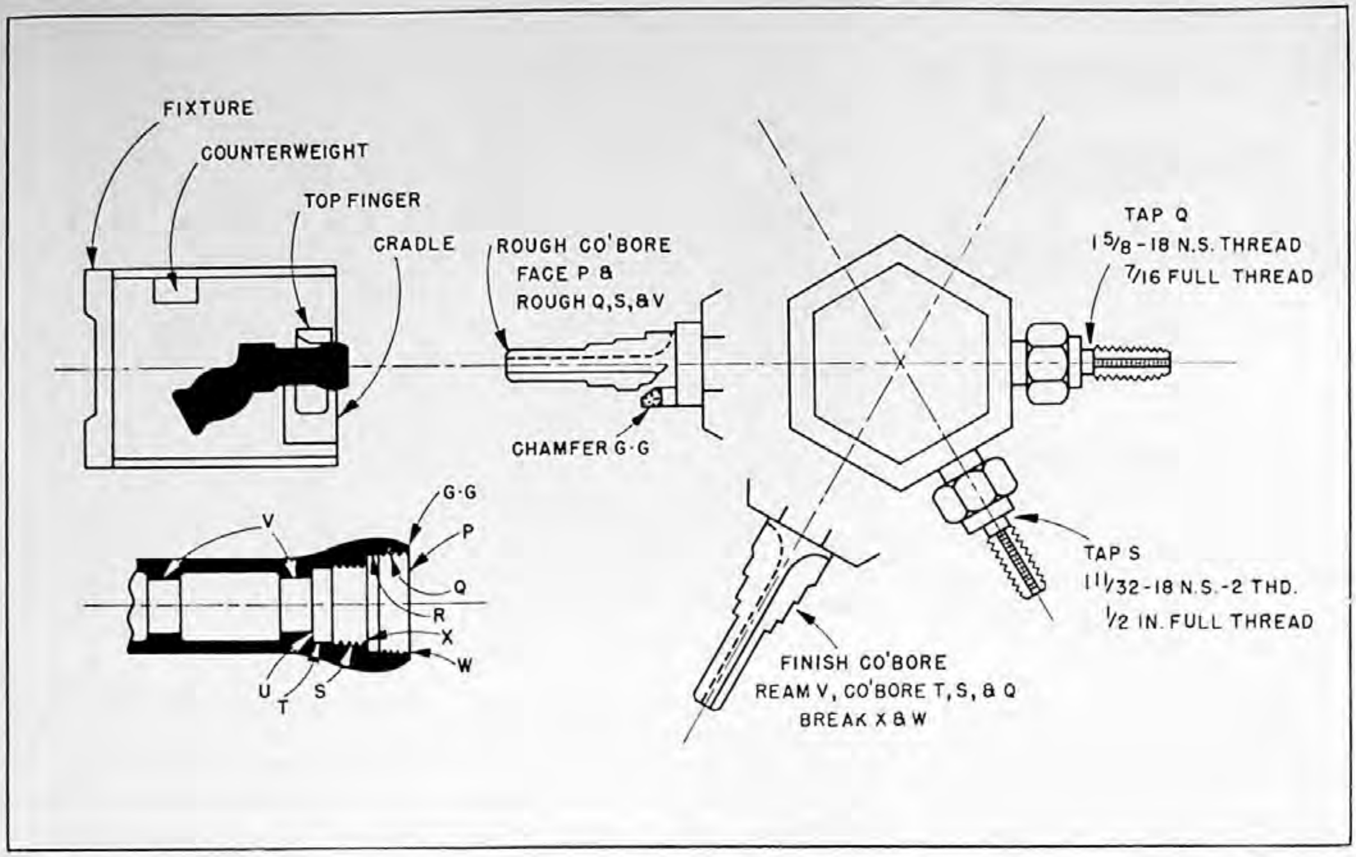


FIGURE 3

mum benefits of motor ventilation may be obtained.

Spindle speed control is obtained by setting buttons in one to four drums mounted to the rear end of the turret ram slide. These buttons actuate electric limit switches which bear a timed relation to specific faces of the hexagon turret. When the switches are tripped by turret indexing, circuits are set up to govern the spindle action desired for any given turret face.

An electric plugging switch on the motor and an automatic brake on the drive pulley shaft stop the spindle after the cutting operation. Arranged in combination with these devices is a spindle positioning unit, which is useful for side-opening and indexing fixtures and with two-jaw chucks having form jaws. By stopping the spindle with the holding device in a repetitive position, it is possible to establish a rhythm in loading and unloading successive work parts.

Through this system of automatic control, the spindle starts, stops, reverses, and changes speed automatically, thus relieving the machine operator of the control of these phases of machine operation.

Additional design characteristics of this machine permit it to operate continuously at 1500 r.p.m. on chucking work without sacrificing the sensitivity of depth control for automatic tap reversing and vibrationless operation which is essential for the production of smooth finish and size control on the work.

This machine thus answers many requirements fundamental to cutting non-ferrous work materials.

Figure 2 is an example of a brass casting which must be machined quickly to close limits of tolerance, finish, and concentricity. The part drawing shows that this is a precise machining job and a true test of any lathe's ability to combine high production with accuracy.

Figure 3 is a diagram showing the tooling arrangement used on the 16-inch Electro-Cycle for producing this part. Due to the unusual shape of the casting, a special holding fixture is required. The spindle positioner of the Electro-Cycle machine therefore permits loading successive castings into the fixture in the manner most conducive to speedy handling.

Multi-step carbide-tipped counterbores are used in Stations 1 and 2 of the hexagon turret for cutting the indicated surfaces. This type counterbore is accepted by the brass industry as best for machineing short chip materials. Note that only one roughing and one finishing cut are required to meet the unusual finish requirements and dimensional tolerances.

Stations 3 and 4 of the hexagon turret are occupied by solid taps for producing the threaded surfaces. These tapping operations are expedited by the ability of the machine to drop automatically from a fast counterboring speed to a low speed for tapping, then back to a high speed in reverse for backing out the taps.

The sum effect of reduced machine and work handling time and faster cutting due to higher spindle speeds, makes it possible to produce this part in 28 seconds.

FIGURE 4

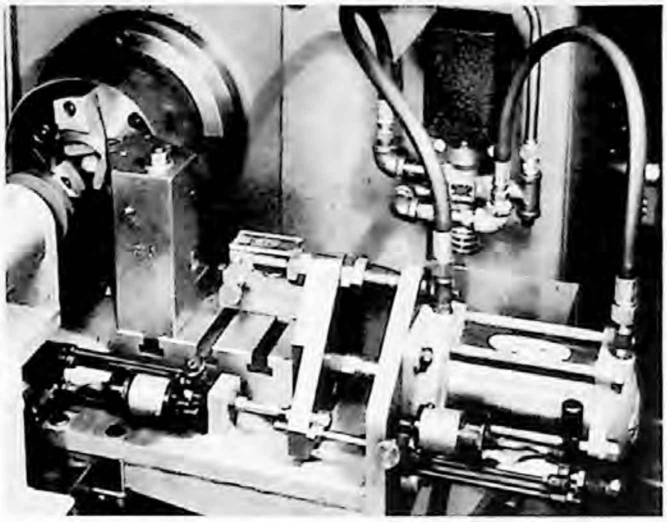


FIGURE 5

Not all jobs made from brass must be produced to the tolerances and limits of concentricity indicated on the part in Figure 2. In the fittings and plumbers goods industries there is a large variety of work which requires medium close tolerances and finish, with speed of production paramount.

A group of typical jobs of this nature is illustrated in Figure 4. Note the common appearance of internal and external threads on this type work. Changing spindle speeds and direction of rotation due to threading requirements is not as easily handled on conventional turning equipment as on the 16-inch Electro-Cycle. In consequence, this type work may be machined at faster rates with the new design lathe. Production for this group of parts, depending upon the part, ranges from 38 to 109 percent greater on the 16-inch Electro-Cycle than on other types of turret lathe.

Still another example of how machine handling time may be further reduced with the 16-inch Electro-Cycle is illustrated in Figure 5. In this case, the cross slide of the machine is fitted with an air cylinder and a system of limit switches and hydro-checks, all tied in with the spindle start and stop control, so that once the cycle on the work is initiated, machine operation can be combined with others in a group.

The first operation on the nut (*shown in the chuck in Figure 5*) is done on a multi-spindle chucking automatic. One side of the steel casting is faced and chamfered, the hole bored, chamfered, and threaded. The same operator who handles the chucking automatic also loads the 16-inch Electro-Cycle on which the opposite face of this nut is faced and chamfered from the cross slide. The cycle time of the two machines are such that they can be handled by one operator.

Shown in place of the usual hexagon turret on the Electro-Cycle is an air-operated ram. This is used to hammer the finished side of the work against the stop faces of the chuck jaws. In other words, close limits of parallelism between first and second operation faces must be held, although the same rough surfaces are used for gripping in both operations. With the work seated properly against the jaws, the second operation face can be cut parallel to the first operation face, even though the nut itself is running eccentric to the machine spindle center line as a result of holding on the rough perimeter of the part.

The advantages of Electro-Cycle control for reducing handling time in the cycle of parts produced from non-ferrous materials also has worth-while advantages for machining other work materials. Accordingly, a similar machine (*see*

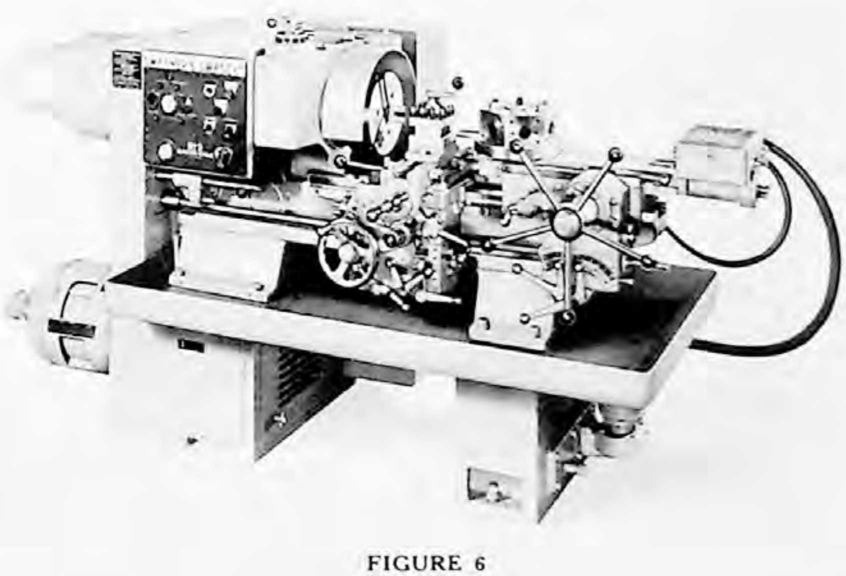


FIGURE 6

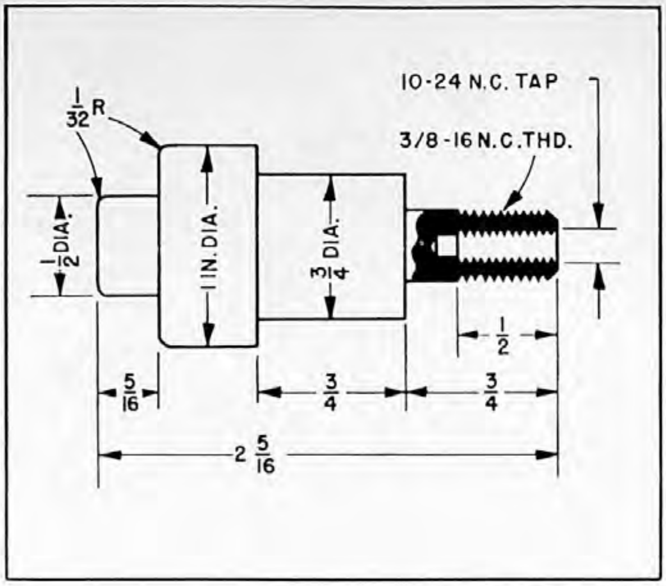


FIGURE 8 (ABOVE)

FIGURE 7 (LEFT)

Figure 6) was designed to cut iron and steel which incorporates all of the automatic controls present in the 16-inch Electro-Cycle. Due to greater torque requirements for cutting ferrous materials, the headstock of this machine is equipped with hydraulically controlled clutches which engage back gearing on either side of the motor for cutting at slow speeds. The machine is also equipped with a universal cross slide with power feed in all directions to accomplish a greater variety of work. The lathe also may be used for bar or chucking work.

Shop men are familiar with the wide variety of miscellaneous studs, shafts, bushings, etc., manufactured in most shops which, by vir-

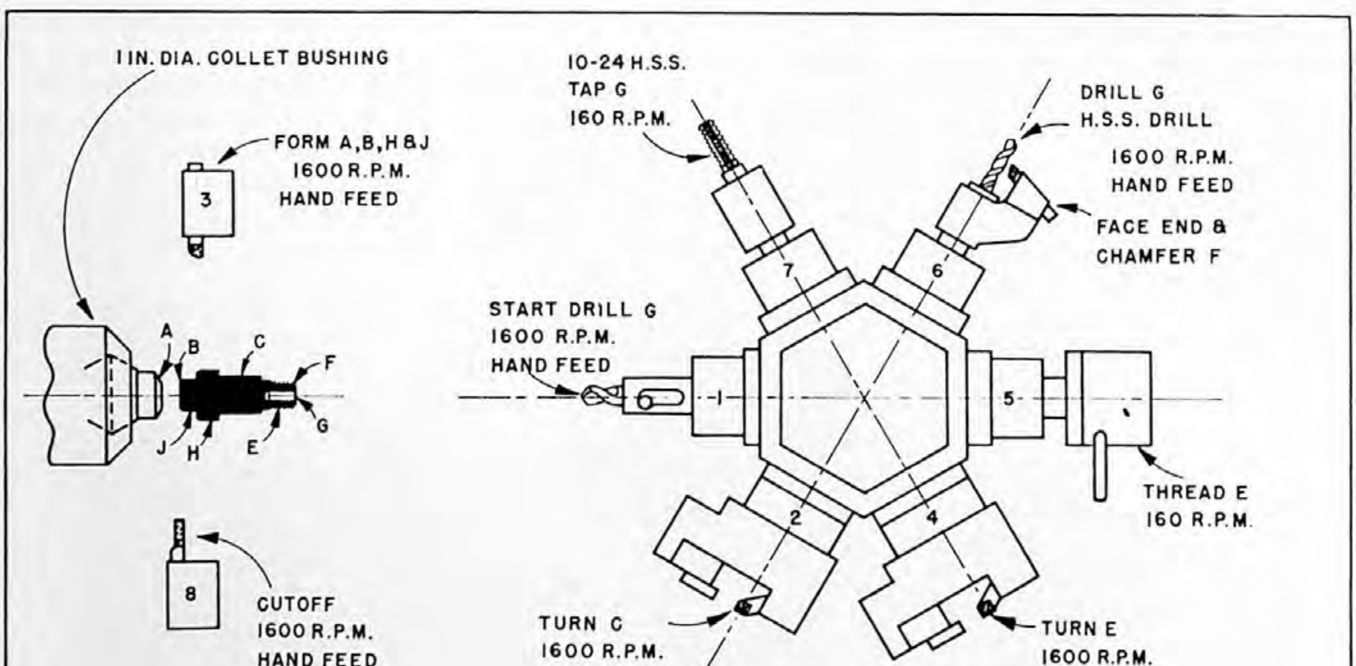


FIGURE 9

tue of their commonplace nature, often do not receive the attention they deserve for efficient production. This type work is illustrated in Figure 7 and is ideal for the machine illustrated in Figure 6.

For example, the shoulder screw illustrated in Figure 8 is a typical example of the shop work grouped as "common parts." Due to the threading operations and variety of diameters on this part, it may be produced efficiently on the back geared Electro-Cycle machine illustrated in Figure 6. Illustrated in Figure 9 is the tooling used to produce this part in 55 seconds per piece. Single turning tools in Stations 2 and 3 of the hexagon turret reduce the one-inch bar diameter to ¾ and ⅜-inch respectively, while a self-opening die head and solid tap are used for producing the threads. The carbide turning tool in Station 2 cuts the work at 1600 r.p.m., or 420 surface feet per minute. This tooling arrangement requires four changes in spindle speed together with two changes in the direction of spindle rotation. Therefore, the Electro-Cycle machine with its automatic control of these spindle functions, effects a direct reduction in handling time.

This shoulder screw can be produced on a multiple spindle automatic in 18 seconds. Therefore, it is obvious that for small to medium size production runs, the 55-second turret lathe cycle time is highly satisfactory.

STANDARD VS SPECIAL TOOLING

PART I When to apply standard and/or special tools to a setup

WHEN to apply standard, special or combination of both types of tools to a turret lathe setup is, in many instances, a very important factor governing not only the cost of machining operations but the overall cost of machining and tooling as well.

In general, *special* tools are used:

1. For unusual cutting operations such as contouring, single point shoulder threading, or slab facing.

2. To solve difficult chucking problems presented by fragile work parts, end-to-end concentricities, angular tolerances, or oddly shaped work.

3. To secure additional tooling rigidity for heavy feeds, or to hold very close tolerances.

4. To permit use of multiple and combined cuts when they are beyond the capacity of standard tools.

5. To overcome certain clearance limitations, thereby permitting work to be handled in some instances on the "next size smaller" turret lathe.

Standard tools are used when a large variety of standard work shapes and tolerances are to be produced with a minimum investment in tooling.

Note that no reference is given to production quantities. This factor is important enough to warrant separate attention.

One very important development which has given a new meaning to turret lathe tooling—as it is affected by quantities—is the wide range of standard tools now available.

Most machine tool builders make a wide range of standard tools, many of which have resulted from constant duplication of similar, but special, items produced in

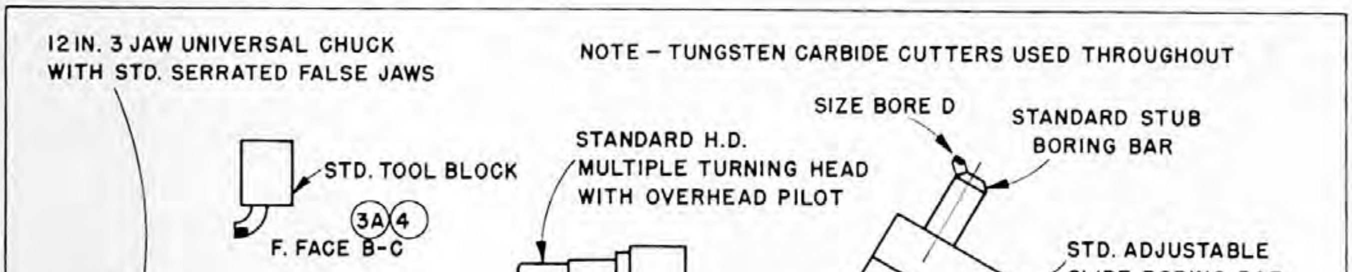


FIGURE 1

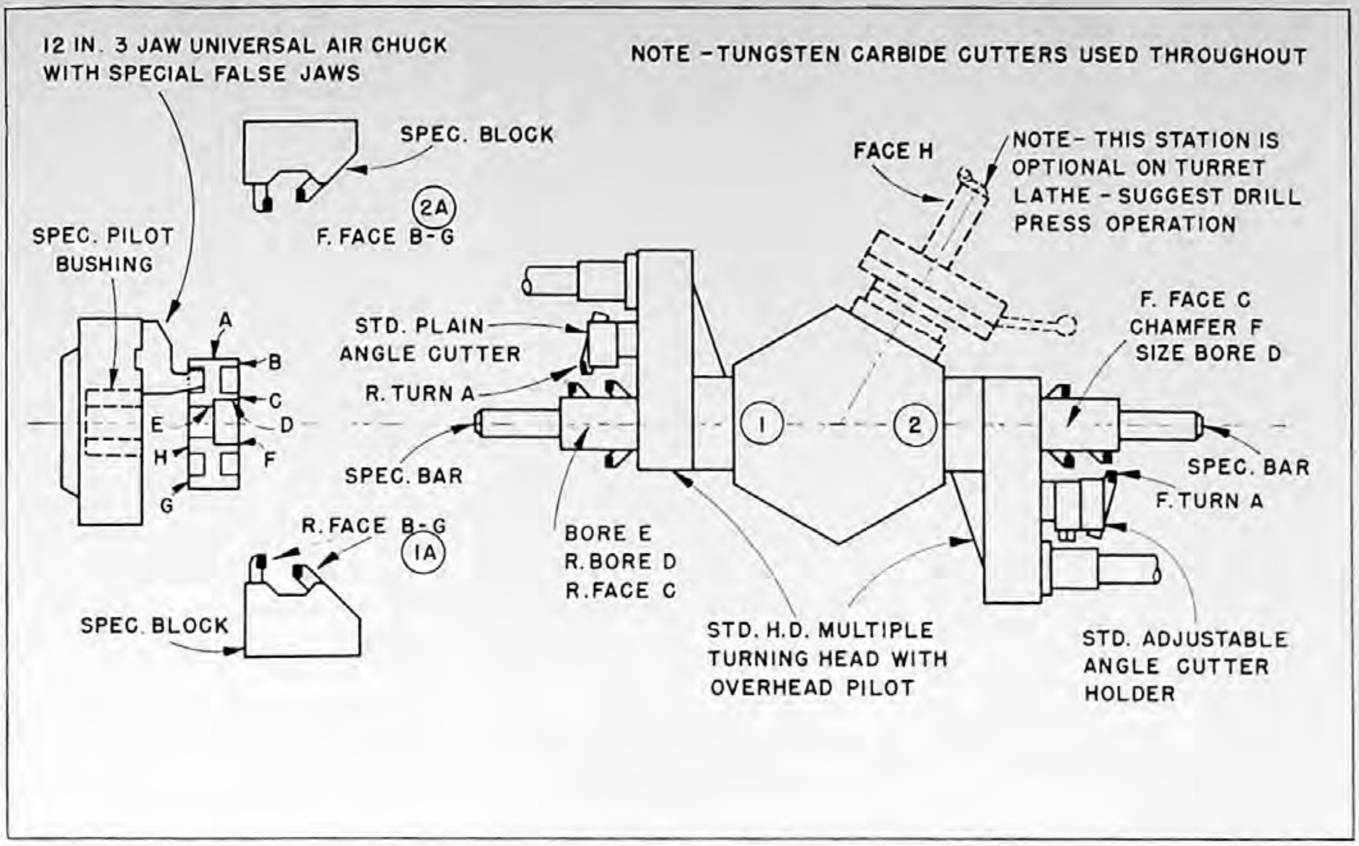


FIGURE 2

past years. These tools are rugged, flexible, and usually adjustable—characteristics formerly available only in special designs—and may therefore be left in permanent setups on the turret lathe for jobs of average complexity.

The permanent setup reduces setup time, thus making practical the application of combined and multiple cuts to lot sizes in lower ranges. Tooling of this type is moderate in cost. Through flexibility, rigidity and accuracy, this cost can be spread over many jobs —a further incentive to apply them to small lot jobs.

These same advantages apply to standard holders and extend their usefulness to jobs in the larger lot range.

Figure 1 illustrates tooling for a cast iron flywheel produced completely with standard holders and carbide tools. Production time per piece, for both first and second operations, is seven minutes.

The casting is held in a conventional three-jaw universal geared scroll chuck equipped with standard serrated false jaws. Inasmuch as special jaws are not to be considered in this setup, it is necessary to grip the work on the outside diameter. This means that matched cuts must be taken in the first and second operations. The tool holders on the hexagon turret are all standard. Special single bit carbide-tipped tools are ground to suit the job.

The first step in this operation is to rough turn part of the outside diameter in combination with rough boring the hole "D." The heavy duty multiple turning head with overhead pilot allows these cuts to be combined. These operations are also combined with rough machining face "B" from the tool post on the front cross slide. When the rough turning and boring cut is completed, the turret is indexed to station No. 2, and the rough facing cutter is allowed to complete facing of hub "C" in combination with boring hole "E."

The second piloted multiple turning head is then positioned and the outside diameter "A" is finish turned for the same length in combination with semi-finish boring and chamfering hole "D." This cut is taken in combination with a finishing cut on face "B." Upon completion of the turning cut, this head is removed from the cutting area and a finish facing cut to hub "C" is applied from the rear cross slide.

At the conclusion of these cuts, the adjustable vertical slide tool with stub boring bar is indexed into position to size hole "D."

Due to the method of chucking with standard devices, the part requires a second operation. Soft chuck jaws bored to suit the previously turned diameter "A" are used, and similar tooling to that shown in Figure 1 is applied to rough and finish turn the remainder of diameter "A" and complete the facing of flange "G" and hub "H."

The reduction in setup time, which such a permanent arrangement of standard tools has on jobs of an average nature, is readily recognized. All of the standard tools sketched remain on the machine and the two blank hexagon turret faces are equipped with

	FIGURE 1	FIGURE 2	
1. Cost of standard tools	$1,100	$ 520	
2. Consider depreciating standard tools with machine at 15 year rate—yearly depreciation:	73.40	34.70	
3. Determine 2,000 hours of yearly depreciation—hourly depreciation:	.037	.017	
4. Calculate standard overhead rate at $2.50 per hour, excluding depreciation, then total overhead (Item 3 plus $2.50).	2.537	2.517	
5. Assume rate per hour for direct labor.	1.50	1.50	
6. Total labor and overhead per hour—(Item 4 plus Item 5).	4.037	4.017	
7. Total labor and overhead per minute.	.067	.066	
8. Cost of special items all depreciated in one lot.	120	1,235	
9. Production time per piece in minutes.	7.0	3.6	
10. Cost per piece (labor and overhead) (Item 7 times Item 9).	.469	.238	
11. Difference in cost per piece. Subtract the lesser from the greater in Item 10.	.469	—.238	= .231
12. Difference in cost of specials. On Item 8 subtract the lesser from the greater.	1,235	—120	= 1,115
13. Point of equal cost per methods Figures 1 and 2. Divide answer to Item 12 by answer to Item 11.	$\frac{\$1,115}{.231} = 4,826$ pieces		

Chart for determining production quantities where equal cost per piece results with either standard or special tool setup.

standard flange tool holders in which reamers, die heads or tap holders are mounted. The six standard tools used on this job represent only a few of many hundreds of holders from which tools can be selected to suit particular machining problems.

This same flywheel—produced in larger quantities—presents the opportunity of successfully combining both standard and special tools and holders with a resultant increase in production. Tooled as shown in Figure 2, the part is produced complete in one operation in 3.6 minutes.

This setup provides special chuck jaws which allow the outside diameter to be completely machined in the one pass and also allows flange "G" to be back faced in the same chucking. Hub "G" is either machined as a second operation on a drill press or blind faced from the hexagon turret in the turret lathe setup by means of a quick acting slide tool and stub boring bar.

The first step in this operation is to use the same heavy duty multiple turning head with overhead pilot and angle turning holder for rough machining outside diameter "A" in one pass. Arranged in combination with this turning tool is a piloted boring bar containing a tool for machining hole clearance "E," rough boring hole "D" and rough slab facing hub "C." This piloted boring bar is supported by an anti-friction pilot bushing in the bore of the chuck.

The bar is specially designed for this job. Arrangement of the single bit tools in the piloted bar permits combination or simultaneous cutting on bores "E" and "D," thus eliminating a separate operation for machining clearance hole "E" as was required in the setup using completely standard tools. The slab facing cutter for hub "C" combined in the finishing piloted bar eliminates the necessity of positioning the cross slide for the facing cut and also saves cutting time in that it can be combined with machining the bores.

Operations performed by this first hexagon turret station are combined with a special tool block mounted on the front of the cross slide which is used to straddle face flanges "G" and "B." The tool block is special, and is an improvement over the standard cross slide tool block in that it combines the cutting time for machining face "G" with that required for machining face "B."

The second hexagon turret station holds another standard multiple turning head with overhead pilot and an adjustable angle tool holder for finish turning outside diameter "A" in one pass. Another special piloted boring bar is used with tools to size and chamfer hole "D," and finish slab face "C." These cuts are taken in combination with the special straddle facing block on the rear of the cross slide used to finish cut faces "B" and "G." It is not considered necessary in this special tooling setup to take a separate size boring cut on hole "D" because piloting the bar in the second hexagon turret station permits the tolerance to be held without an additional and separate sizing cut. The increase in production obtainable with this setup—which includes both standard and special tools—should not be allowed to prevent the economical use of completely standard tooling arrangements where lot sizes are low and variable in nature.

Simple guides or rules can be followed in determining—in production lot sizes—the point where it becomes profitable to incorporate special tools into the setup to secure lower production time. The principle of "equal cost per piece" can be used to determine how many pieces must be produced to justify the added tooling expense required by the faster machining method.

Admittedly, many concerns differ in their accounting approach in establishing production costs. However, a typical example should serve as a guide for individual investigations. The advisability of making comparisons is borne out by the vast differences in production. Many shops fail to organize their tool planning and engineering with sufficient detail to allow these savings to be made.

Method of calculating (*see accompanying chart*) determines where "equal cost per piece" exists when using a standard tool setup (*See Figure 1*) and when using standard tools combined with a substantial number of special tools (*See Figure 2.*)

Consulting the chart, it is readily determined that if the flywheel is machined with the tooling setup in Figure 2, the point of equal cost per piece is reached when the quantity approximates 4,800 pieces. That is, a minimum of 4,800 pieces is required to pay for the increased tooling investment which results in faster production time.

Below this quantity, it is cheaper to produce with the tooling setup in Figure 1, unless the urgency of the job supports the increased investment in special tooling.

Note that the tools in Figure 2 can pay for themselves in about 363 hours of operation at 80 percent efficiency. This is a little over two months operation on a single shift, eight hours per shift, basis.

Often the complexity of the part makes it easier to recognize conditions which warrant the use of special tooling.

Figure 3 illustrates a special retractable shoulder threading tool designed to single point chase square threads to a shoulder. Because it is difficult to cut an unmodified square thread with die head equipment, it is recommended that this type of thread be chased with a single point tool.

Design of the part for which this particular tool was made requires that the thread be cut right up to the shoulder. This requirement, in combination with the coarse pitch of the thread, necessitates use of a fixture with provision to retract the threading cutter away from the shoulder at the proper instant to avoid damage to the part and tool. The chasing tool is held in a small slide within the main tool block and is adjusted to cutting position by a cam actuated by a lever.

As the tool feeds along the work toward the spindle, the tool block approaches and contacts a trip rod mounted to the head of the machine. This trip rod releases the cutter slide and causes the slide and tool to retract rapidly away from the work so that the tool does not gouge into the shoulder.

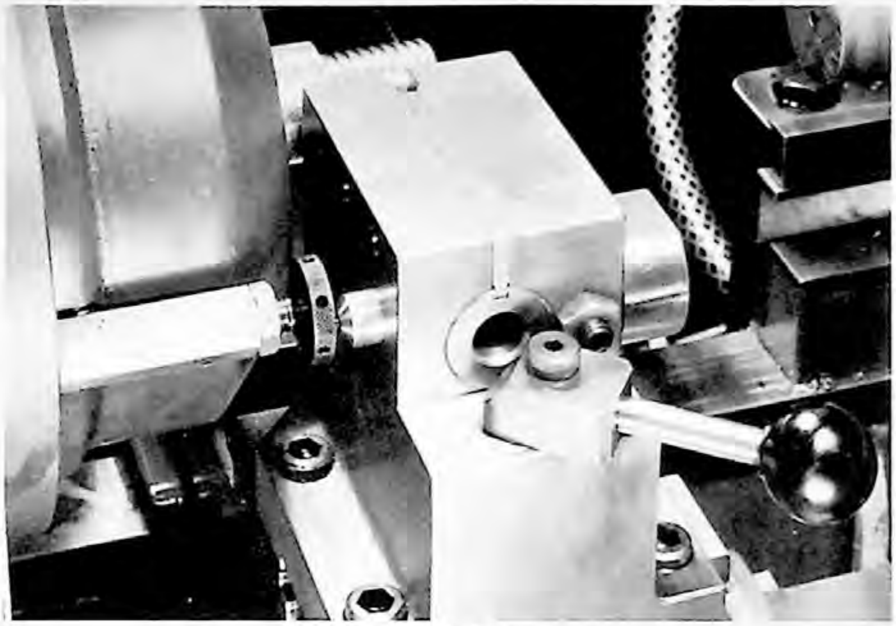


FIGURE 3

FIGURE 4

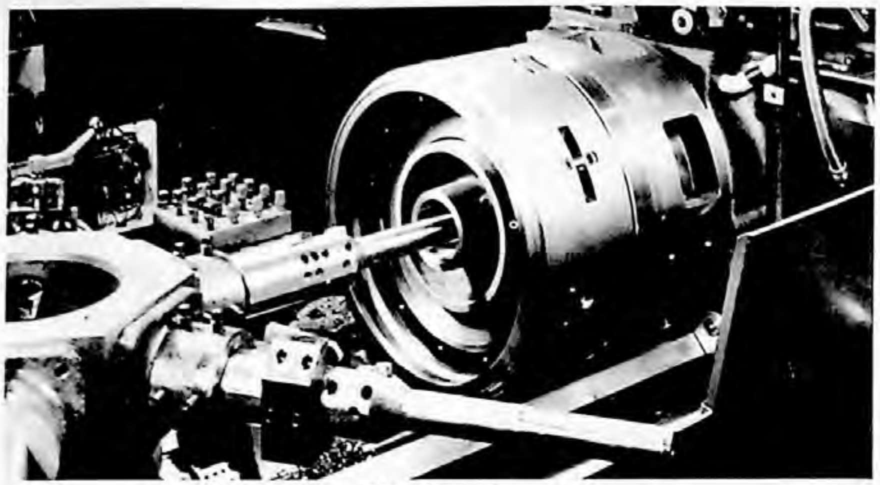


FIGURE 5

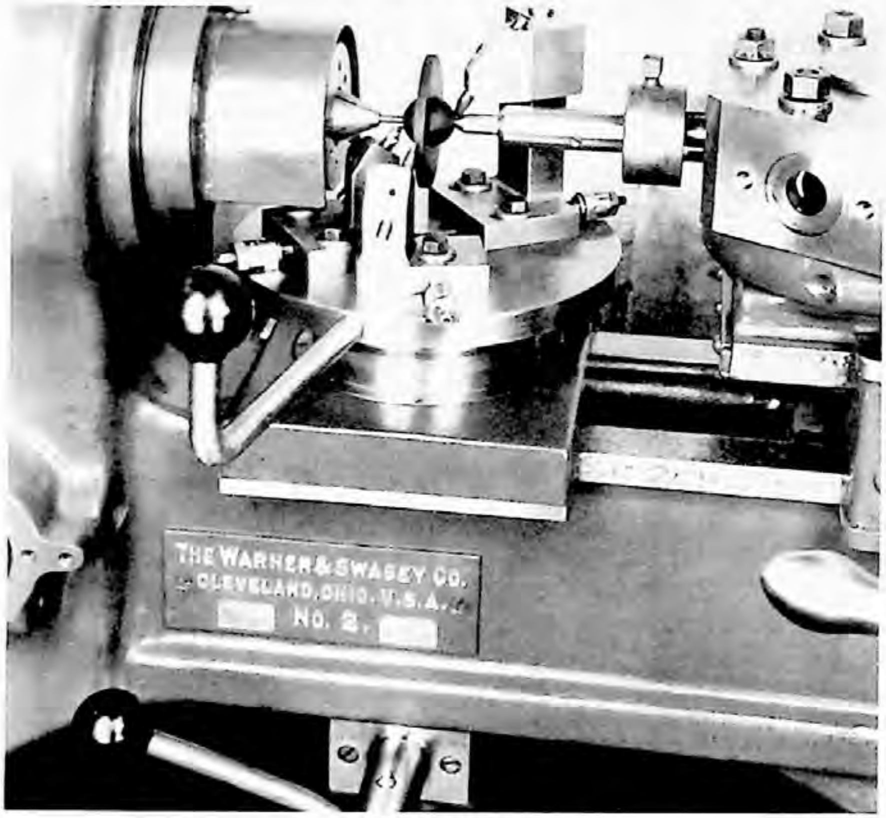


FIGURE 6

FIGURE 7

This fixture, while special, can be used for a variety of similar threading work and certainly accomplishes a difficult operation which would require unusual manual skill if done with standard equipment.

Another class of work which readily justifies special tooling is where production requirements are high or where unusual holding methods are indicated.

The casting shown in Figure 4 is a steel mine car wheel with bearing bores on either side of internal shoulders and which requires facing cuts to be taken on the hubs. A characteristic of this type of work is that gripping location must be taken from the chilled thread and extremely good concentricity must exist between the bearing bores on either side of the wheel.

In view of the large quantities produced, a holding device which functions like a three-jaw universal chuck was designed. Shown at the left in Figure 4 is a cartridge built with a universal arrangement so that three pins come down on the tread of the part and locate it radially. The three hand clamps are then positioned to hold the wheel in the cartridge.

The cartridge itself is machined with locating diameters on either end and it is gripped, one end at a time, in an air operated finger fixture mounted on the spindle of the turret lathe, thereby permitting each side of the part to be machined. Figure 5 illustrates the cartridge with part held in position by the air finger fixture. This type of holding device permits holding concentricity from end to end, and also allows loading of another cartridge while cuts are in progress on the part being machined.

Figure 5 also shows a partial view of the hexagon turret tooling. Note that piloted bars are used so that combined boring, slab facing and chamfering can be accomplished in one turret position. From actual tests, it was established that piloting permitted feeds of .040-inch per revolution to be taken on this difficult-to-machine material and yet maintained extremely satisfactory size control and rate of production.

A further application for special tools is illustrated in Figures 6 and 7. The part is a hard rubber water meter disc. The two hemispheres and a radius on the outside diameter of the flat disc require machining. For reasons of concentricity and production, these cuts must be taken simultaneously. Production quantities are extremely high, thus requiring the fastest possible method of manufacture. While special machine equipment could undoubtedly be designed to produce the part, this example furnishes additional proof that standard turret lathes can be very profitably equipped with special attachments and tooling to warrant their use on jobs involving large production quantities.

The tool blocks which carry the diamond-tipped cutters for machining the hard rubber disc are mounted on a platten which rotates under the part. The handle fixed to the circular platten is used to hand feed the diamond-tipped cutters through their paths of travel. Another handle mounted beneath the bed of the turret is used to raise and lower the platten and cutters from cutting position so that the part can be readily loaded and unloaded.

Figure 7 shows an additional development in this type of device. Power feed to the circular platten and tools is accomplished by use of an air cylinder, hydraulic feed checks and limit switches. The operator need only lower the platten, load the piece, raise the platten and engage the pneumatic feed. The cutters progress through their travel and return to original position in preparation for the next part to be machined.

This job represents the ultimate in special tooling. However, quantity involved justified the means used to increase production rate.

STANDARD VS SPECIAL TOOLING

PART II

Cost Analysis is the means of proving in special tools on short run jobs

WITHOUT question, a large percentage of jobs produced on turret lathes are under-tooled. It is an exception to the rule to find a job over-tooled.

Under-tooling may occur for several reasons. Some of the more important reasons being:

1. An incomplete grasp of some of the side issues to turret lathe practice.

2. Lack of attention to the tooling possibilities of the work scheduled over the machine.

3. No concept of the exact quantity of work at which comprehensive tooling produces more economically than simple, less expensive tooling.

Proper understanding of the side issues in turret lathe practice promotes better tooling efficiency. This is, in fact, the main reason for this series of articles on Turret Lathe Practice.

More specifically, however, the press of business among shop and engineering personnel all too often prevents more than a cursory, almost an instinctive, effort in tooling jobs as their individual natures demand for profitable operation. That, plus a fairly general reluctance on the part of turret lathe users to take the time to calculate the comparative returns from various types of tooling layouts, often imposes undue limitations on the true productive capacity of the machine.

While the increased use of standard universal tooling has effectively lowered the cost of small lot production on the turret lathe, no such obvious list of tools exists for cutting costs in the higher levels of production. Nevertheless, the calculated approach to the tooling problem in the higher levels of production pays equally high dividends.

How, then, can the turret lathe user determine when the higher cost of specialized tooling is justified by the faster production thereby secured?

Obviously, the key to the whole matter is determining the point in work quantities where the cost of producing is the same for two tooling layouts involving different investments. Or, expressed differently, how many pieces of work must be made with the special tooling setup before the aggregate savings in cost per piece equal the tooling investment. It is as easy as that!

Certain simplifying assumptions may be made to speed the calculations of this balance point in production. For example, assume that:

A. There *is* a choice between tooling layouts and that special tools are not necessarily *demanded* by the unusual nature of the job.

B. Machine depreciation is ignored as a constant when optional tooling layouts for the same machine are being considered.

C. Setup time will be about the same for the various combinations of tooling arrangements. For longer run jobs, slight differences in setup time will not have much effect on the balance point in work cost.

D. The various "intangibles" credited to one or the other type of layout such as tool maintenance, tool setting, availability of tools, lower operator fatigue, etc., will, in general, balance themselves out and, therefore, be canceled from the analysis of relative cost.

Certain factors then remain to be evaluated. These are:

A. Direct hourly labor rate, including fringe benefits.

B. Factory overhead or burden rate per hour.

C. Hourly production rate obtained from each tooling layout being analyzed.

D. Capital life, or period over which the cost of standard tools is to be recovered.

How a production analysis is made of two alternate tooling setups is shown by the following example.

A choice must be made between two tooling methods, for a No. 4 Turret Lathe, involving different combinations of standard and special tools to produce the Cover Plate *Part No. 1* in Figure 1. These setups are shown in Figures 2 and 2-A.

What is the minimum number of cover plates needed to justify the greater expense of special tools called for by the faster setup in Figure 2-A?

An analysis of the expected production rate and tooling costs must be made first. These facts are listed in Table 1.

Assume that direct labor plus fringe benefits equals $1.80 per hour.

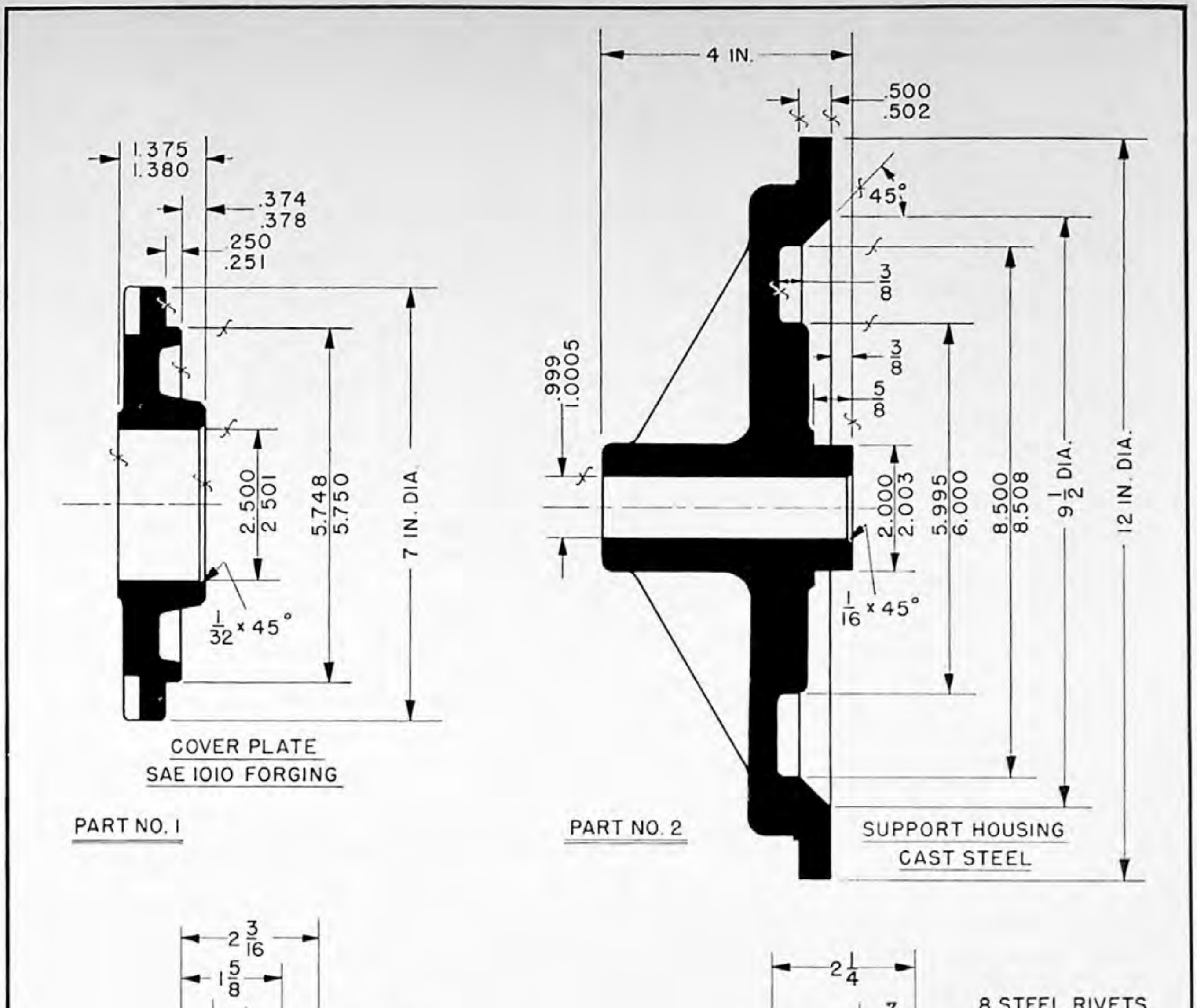

4 IN.
.500
.502
1.375
1.380
.374
.378
.250
.251
45°
3/8
3/8
5/8
.999
1.0005
2.500
2.501
5.748
5.750
7 IN. DIA
1/32 x 45°
2.000
2.003
5.995
6.000
8.500
8.508
9 1/2 DIA.
12 IN. DIA.
1/16 x 45°
COVER PLATE
SAE 1010 FORGING
PART NO. 1
PART NO. 2
SUPPORT HOUSING
CAST STEEL
2 3/16
1 5/8
1 1/8
1.0015
1.003
4 7/8 DIA.
1 7/8
2.500
2.502
3 7/8 DIA.
5 1/2 DIA.
6 1/2 DIA.
1/32 x 45°
38°
38°
51/64
51/64
DOUBLE PULLEY SHEAVE
CAST IRON
PART NO. 3
2 1/4
7/8
8 STEEL RIVETS
FACE HEADS
.250
.255
1.000
1.002
4.003
4.000
5.501
5.503
6 IN. DIA.
STEEL INSERT
1 1/4 TAPER
PER FOOT
MAGNETIC
IRON
1/16 x 45°
MAGNETO COVER ASS'BLY
ZINC DIE CAST BODY
PART NO. 4

FIGURE 1

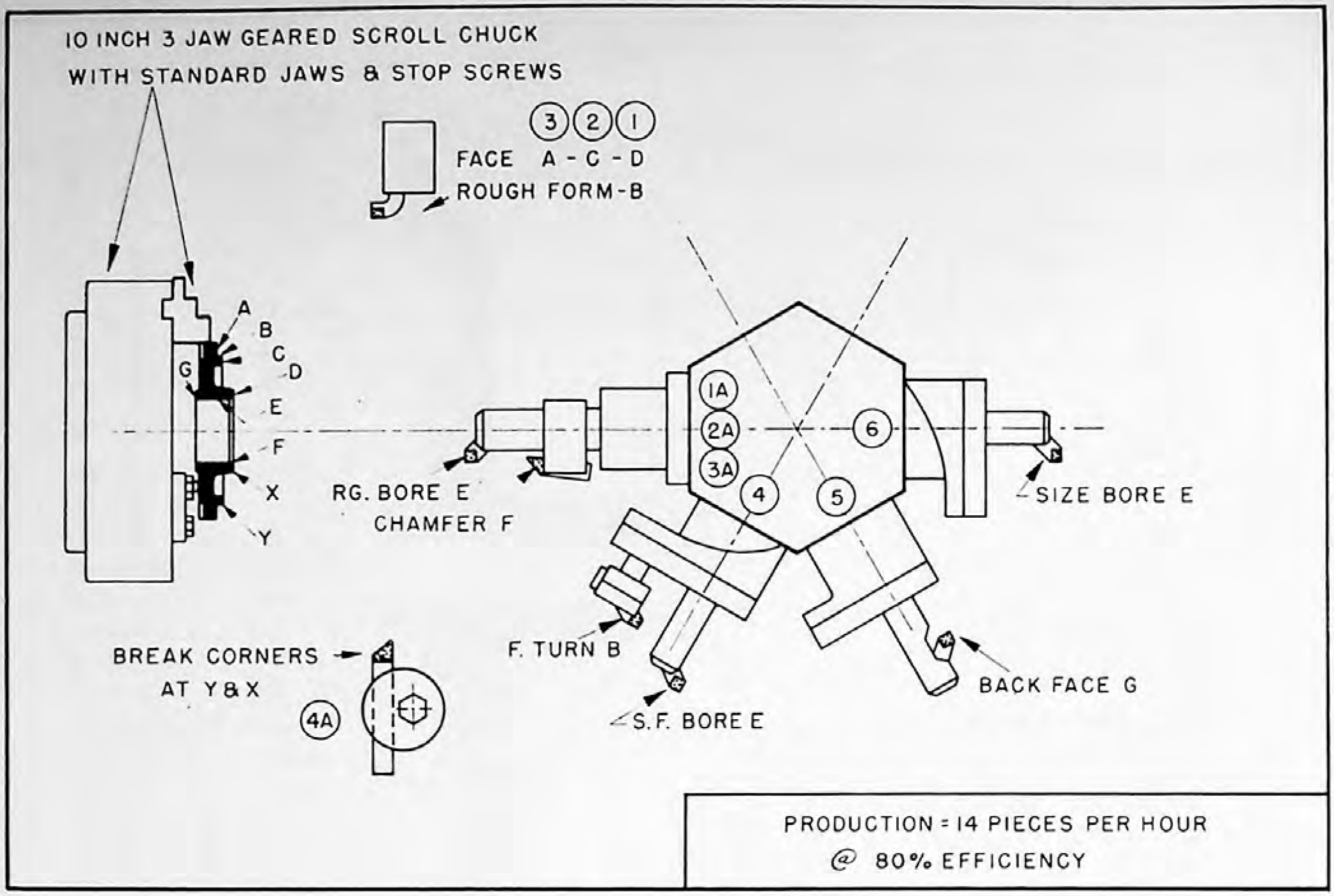


FIGURE 2

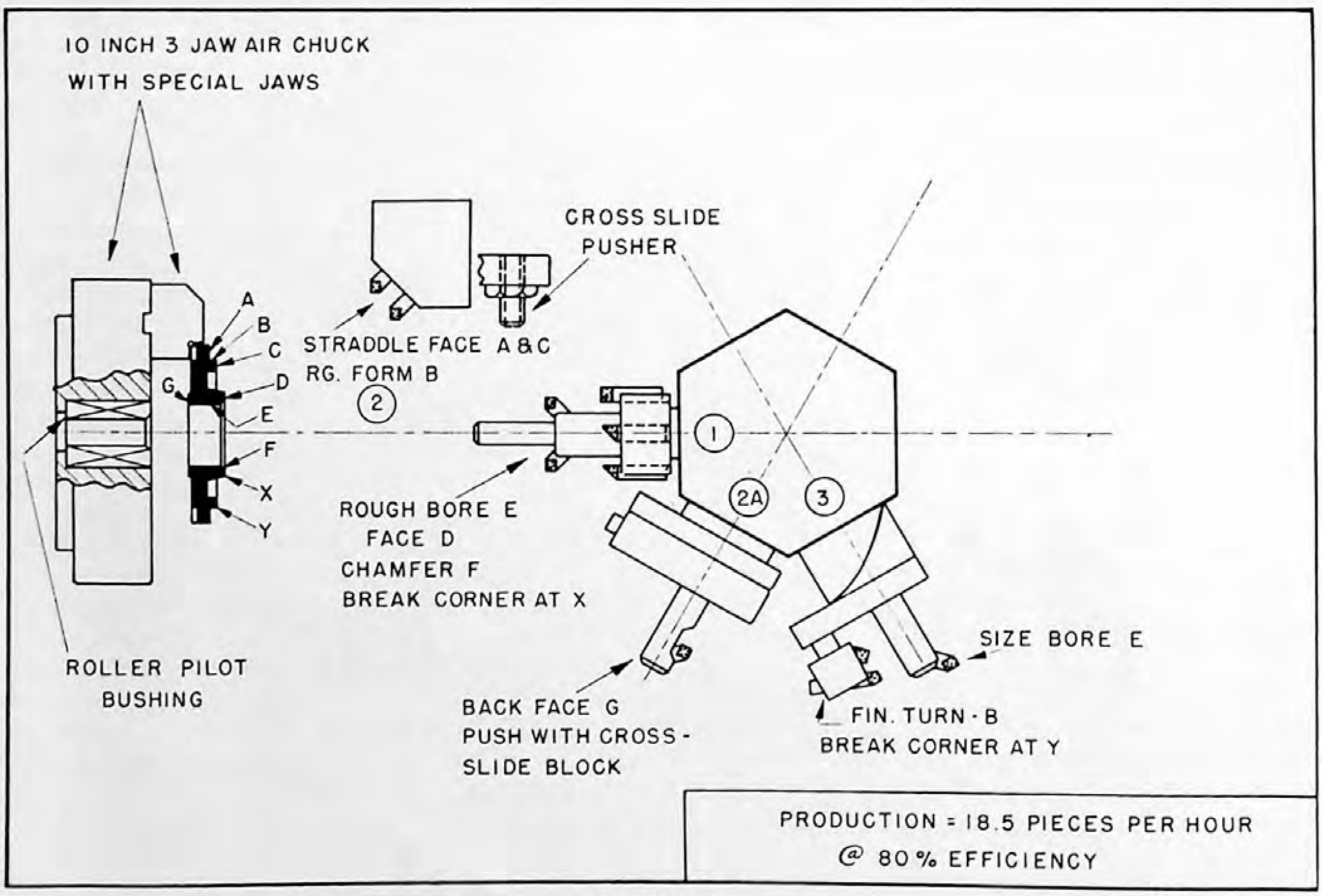


FIGURE 2A

Assume that capital life of all standard tools is 8,000 hours. *Four years—2,000 hours per year.*

With this calculated or estimated data at hand, the analysis may be continued in accordance with Table 2.

This analysis shows that approximately 15,700 cover plates must be machined before the total savings will amount to the difference in the special tooling costs of $1,250.

As a next step, it is important that the tooling analyst decide whether the setup in question will operate on a production basis or in small lot quantities spread over a period of years. Obviously if only 200 cover plates per year are to be machined, an excessive period of time must elapse before a total of 15,700 plates would be completed. This introduces the danger that obsolescence of the part or tool deterioration might occur before the aggregate number of parts needed to amortize the tooling costs could be produced.

In that case, it is obvious that the setup in Figure 2 would be more desirable, or that some modification of the setup in Figure 2-A be made and again compared with the setup in Figure 2. In any event, the setup ultimately chosen must reconcile the best possible cost savings with, (a) the expected life of the tools used to obtain that savings, and (b) the life expectancy of the job.

Parts No. 2, 3 and 4 in Figure 1 illustrate three other typical chucking jobs which may be analyzed as above. Recommended optional setups are illustrated in Figures 3, 3-A, 4, 4-A, 5 and 5-A. The production times from all of these setups as well as the standard and special tooling costs are listed in Table 3.

Based on the data in Table 3, a composite analysis sheet (*See Table 5*) has been compiled.

Notice that setup 3-A shows a 58 percent increase in production over the setup in Figure 3, with only a net addition to the cost of

SETUP	PIECES PER HOUR	STANDARD TOOL COST	SPECIAL TOOL COST
Figure 2	14	$1,090	$ 185
Figure 2-A	18.5	$ 770	$1,435

TABLE 1

		Figure 2	Figure 2-A
1.	Standard tool capital cost per hour	$ .136	$ .096
2.	Standard tool capital cost per piece	$ .0097	$ .0052
3.	Direct labor cost per piece	$ .128	$ .097
4.	Factory overhead, per piece	$ .179	$ .135
5.	Total cost per piece (Sum of Items 2, 3 and 4)	$ .3167	$ .2372
6.	Net difference in cost per piece:	$ .0795	
7.	Cost of special tools	$185	$1,435
8.	Difference in cost of special tools:	$1,250	
9.	Number of pieces required with setup 2-A to recover additional cost of $1,250 equals $1,250 divided by net difference in cost per piece, .0795 or 15,700 (approximate).		

TABLE 2

SETUP	PIECES PER HOUR	COST OF STANDARD TOOLS	COST OF SPECIAL TOOLS
Figure 2	14	$ 1,090	$ 185
Figure 2-A	18.5	$ 770	$ 1,435
Figure 3	2.4	$ 2,070	$ 390
Figure 3-A	3.8	$ 1,255	$ 593
Figure 4	6.0	$ 1,295	$ 278
Figure 4-A	9.0	$ 1,070	$ 1,465
Figure 5	9.5	$ 1,200	$ 250
Figure 5-A	16.0	$ 450	$ 1,190

TABLE 3

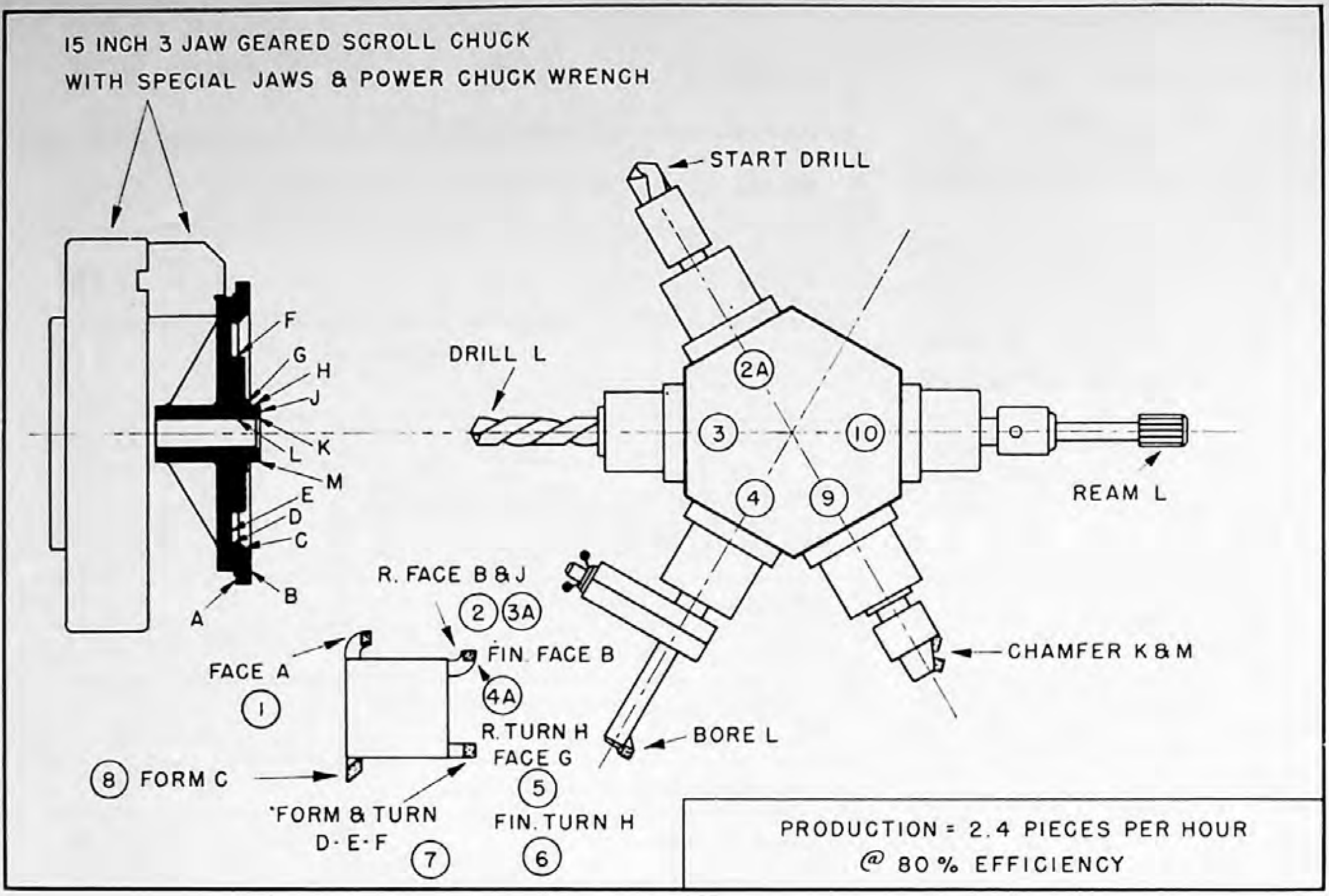


FIGURE 3

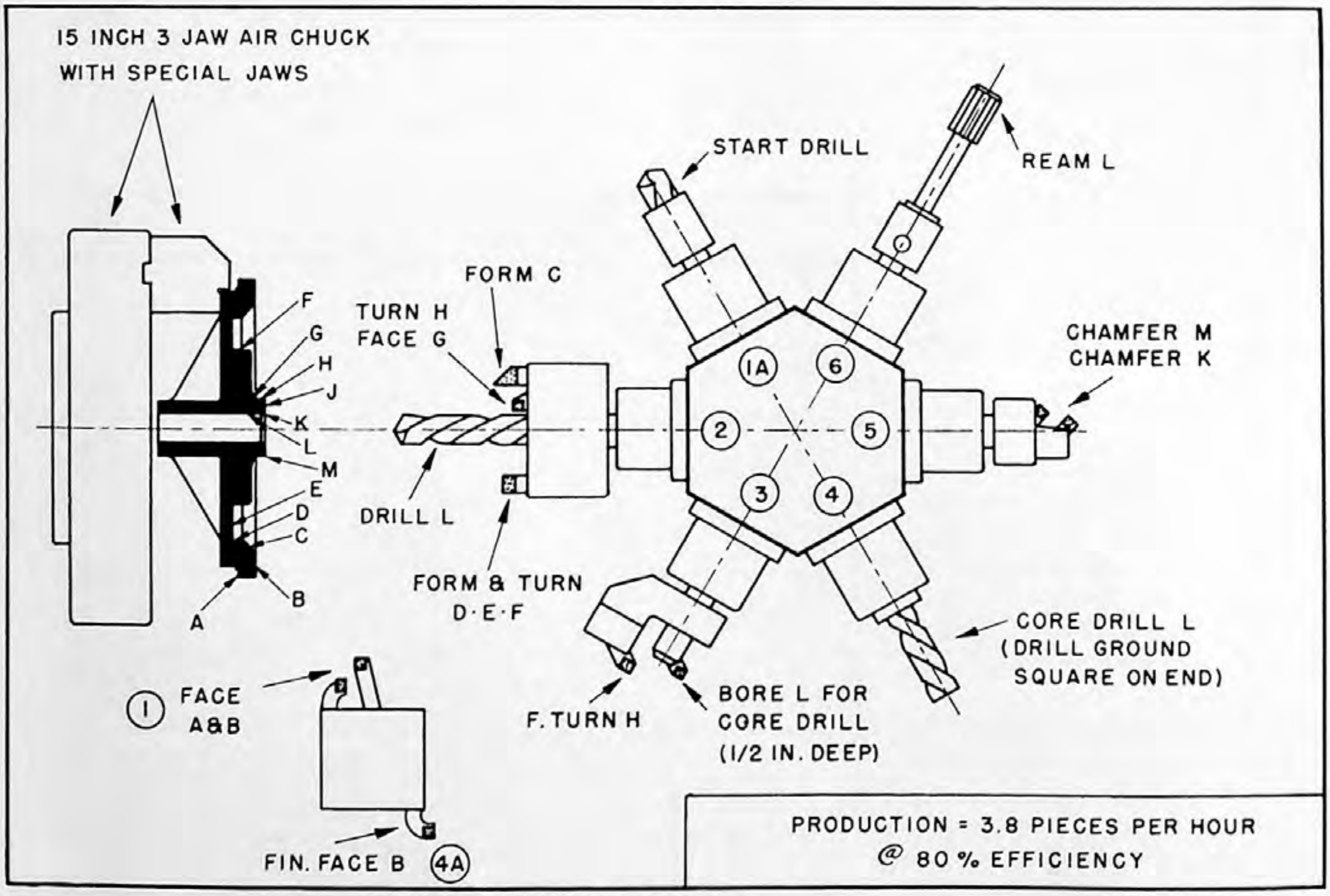


FIGURE 3A

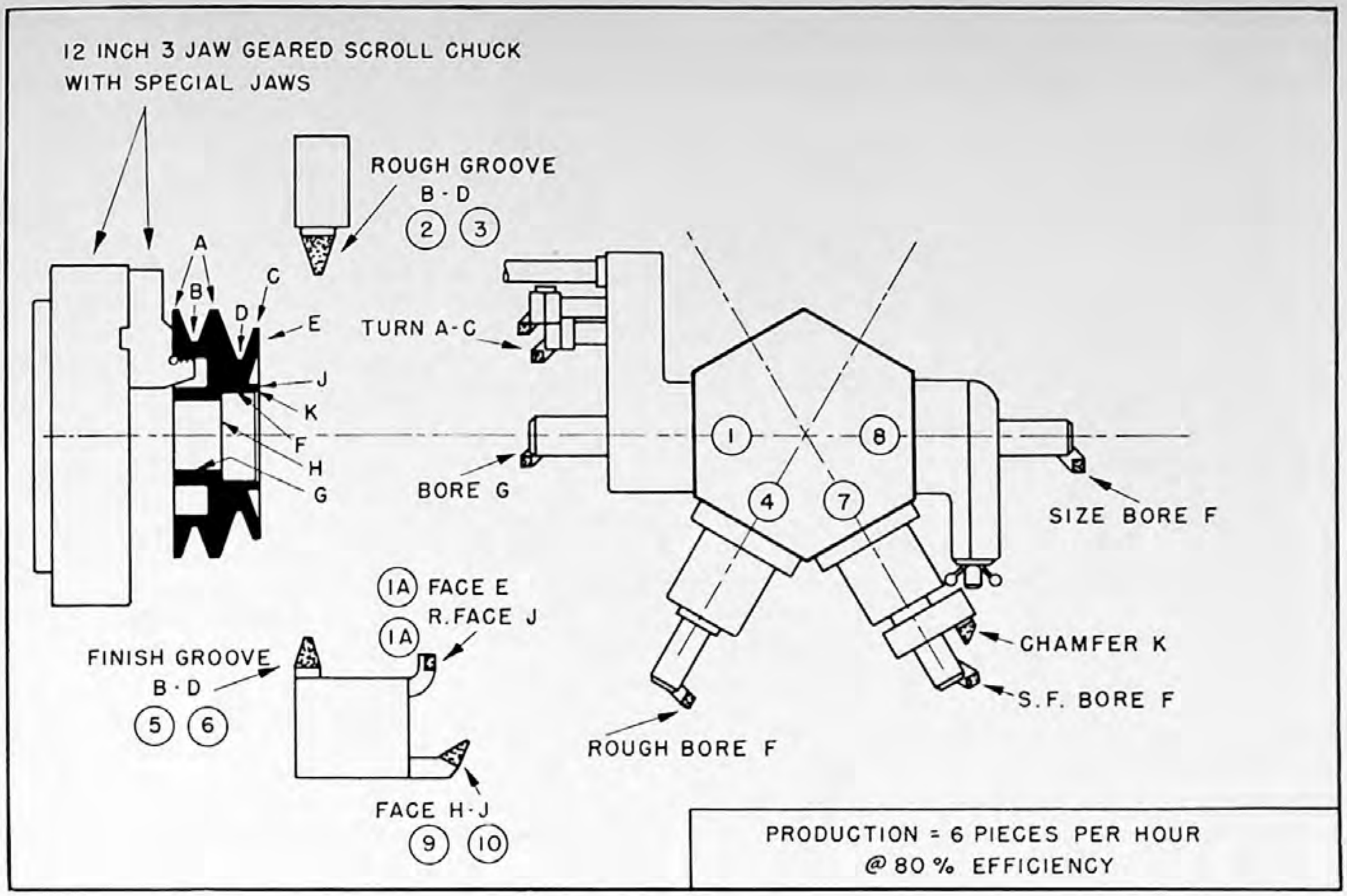


FIGURE 4

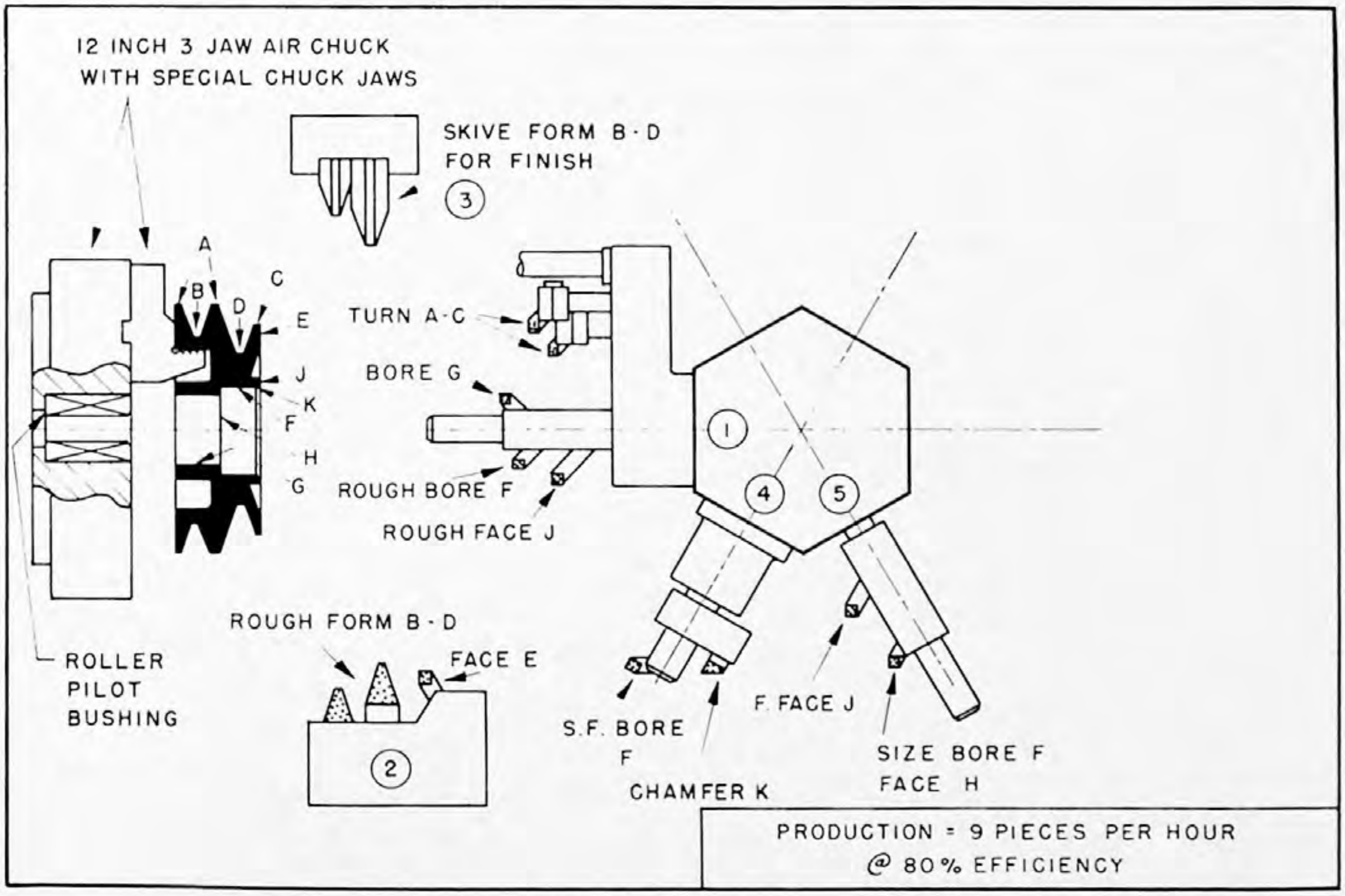


FIGURE 4A

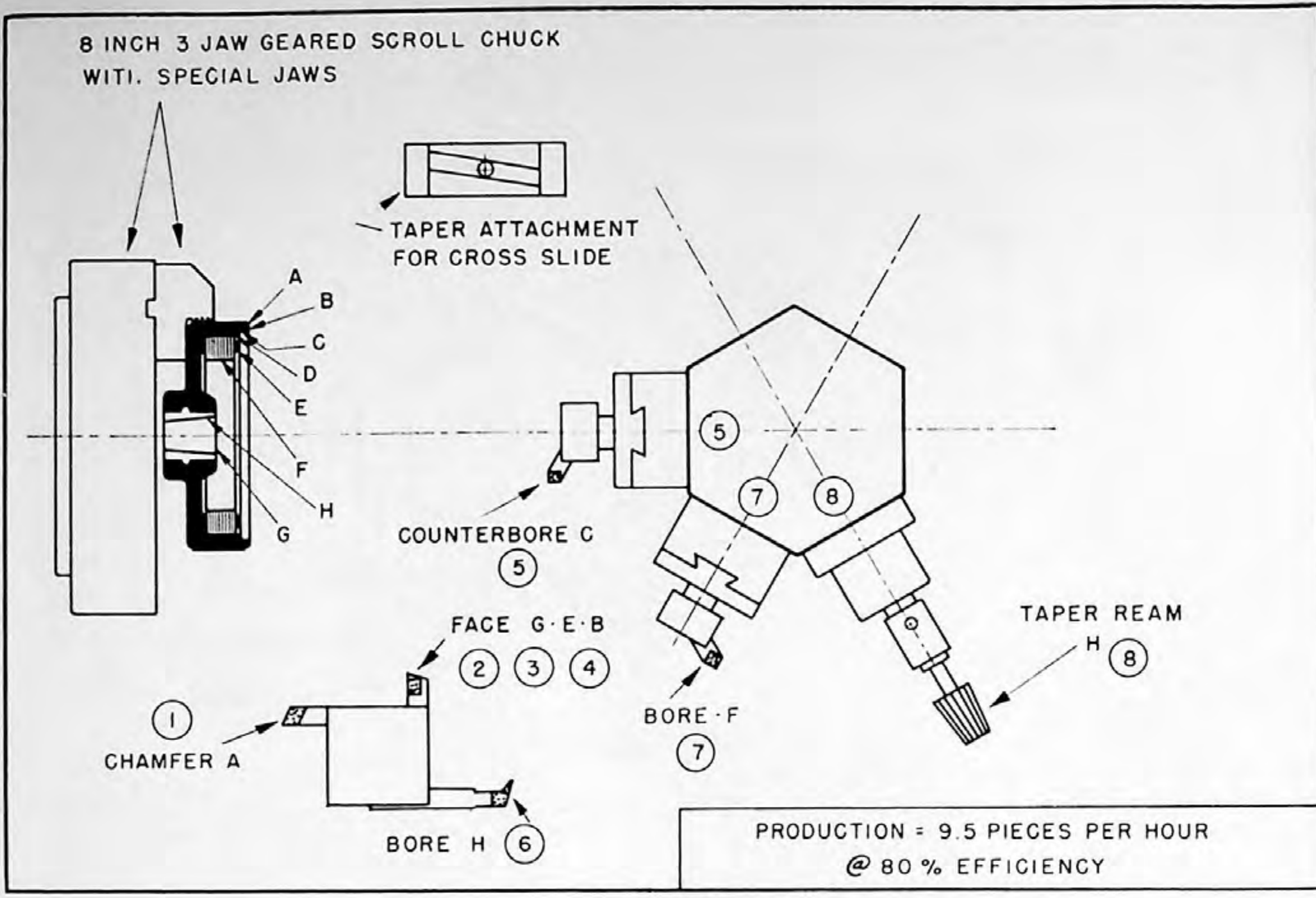


FIGURE 5

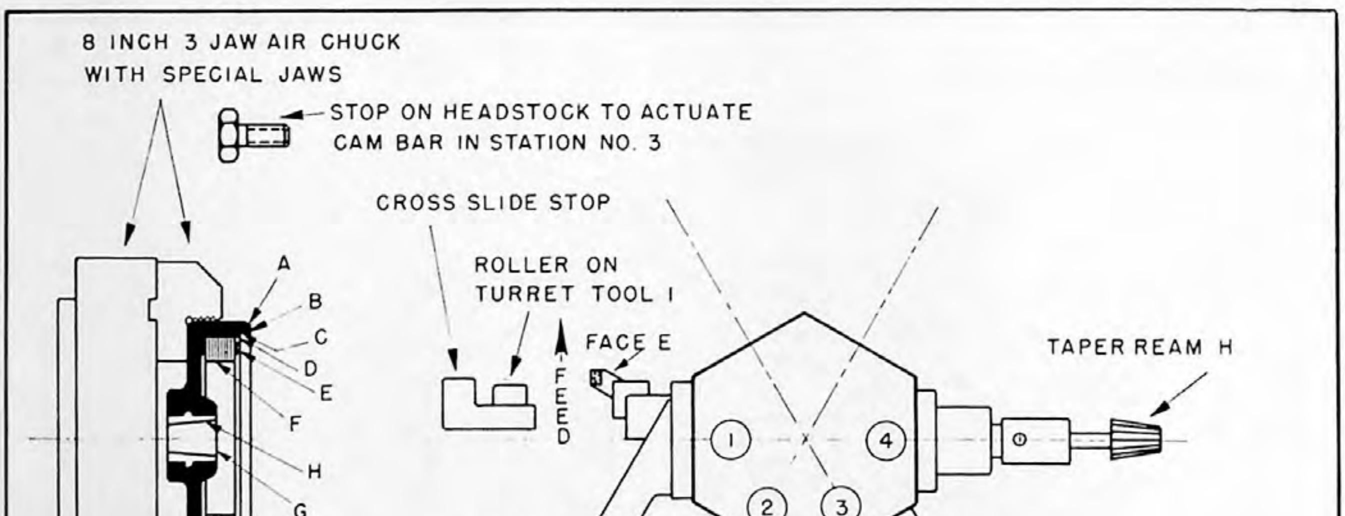


FIGURE 5A

special tools of $203. On that basis, 280 pieces are required to amortize the tooling—74 hours steady production at 80 percent efficiency.

The increase in production efficiency may be summarized for all four typical jobs in Table 4.

As previously mentioned, a large percentage of turret lathe jobs are under-tooled. This is most often the case with jobs that can to all intent be done well enough with standard equipment. Consequently, time and effort are not expended on extending the tooling analysis to the very limit of production possibilities consistent with the number of pieces to be made. Under-tooling therefore results—not as a measure of the efficiency of the setup, but rather as a measure of the loss in cost savings, which a more comprehensive setup might return to the turret lathe user.

For jobs which carry the option of standard or special tooling, it is easily proved that the advantages of special tooling primarily concern their ability to reduce handling and cutting time. An analysis of the four typical chucking jobs illustrated in this article shows that the reduction in handling and cutting time is attributable, in a large degree, to improved arrangements of tools to allow greater multiple and combined cutting. In some instances, the tool design itself allowed greater feeds with consequent reduction in cutting time.

For convenience, these factors which brought about the reduction in handling and cutting time for the various setups involved are listed in Table 6.

SETUP	PRODUCTION INCREASED (PERCENT)	WORK COST REDUCED (PERCENT)	HOURS TO AMORTIZE SPECIAL TOOLING COST
2-A	32	25	850
3-A	58	38	74
4-A	50	34	520
5-A	68	58	655

TABLE 4

	Figure 2	Figure 2-A	Figure 3	Figure 3-A	Figure 4	Figure 4-A	Figure 5	Figure 5-A
1. Standard Tool capital cost per hour (Cost of tools ÷ 8000 hours)	$.136	$.096	$.258	$.157	$.162	$.134	$.15	$.056
2. Standard Tool capital cost per piece (Item 1 ÷ number of pieces per hour)	$.0097	$.0052	$.107	$.041	$.027	$.015	$.0158	$.0035
3. Direct Labor cost per piece (Labor $1.80 per hour ÷ number of pieces per hour.)	$.128	$.097	$.750	$.473	$.300	$.200	$.190	$.113
4. Department burden per piece ($2.50 per hour excluding depreciation ÷ number of pieces per hour)	$.179	$.135	$1.04	$.66	$.417	$.278	$.264	$.156
5. Total cost per piece (Items 2-3-4)	$.3167	$.2372	$1.897	$1.174	$.744	$.493	$.470	$.197
6. Net difference in cost per piece	$.0795		$.723		$.251		$.089	
7. Cost of Special Tools	$185	$1,435	$390	$593	$278	$1,465	$250	$1,190
8. Difference in cost of Special Tools	$1,250		$203		$1,187		$940	
9. Number of pieces required to recover excess cost of special tools for faster producer (approximate).	15,700		280		4,700		10,500	

TABLE 5

HANDLING TIME	CUTTING TIME
Figure 2-A	
Air Chucking	Piloted cutter bar and special chuck jaws permit increased feeds.
Multiple Cutting in Stations 1, 2, and 3	Simultaneous facing cuts from cross slide and Turret Station 2-A Simultaneous boring and turning in Turret Station 3. Simultaneous cutting in Station 1.
Figure 3-A	
Air Chucking	Combining of cuts in Stations 1, 2, and 3. Drill acts as pilot in Station 2.
Reduction of square turret maneuvering by transfer of certain operations to hex turret.	Substitution of square-end multi-flute core drill in Station 4 for slender stub boring bar permits increased boring feed.
Multiple cutting in Stations 1, 2 and 3.	
Figure 4-A	
Air Chucking	Piloted bars permit increased feeds.
Better arrangement of tools on both turrets for multiple cutting.	Better arrangement of tools on both turrets for simultaneous cutting.
Use of skiving cutter eliminates need for working to a finish stop position.	
Less maneuvering of cross slide and square turret	
Figure 5-A	
Air Chucking	
Transfer of all tooling to pre-set stops on hexagon turret	Simultaneous cutting in Stations 1, 2, and 3.
Elimination of hand-set taper attachment	
Better arrangement of tooling for multiple cutting	

TABLE 6

STANDARD VS SPECIAL TOOLING

PART III Further data on Cost Analysis

THE cast iron cover shown in Figure 1, has characteristics found in many jobs produced on chucking turret lathes. It can be used to illustrate the effect of different tooling methods on the cost of production.

Figures 2, 3 and 4 are three common tooling methods which may be applied to this casting. The tooling cost and rate of productivity as well as setup time are different for each method. An analysis of each method will show the conditions under which it is the *proper* method to use.

Figures 2a and 2b illustrate a simple tooling setup for the cover. This method requires two operations. Obviously, the tooling investment is quite low, as the tools consist primarily of carbide-tipped cutters. In order to use standard jaws in the hand-operated three-jaw scroll chuck, the piece is gripped on diameter A. However, this permits only one half of diameter A to be machined and requires that the rest of the diameter, as well as face N be machined in a second operation. Note that simplicity is obtained in this setup by sacrificing the benefits of taking cuts in multiple and combination for both tool slides.

This type tooling setup is commonly found in "small lot" shops. Such shops resort to the simple setup in the belief that longer setup times and greater tool costs cannot be supported by short run work. This is only a half truth. Arbitrary adherence to that policy frequently prevents the recovery of available profits on many jobs because of under tooling.

The typical chucking job shown in Figure 1, is that kind of job.

Note that the tooling setups in Figures 2a and 2b produce at a rate of 4.6 pieces per hour net, and may be set up in 2.3 hours total time.

Figures 3a and 3b differ from Setups 2a and 2b in the quantity of standard tools used. These tools permit the arrangement of cutters for multiple and combined operations—the most important principle of good turret lathe practice.

With the cutters arranged as in Figures 3a and 3b, machine handling time is saved because stops for work diameters and longitudinal dimensions are preset. Thus, a much simpler arrangement of cutters on the cross slide *(Figures 3a and 3b)* results by comparison with those in the previous tooling arrangement. As a matter of fact, when cutters are required to perform *multiple functions,* as in the setup in Figures 2a and 2b, the time used to maneuver the cross slide during the work cycle may exceed the additional time required to set up those cutters in a permanent arrangement, such as in Figures 3a and 3b. Most certainly, less operating skill is required to produce good work with Setup 3.

Total setup time for operations 3a and 3b is 2.6 hours compared with the 2.3 hours for the previous illustration.

Setups 3a and 3b can produce at the rate of 6.8 pieces per hour net, compared with 4.6 pieces per hour net for Setups 2a and 2b.

Figure 4 illustrates still another method of tooling the cast iron cover. In this setup, special tools are used more extensively in combination with about the same number of standard tools shown in Figures 3a and 3b.

This setup demonstrates the maximum use of combined and multiple cuts. This is an important distinction between Setups 3 and 4, and the method illustrated in Figures 2a and 2b, which could not use the principle of combined cuts because of the multiple functions of cutters held on the cross slide.

The setup in Figure 4 carries out the principle of *multiple* cuts on the cross slide through the use of special cutter blocks. As a result

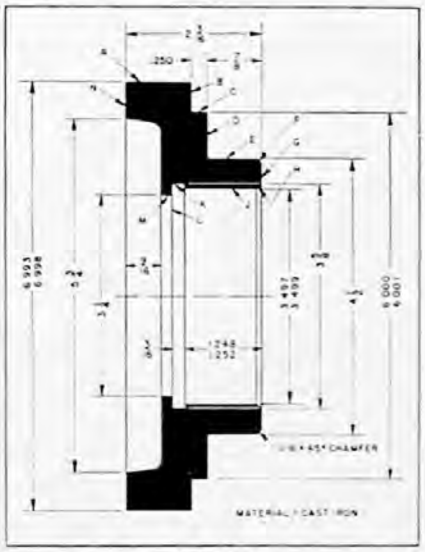


FIGURE 1

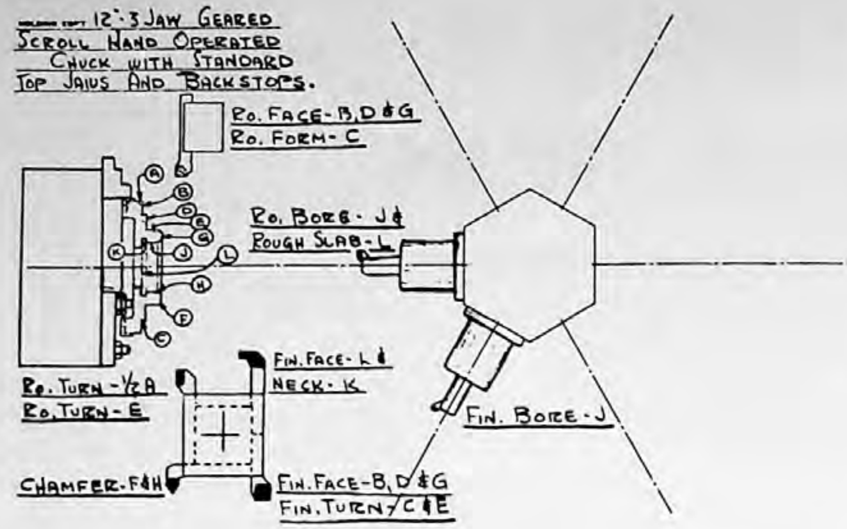


FIGURE 2a

of the special and standard tooling arrangement shown, a net hourly production of 16.5 pieces is obtainable in one operation. Special chuck jaws are designed for use in an air chuck, and arranged to grip inside the rim of the cover so that a turning cut can be taken on surface N. Hence, a second handling of the piece is avoided and further advantage is obtained in combining the machining of these two surfaces with other cuts in the operation.

How then may the choice between three such typical tooling methods be made if the cover is produced, for example, six times a year in lots of 50 pieces per run.

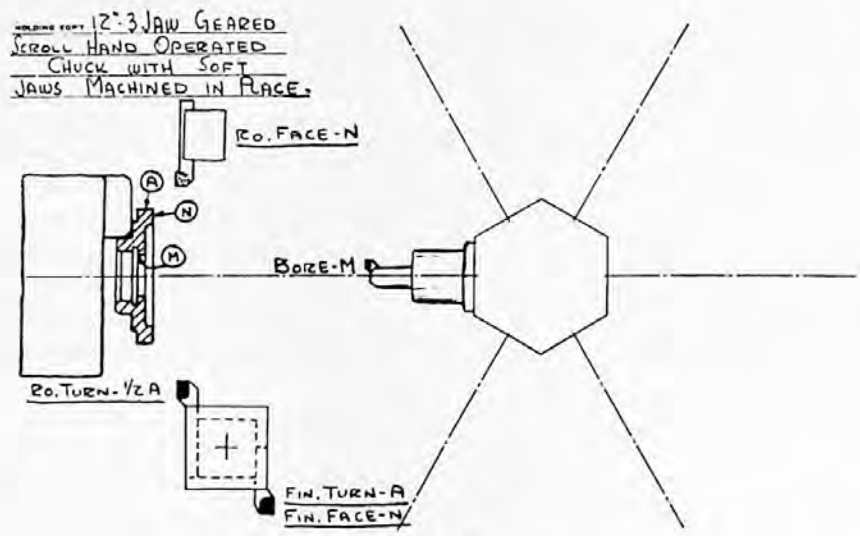


FIGURE 2b

Method	COMPLETE SETUP TIME (HOURS)	PIECES PER HOUR	COST OF STANDARD TOOLS AND EQUIPMENT	COST OF SPECIAL TOOLS
A	2.3	4.6	$ 736.00	$ 80.00
B	2.6	6.8	$1,810.00	$ 165.00
C	3.1	16.5	$1,724.00	$1,095.00

TABLE 1

First, compare Methods A and B. Listed in Table 1 are the various setup times, hourly production, and the estimated costs of standard tools and equipment and costs of special tools for each setup. Note that in Method B, the cost of special tools has doubled, while a considerable number of standard tools are required to obtain the increase in hourly production.

The factors which must be considered in determining whether Method B is a practical improvement over Method A are setup time, hourly production, depreciation allowance for standard tooling, and the number of pieces required to recover the cost of the special tools.

In Table 2, note that a synthetic production cost per hour of $4.24 and $4.37, is arrived at for Methods A and B. These figures, divided by the respective hourly production rates, result in a cost per piece for Method A of $.94 and a cost per piece for Method B of $.64. This is a net saving per piece of $.30, and if this figure is divided into the difference in special tooling costs *($165 less $80)*, it is determined that a total of 280 pieces are required to pay for the additional cost of the special tools.

However, this does not take into consideration the additional cost of setup time for Method B over Method A. Actually, for six setups this amounts to 6 × 18 minutes per setup, or 1.8 hours × $4.37 an hour which equals $7.87. Therefore, about 25 additional pieces must be produced at a higher production rate in order to recover the cost of the additional setup time, making a total of 280 + 25, or 305 pieces which must be produced to recover entirely the extra cost of the special tools.

Thus, it has been shown that if six 50-piece setups were made on the cover, the additional cost of special tooling could be repaid.

In like manner, Methods A an C or Methods B and C may be compared.

If Method C is chosen over Method A, then it can be proved that approximately 1,550 pieces are required to pay for the extra cost of special tools, making the same six setup allowance. About 2,500 pieces are required to prove out the difference in cost between Methods B and C.

Note that in all cases, the cost of the standard tools has been depreciated on the basis of four 2,000-hour years, or 8,000 hours. The fundamental idea behind the use of standard tools is that this type tooling is flexible and universal and may be applied with equal facility to a large number of jobs produced on the turret lathe. Of course, this is not usually the case with special tools which are normally charged against the job itself.

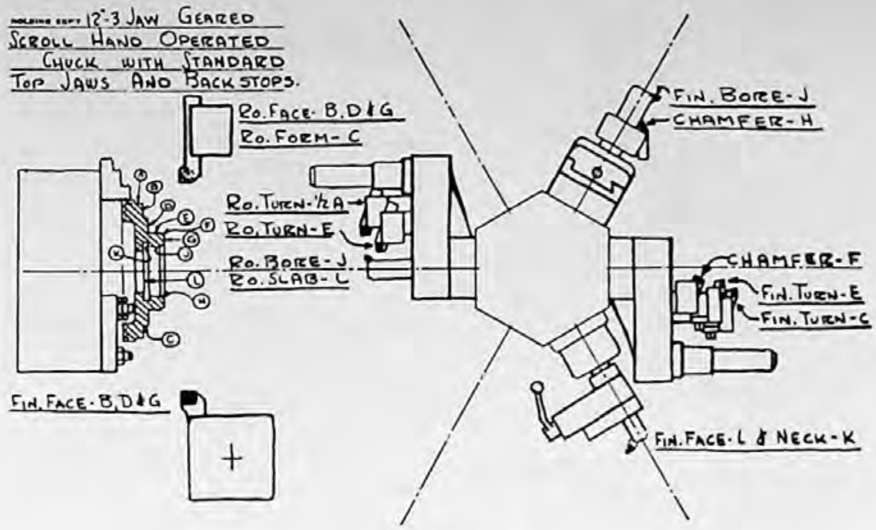


FIGURE 3a

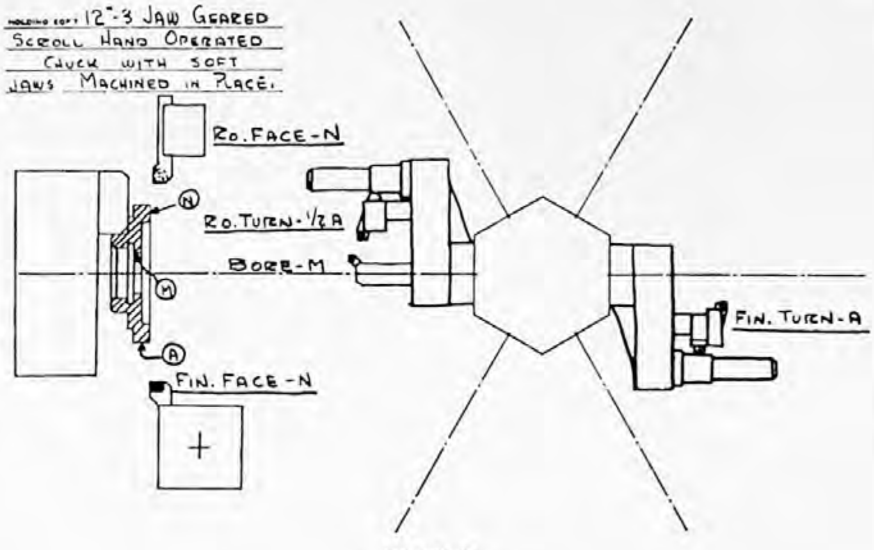


FIGURE 3b

This brings out the important conclusion that the method shown in Figures 3a and 3b *should be in wider use in more turret lathe shops.* For example, in spite of the rather heavy investment in standard tools, and the slightly higher cost of special tools, the hourly production has been boosted substantially enough to provide a quick payoff on the special tools—at the same time justifying the purchase of the standard tooling equipment for use on other jobs where it is likely the same ratio of production increase will apply.

For example, if this production increase is maintained on the average job produced with standard tooling, a mere total of 6,000 pieces of all kinds would be required to pay completely for the standard tools, in addition to the normal set-aside for allowable depreciation.

Another important conclusion drawn from this analysis concerns the period over which the number of pieces determined in the calculations need be produced.

For example, it was determined

METHOD	A	B	C
Cost of Standard Tools	$736.00	$1,810.00	$1,724.00
Hourly depreciation of standard tools (8000 hours)	$ .09	$ .22	$ .21
Hourly overhead rate (less depreciation)	$ 2.50	$ 2.50	$ 2.50
Hourly labor rate	$ 1.65	$ 1.65	$ 1.65
Total:	$ 4.24	$ 4.37	$ 4.36
Pieces produced per hour	4.6	6.8	16.5
Cost per piece	.94	.64	.26
Special Tool cost	80.00	165.00	1095.00

From: A to B

$165.00 -$80.00 = $85.00 ÷ $.30 = 280 pieces required to pay for specials

From: A to C

$1,095.00 -$80.00 = $1,015.00 ÷ $.68 = 1,490 pieces required to pay for specials

From: B to C

$1,095.00 -$165.00 = $930.00 ÷ $.38 = 2,450 pieces required to pay for specials

TABLE 2

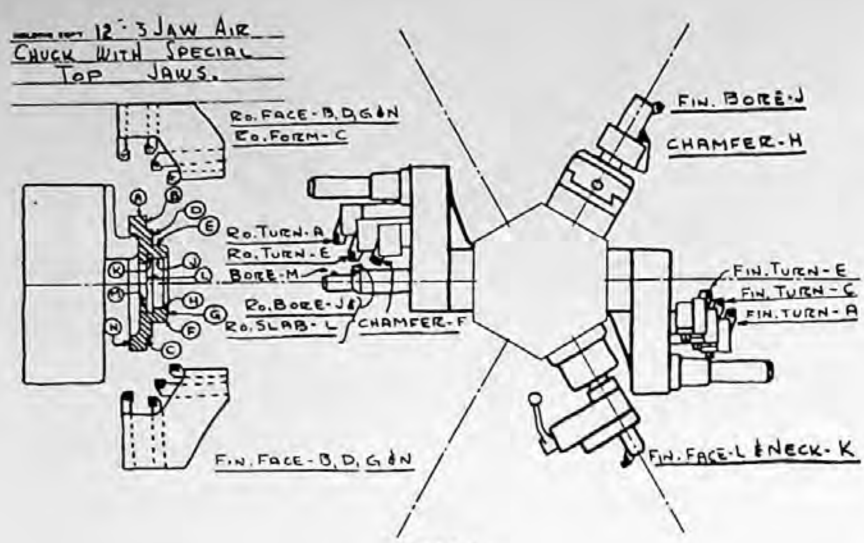


FIGURE 4

that about 2,500 pieces were required to pay for the special tools in the comparison between Methods B and C. This is only about one month's continuous production which would satisfy the most strict policy of tool cost recovery.

On the other hand if these pieces were only run at the rate of 100 per year, obsolescence of the part or tools undoubtedly might occur before a sufficient number of pieces could be run to repay the cost of the tools. Individual questions of this kind must be settled in reference to individual company policy and expected production requirements.

Still another factor has an important bearing on the selection of a proper tooling method. This factor concerns the *ability of the turret lathe and department "as tooled" to turn out the number of jobs required in the alloted time.*

Using the cast iron cover and the same three different kinds of setups as examples, the effect of *method* on capacity can be illustrated.

For example,. suppose two jobs a day for five days must be turned out in quantities listed in Table 3. For simplicity, assume that each job happens to be similar to the cast iron cover and is set up and produced at the same rates as each method—the only difference between jobs being the variable lot sizes.

		Method A			Method B			Method C		
		HOURS			HOURS			HOURS		
	LOT SIZE (PIECES)	SETUP	RUN	TOTAL	SETUP	RUN	TOTAL	SETUP	RUN	TOTAL
Monday	10	2.3	2.8	5.1	2.6	1.5	4.1	3.1	.6	3.7
	35	2.3	7.6	9.9	2.6	5.1	7.7	3.1	2.1	5.3
Tuesday	50	2.3	10.9	13.2	2.6	7.4	10.0	3.1	3.0	6.1
	15	2.3	3.3	5.6	2.6	2.2	4.8	3.1	.9	4.0
Wednesday	40	2.3	8.7	11.0	2.6	5.9	8.5	3.1	2.4	5.5
	20	2.3	4.4	6.7	2.6	3.0	5.6	3.1	1.2	4.3
Thursday	10	2.3	2.8	5.1	2.6	1.5	4.1	3.1	.6	3.7
	10	2.3	2.8	5.1	2.6	1.5	4.1	3.1	.6	3.7
Friday	5	2.3	1.4	3.7	2.6	.8	3.4	3.1	.3	3.4
	50	2.3	10.9	13.2	2.6	7.4	10.0	3.1	3.0	6.1
		Total Hours: 79.6			Total Hours: 61.3			Total Hours: 45.8		

TABLE 3

What effect have Tooling Methods A, B and C on the capacity of of the department to turn out these 10 jobs?

Reference to Table 3 shows that Method A would require 79.6 total hours. On a 40 hour week basis, this would mean the use of two machines or operation of a second shift.

Method B requires 61.3 hours or about 1½ machines or shifts, while Method C accomplishes the required work in 45.8 hours.

Here then is another important slant on the effect of tooling method on the cost of operations. As a matter of fact, Method C indicates that *on the basis of direct labor alone,* the wages of one operator for one year are saved, compared with Method A.

Several conclusions can be drawn from facts presented in this article:

1. Only the very smallest of lot sizes *(perhaps one to five pieces)* should be produced according to Method A *(short setup and low tool cost),* even though opportunity exists for multiple and combined cutting on the part.

2. Comprehensive standard tooling should be utilized to take full advantage of multiple and combined cutting on lot sizes ranging from five pieces upward. This should be done in spite of the *apparent* ill effects of longer setup time and time required for tool cost recovery.

3. Simple special tools such as cross slide cutter blocks, chuck jaws, boring bars, etc., more than repay their cost in overall savings and should be applied without hesitation to very modest size job lots.

4. Work types and flow through a turret lathe department should be *analyzed* to determine the overall kind of tooling setup best suited to the work. Use of this setup may, in isolated cases, henceforth produce at greater expense, but these cases will be greatly out-numbered by the jobs whose efficiency will be raised.

STANDARD VS SPECIAL TOOLING

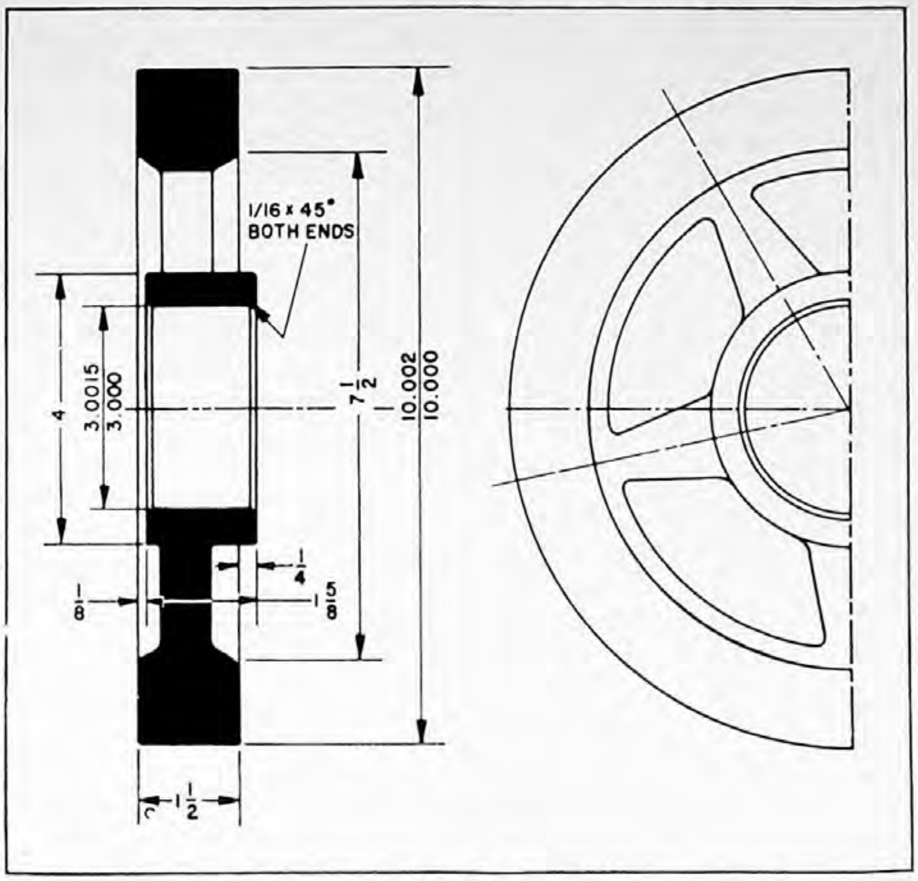


FIGURE 1

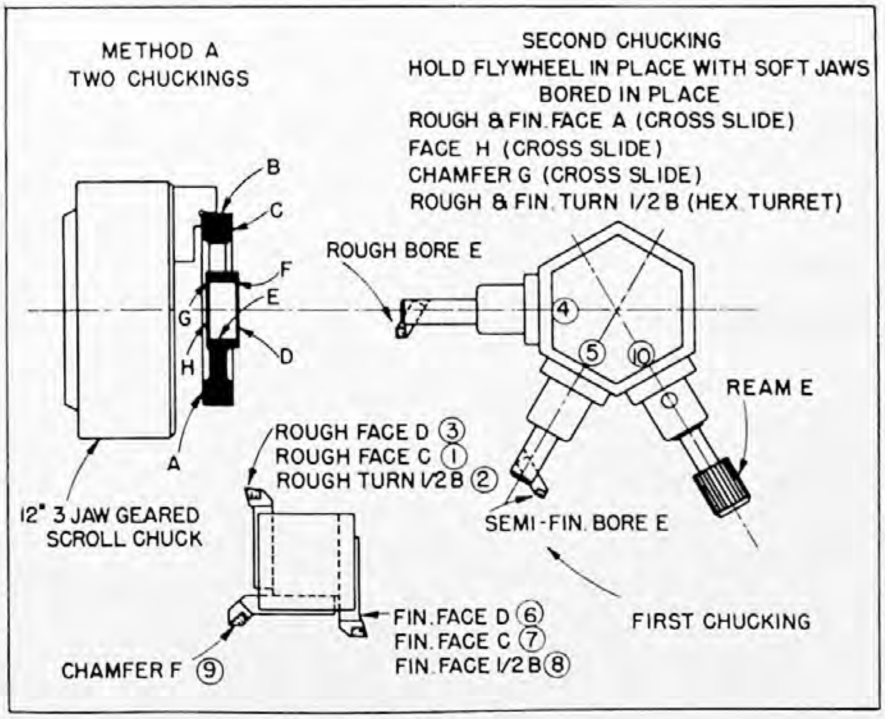


FIGURE 2

PART IV

Obtaining a bonus in turret lathe capacity by using proper tooling

THERE IS a simple way of adding an extra turret lathe or two to your present equipment without actually buying more machines! This is especially important at the present time when shops cannot augment equipment inventories fast enough to meet sudden increases in production demands.

You can get this bonus in turret lathe capacity *by tooling your machines properly.*

If this sounds like an old story, stop and think for a minute! Answer this question: how long would it take your shop to produce the cast iron flywheel in Figure 1—13 minutes — nine minutes — or 6-½ minutes?

Now ask yourself, "Would our time be the right time for our own shop conditions?" This question is not so easy to answer without some analysis and that is the purpose of this article: to illustrate the principles of multiple tooling on a typical job with data on how to identify the proper machining methods for your own shop.

Refer to Figure 2. Here is a simple two-operation method of producing the flywheel. It is a simple method but not necessarily a low cost method. Unfortunately, it is in common use in production shops where the usually exaggerated penalties of longer setup times and tooling costs serve to suppress the use of more extensive tooling methods.

Next refer to Figure 3, which illustrates another two-operation method, this time involving even more tooling costs and longer setup time.

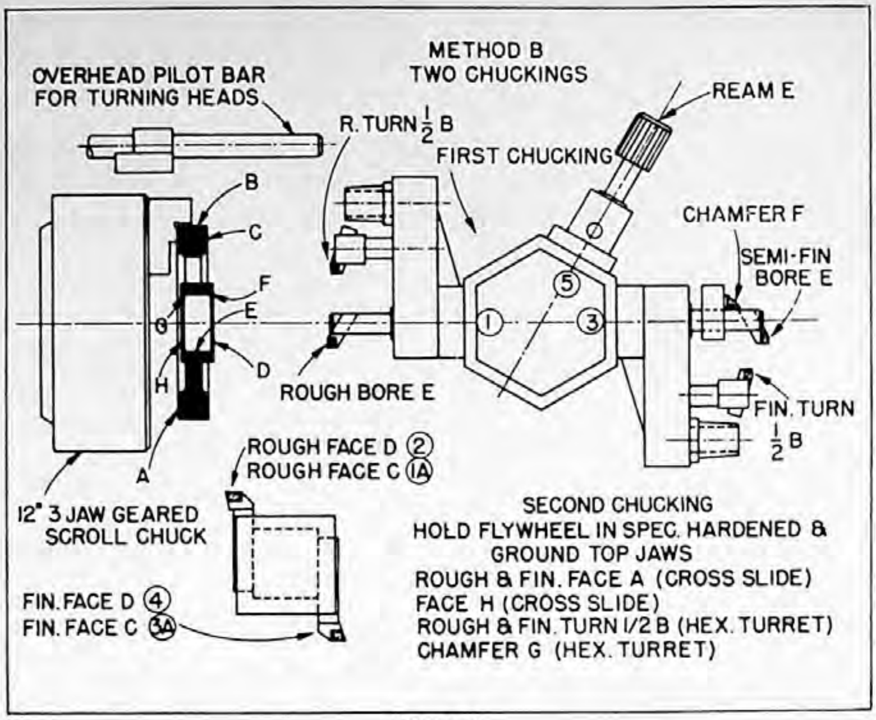


FIGURE 3

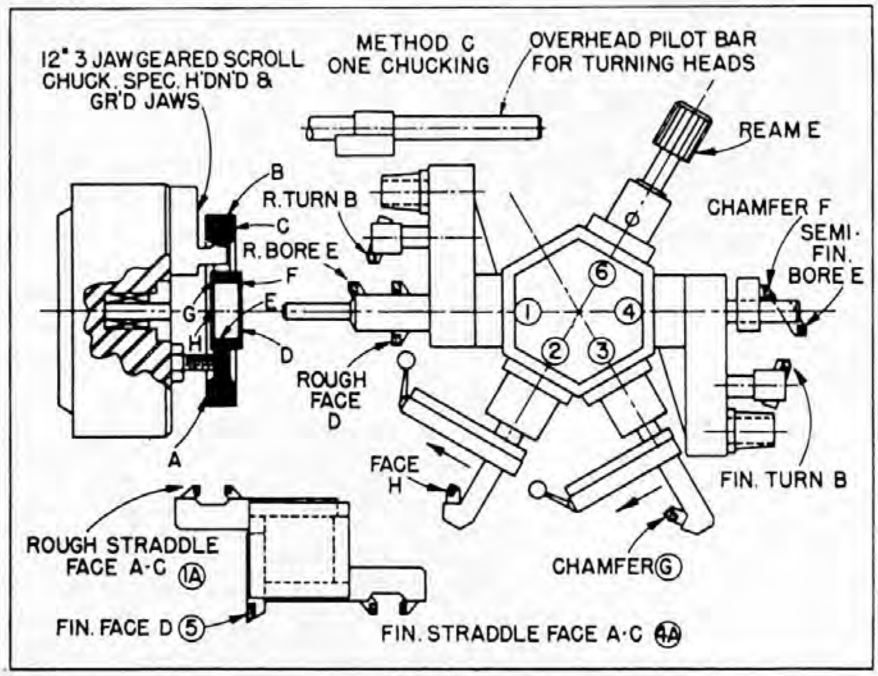


FIGURE 4

METHOD	TOOLING COSTS		FLAT TIME PER PIECE (Minutes)	SETUP TIME (Hours)
	Standard	Special		
A	$ 895	$ 95	13.6	2.6
B	$1,245	$ 233	9.0	3.2
C	$2,118	$1,568	6.5	3.4

TABLE 1

Also see Figure 4. This is a one-operation method which requires the most tooling expense and the longest setup time.

Table 1 compares basic facts about these three methods. Inspect this table carefully and note the relationship between production time, setup time and tooling costs for Methods A, B and C.

Now suppose for the moment your shop must produce this cast iron pulley for the first time and a choice of method must be made.

Consider first Method A, illustrated by Figure 2. While this setup satisfied some of the principles of good turret lathe practice and may thus appear to represent a good method, it is clear that the setup is not arranged to take full advantage of multiple cutting. In other words, all facing and turning operations are done from the cross slide while a bare minimum of cutting is performed from the hexagon turret. Nor does the sequence of individual cutting operations indicate any combination of cuts between the square and hexagon turrets.

As a matter of fact, it is difficult to visualize a more simple arrangement of tooling for the cast iron flywheel. Hence the setup time and tooling costs are low, and they therefore *seem* advisable for low or medium lot size production.

This type setup is very common; it is habit forming in regard to general turret lathe tooling practice, and it is therefore often responsible for a low rate of efficiency in turret lathe departments.

Now let us consider Method B, a two-operation method involving an additional investment of a few hundred dollars in standard tools and a slight increase in special tools, consisting mostly of cutters, and a set of special second operation hardened and ground chuck jaws.

A carefully considered analysis of

setup time indicates that the total time to set up Method B is 3.2 hours compared to 2.6 hours for Method A. Note however, that the tools in Method B are arranged to be used so that cuts from the cross slide can be combined with cuts from the hexagon turret, thus saving cutting time, and that cuts on the hexagon turret are arranged where possible in multiple, thereby saving both cutting time and machine handling time.

Thus, the reward for the slightly increased setup time in Method B over Method A is a reduction in the flat time per piece from 13.6 minutes to 9 minutes.

Observe that, as yet, these comparisons of setup times and production times together with tooling costs are meaningless and do not provide by themselves a sound basis on which to select either of the setups for any given shop conditions.

Before proceeding further with that type of analysis, refer to Figure 4, which illustrates Method C.

This is the type of turret lathe setup which is usually avoided by shops except those where the very highest of production lot sizes are produced. This setup again requires an increase in investment in standard tools and a substantial increase in special tooling.

The setup in Figure 4, however, is a good turret lathe setup. It is one which more shops should use.

First of all, by the skillful use of special tooling, the number of chuckings needed to produce the flywheel is reduced from two to one. Aside from the saving in actual production time, supplementary savings in parts storage and work flow accrue through the use of a one chucking setup compared to a method which requires two chuckings. These savings have not been considered in the cost analysis, to be discussed later in this article. They exist, nevertheless.

The machining method illustrated by Figure 4 is simply an extension of the principles brought out in Method B. The tooling on the square turret and hexagon turret is again arranged so that cuts from these two turrets can be performed simultaneously.

In addition, more cuts are arranged in multiple on both turrets. Use of straddle facing cutter blocks on the square turret permits back facing of the flange rim while the front face of the rim is being machined. This reduces cutting time and eliminates one of the machined surfaces calling for a second operation in Methods A and B.

The back face of the hub is machined with the quick acting slide tool and a special back-facing tool from the hexagon turret. The back chamfer is also machined from the hexagon turret. This means that the addition of these standard and special tools eliminates the need for a second operation and at the same time actually reduces the total work handling time and the cutting time.

Method C results in a flat production time of 6.5 minutes and requires a setup time of 3.4 hours.

We have now seen illustrated three basic turret lathe tooling methods for machining a typical casting such as the flywheel. These methods have been identified A, B and C and are in fact the A, B, C's of good turret lathe practice. No one method is better than the other two methods to the exclusion of those methods and the important consideration now becomes one of evaluating each method so that it may be applied where it can produce the most profit.

It should be repeated once again that it is often dangerous to shop efficiency to standardize tooling methods where parts are machined under *varying* conditions and that unless proper consideration is accorded the distinction between tooling methods, important savings are lost.

Refer now to Table 2. This is a table which summarizes some basic facts about Methods A, B and C. For the purpose of cost analysis, the factor of machine depreciation has been excluded. Eight thousand hours are used as the write-off period for standard tools; that is, four 2,000 hour years. Included in the cost per piece analysis is an assumed hourly overhead rate of $2.50 per hour and an hourly labor rate of $1.65.

On the above basis, the total hourly cost of operations is indicated in Table 2 for Methods A, B and C. Note that special tooling costs are not included in this hourly operating cost because special tooling cost is one of the basic factors used to justify the use of one method over another on the basis of the time which one method saves over another in machining.

Table 2 also indicates the production in pieces per 48 minute hour and the consequent cost per piece for each method.

A careful analysis of Table 2 indicates that if you chose Method B over Method A:

You can save 40 cents per piece.

It takes 345 pieces to pay for special tools.

It takes 6.75 pieces to recover the cost of the extra setup time.

The equivalent of 665 Method A machine hours are added to the shop per year per machine.

	METHOD A	METHOD B	METHOD C
Cost of Standard Tools	$895.00	$1,245.00	$2,118.00
Hourly depreciation of standard tools (8,000 hour write off)	$ .11	$ .16	$ .26
Hourly overhead rate (less depreciation)	$ 2.50	$ 2.50	$ 2.50
Hourly labor rate	$ 1.65	$ 1.65	$ 1.65
Total:	$ 4.26	$ 4.31	$ 4.41
Pieces per 48 minute hour	3.5	5.3	7.4
Cost per piece	$ 1.21	$ .81	$ .60

TABLE 2

If you chose Method C over Method A:

You can save 61 cents per piece.

It takes 2,415 more pieces to pay for the special tools than for Method A.

It takes 6.4 pieces to recover the cost of the extra setup time.

The equivalent of 1,328 Method A machine hours are added to the shop per year per machine.

If you chose Method C over Method B:

You can save 21 cents per piece.

It takes 6,310 more pieces to pay for the special tools than for Method B.

It takes 5.7 pieces to recover the cost of the extra setup time.

The equivalent of 500 Method B machine hours is added to the shop per year per machine.

The above tabulated information warrants close study and comparison with your own shop conditions.

Take setup time, for example. Note that between five to seven extra pieces are needed in transferring between setups to justify the extra setup time and additional tooling costs involved in the more complex setup.

This means that if a shop can produce as low as 10 pieces in a lot there is ample reason to select either Method B or C over Method A because the total elapsed production time is still less for Methods B and C even with the longer setup time.

Naturally any amount of production over the basic number of pieces needed to justify the extra setup time and tooling cost is the profit producing margin and the saving per piece may then be fully realized.

Note at this point how the number of pieces to be produced influences the selection of method. This is the total number of pieces to be produced before obsolescence of the work piece occurs, or the end of tool life is reached.

For example, at least 345 work parts must be produced by Method B to justify the extra cost for special tools compared to Method A.

If Method C is chosen over Method A, then at least 2,415 pieces must be produced eventually before obsolescence of the work piece or tool life is reached, in order to pay for the extra cost of the special tools.

Note how comparatively modest these *total* production quantities are.

Now for an important point often overlooked in cost analyses.

Entirely aside from the elements of tool cost recovery, amortization of setup time, and savings per piece, faster producing setups which can be justified on the above basis also add machine hours to a turret lathe department without adding additional machines.

For example, if Method B is chosen over Method A, this is the equivalent of adding 665 Method A machine hours to the shop per year per machine. In other words, the amount of work produced in a 2,000 hour year by Method A can be accomplished by Method B in 1,500 hours.

This means that an additional 500 hours on the machine are available during the year to produce work. Remember that work is produced during this remaining 500 hours not at the efficiency level of Method A but at the increased efficiency of Method B.

In other words, 2,665 Method A machine hours are needed to produce the same quantity of work which one machine working 2,000 hours can produce with Method B. Obviously, if 2,665 work hours per year are needed, this involves either second shift operation, often at premium rates, or the addition of another turret lathe.

A corresponding comparison can be made for Method C over A and for Method C or B.

While we have been keeping in mind a *unit* machine comparison, visualize how these savings are multiplied in a turret lathe department where many machines are involved.

These setups illustrate *principles*. While your shop may not be producing a cast iron flywheel such as indicated in Figure 1, the principles by and large apply to all turret lathe work. It behooves persons responsible for turret lathe operations to cast aside temporarily, existing concepts of shop operations on turret lathes and determine for themselves which of these tooling methods actually suits their shop conditions.

Remember this:

1. Only the very smallest of lot sizes (*perhaps 1 to 5 pieces*) should be produced according to Method A (*short setups and low tool costs*) even though opportunity exists in the shape of the work for multiple and combined cutting.

2. Comprehensive standard tooling should be utilized (*See Method B*) to take full advantage of multiple and combined cutting on lot sizes ranging from approximately five pieces upward. This should be done in spite of assumed though probably non-existent penalties of the longer setup time and time required for tool cost recovery.

3. Simple special tools such as cross slide cutter blocks, chuck jaws, boring bars, etc., more than repay their cost in over-all savings and should be applied without hesitation to very modest size job lots.

4. Work types, and the flow of work through a turret lathe department, should be analyzed to determine individual tooling methods according to classes of work. If the kind of jobs produced are uniform, then a uniform tooling method may be used, otherwise profits can only begin with the specialization of the tooling approach.

5. Use the idea of improved tooling to get the most out of your existing equipment before undertaking the purchase of additional machines.

SPECIAL TOOLS

PART I

A case story of how good tool design reduced tooling cost for a wide range of similar parts

Maximum production, in spite of small lot quantities, is achieved on the cast iron housings shown in Figure 1, by a unique arrangement of special tools which is flexible enough to apply universally to all sizes of housings shown.

As the composite drawing indicates, the housings range in overall size from 8¾ to 15⅛ inches in diameter and 5¼ to nine inches in length. The principal bore varies in size from 6⅝ to 11⅜ inches.

The tooling arrangement used to produce this series of housings is of interest to both the tool engineer and the shop management. Designs which permit borrowing special tools between sizes, the chuck jaw and fixture design, and the tool method, are of interest to the tool engineer because the system may be applied to many similar parts produced in shops where shapes remain the same but sizes vary. Shop management will find this tooling arrangement interesting because production performance can be obtained through special tooling on small lots, at the same time maintaining low setup time in changing from one job to another.

Figure 2 illustrates the general appearance of the first operation tools mounted in place on a large saddle-type turret lathe. Figure 3 is the schematic tooling arrangement which indicates the various cuts taken on one size housing.

In the first operation, these housings are held in special chuck jaws. Figure 4 is a close-up view of these jaws. It will be noted that all three jaws rock or adjust themselves to the cast periphery of the part in a plane parallel to the face of the chuck. Replaceable tool steel blades are fitted into the chuck jaws and gripped by means of wedges so the sharp edge of these blades can be adjusted slightly to cover a range of work peripheries, and can also bite into the chilled interior of the part for firm gripping.

In effect, the distance between the two blades in each jaw provides six widely spaced gripping points. This distributes the chucking pressure over a wider area and minimizes the possibility of distortion in the principal bore of the work. Notice that sponge rubber seals are applied between the rocking section of each jaw and the fixed section of the master jaw to exclude cast iron grit and thus assure free movement of the jaws.

The chuck itself is fitted with an anti-friction pilot bushing to support the piloted boring bars. The design of the piloted boring bars in

FIGURE 1

Stations 1, 3 and 4 of the hexagon turret *(See Figure 3)* utilizes a basic boring bar body to which replaceable tool blocks are bolted, depending upon the number of tools to be supported by the bar and the size of the bore to be produced during the setup. The closeup view in Figure 4 illustrates how these blocks fit in place on the boring bar.

One of the more unusual features of this tooling is the link-type contour turning slide tool. Such a tool is used in Stations 1 and 3 of the hexagon turret for rough and

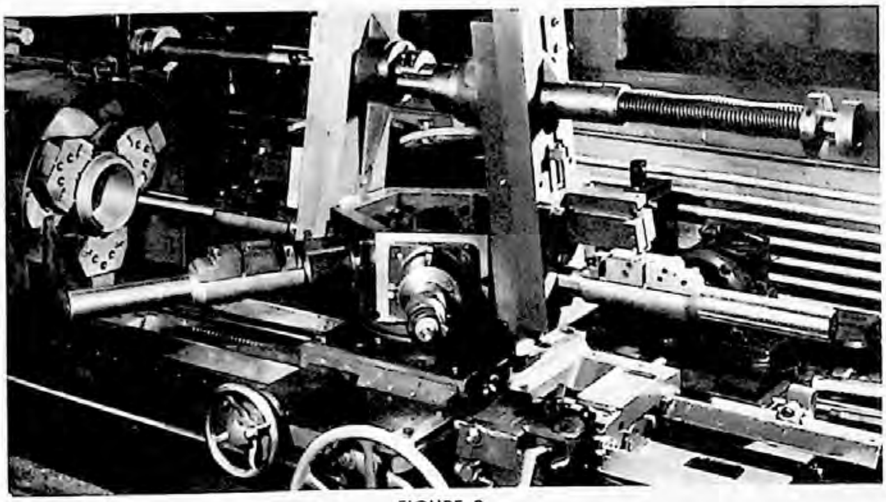


FIGURE 2

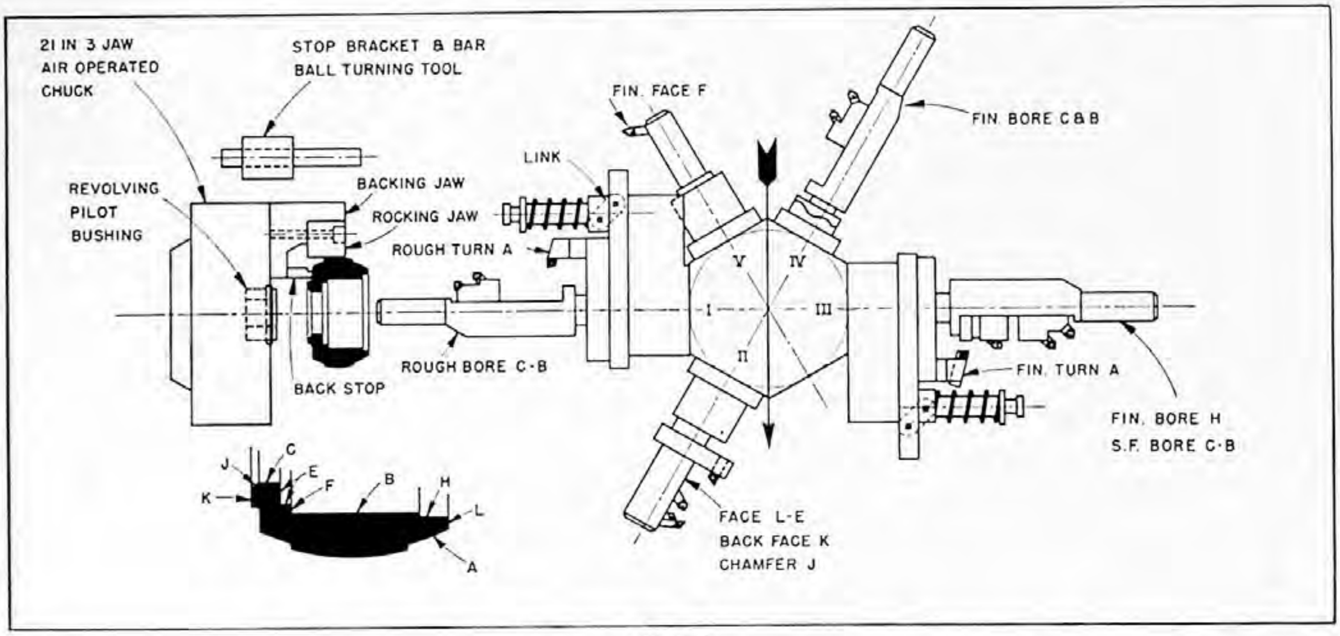


FIGURE 3

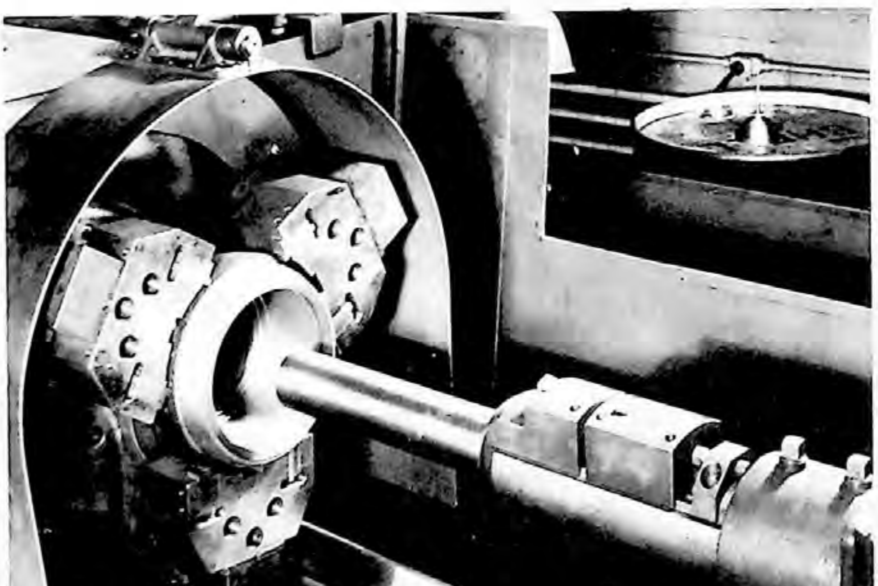


FIGURE 4

finish turning the spherical surface on the outside of the housing. The slide tool operates in this manner:

As the hexagon turret is advanced toward the work, the overhead bar in the slide tool impinges on the stop bracket and bar which is mounted on the head of the machine. Further forward motion of the bar is therefore arrested, while the feeding motion of the hexagon turret can continue toward the work.

A link is attached between the sliding section of the slide tool and the overhead slide bar. Therefore, as the hexagon turret continues to feed forward, the end of the link which is attached to the overhead bar ceases its forward motion and becomes a fulcrum about which the other end of the link rotates. Since this other end of the link is attached to the movable part of the slide tool, it causes that part of the slide tool to execute a spherical path of travel. Inasmuch as the tool block is mounted to the moving part of the slide tool, the correct contour is thus generated on the surface of the work.

Close inspection of the slide tool construction in Figure 2 shows how the turning tool is mounted in a block to the front face of the slide tool. This block is adjusted by a screw in a vertical direction so that the range of spherical diameters for the work shown on the composite print can be obtained with the same tool.

In Station 1 of the hexagon turret *(See Figure 3)* the piloted boring bar roughs out bores C and B, while the slide tool rough turns the spherical segment A. Observe that the shank of the piloted bar extends through a slot in the sliding member of the contour tool and is gripped in the body of the contour tool.

In Station 2 of the turret, a special cutter bar straddle faces surfaces K and E, forms diameter E and faces surface L. *(Note the excellent application of a cross sliding turret machine to this work.)* The utmost parallelism can thus be established between these faces by virtue of simultaneous facing in one setting. At the same time, use of one boring bar for a range of

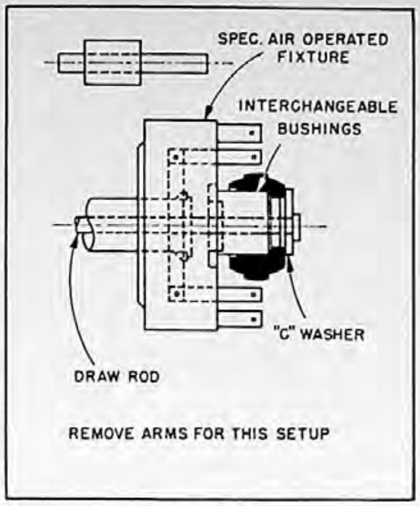


FIGURE 5

diameters is permitted by the adjustability of the cross feeding turret.

In Station 3 of the hexagon turret, the spherical periphery A is finished turned and bore H is finished. Bores C and B are also semi-finished in preparation for the final boring cuts which are taken at Station 4 with another piloted boring bar.

A final sizing cut is taken on Face F from Station 5 of the hexagon turret.

Figure 5 illustrates the work holding method for finishing the other end of the housing. All that remains to be accomplished on the part in this chucking is the rough and finish turning of the other side of the spherical diameter. The same two contour slide tools are used in this operation.

The work is gripped in the second operation on interchangeable bushings, which, in turn, fit to an air-operated drawback arbor. Location is taken from the large accurate bore in the part which is machined in the first chucking. The loading tool shown in Stations 1 and 4 of the hexagon turret permit squaring up the part as it is pushed onto the arbor.

The schematic sketch of the fixture used in this operation indicates that certain arms must be removed for the setup. The reason for showing the fixture in this manner is that the same fixture is used for another style of housing *(See Figure 6)* wherein the work is held onto the arbor by outside fingers rather than by a C washer as in Figure 5. Thus, the same fixture is utilized for both styles of parts, whether the work is gripped by the C washer or by the outside fingers.

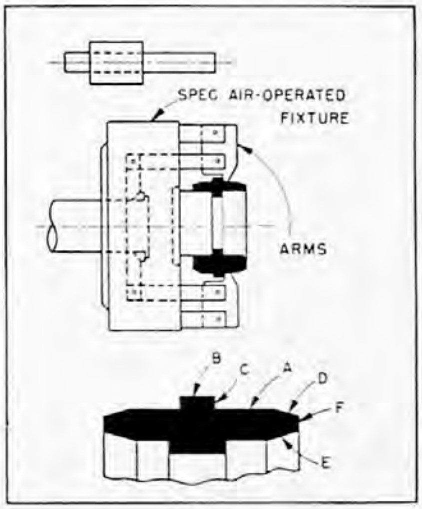


FIGURE 6

SPECIAL TOOLS

PART II

A case story of good tool design and the benefits of putting the job on a hand operated turret lathe

THE ENGINE mount housing in Figure 1 is machined from an SAE 6150 steel casting. It is an ideal turret lathe job for two reasons. The shape of the casting requires a specially designed holding fixture, and the "hand feel" procurable with a turret lathe is important in the elimination of tool withdrawal marks and poorly matched surface junctures. These surface qualities are necessary because the housing is subject to extreme functional stresses.

It is apparent from the work sketch that the thin walls of this casting and the presence of the angular appendage create an unusual gripping problem. Experience with work of this kind indicates that the properly designed holding fixture must provide for basic location from the angular appendage and supplementary clamps to grip the part on the wall area firmly enough to locate and support, but not severely enough to introduce distortion.

A hand clamping fixture is the only type of holding device compatible with reasonable cost which can be adapted to a job of this kind. Figure 2 is a sketch of this fixture. The extension, which is cast on the work at a 55-degree angle to the main part of the housing, is gripped in the fixture by the Compensating Clamp A, while a series of fixed and adjustable Back-Up Screws B are used to locate the casting in the fixture longitudinally.

The gripping action on the cast extension automatically locates the housing radially in the fixture but a set of three screw-adjusted Compensating Clamps C are brought to bear on the rim of the casting to give further radial adjustment for stock distribution and to provide support for the part during removal of the substantial stock allowance. These rocking clamps adjust themselves to the uneven periphery of the rim and, in addition, space the chucking points so that adequate pressure can be applied to the work without affecting the roundness of the internal surfaces. Two screw-adjusted toe clamps are brought to bear on opposing ears of the casting as an additional precaution against slippage of the work under the heavy cuts.

In effect, this fixture allows the part to be gripped at six points, all compensating, while six additional contact points back up the work against cutting end thrust. This type of work suspension is difficult to achieve in an automatic or

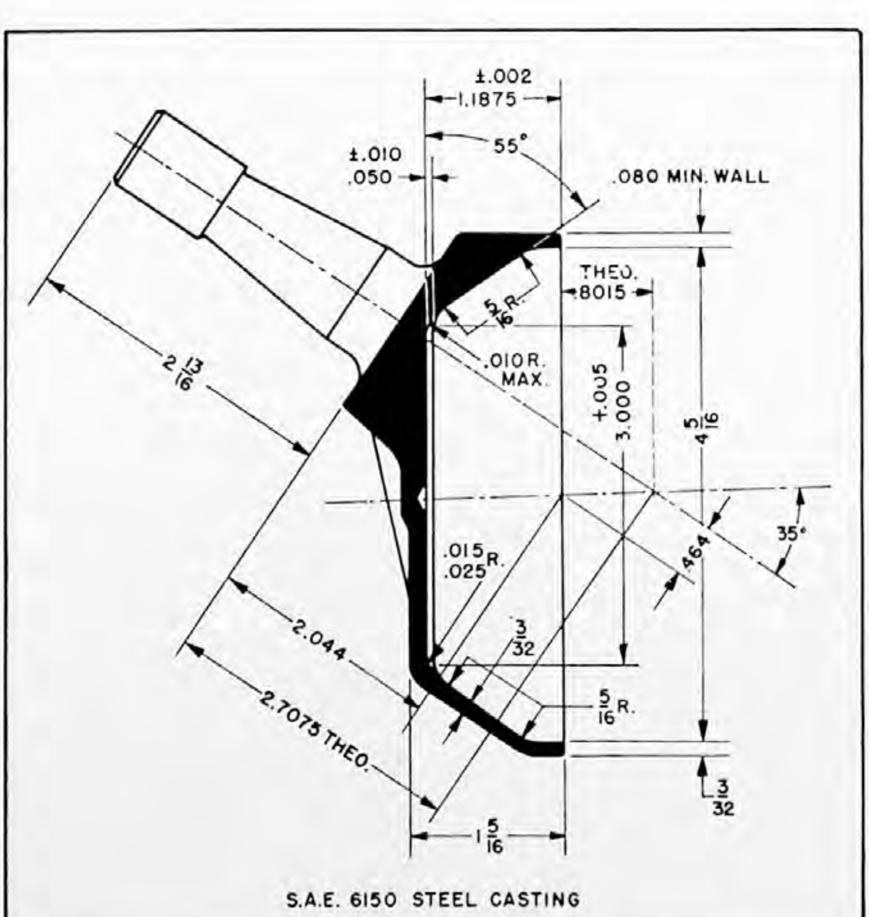


FIGURE 1

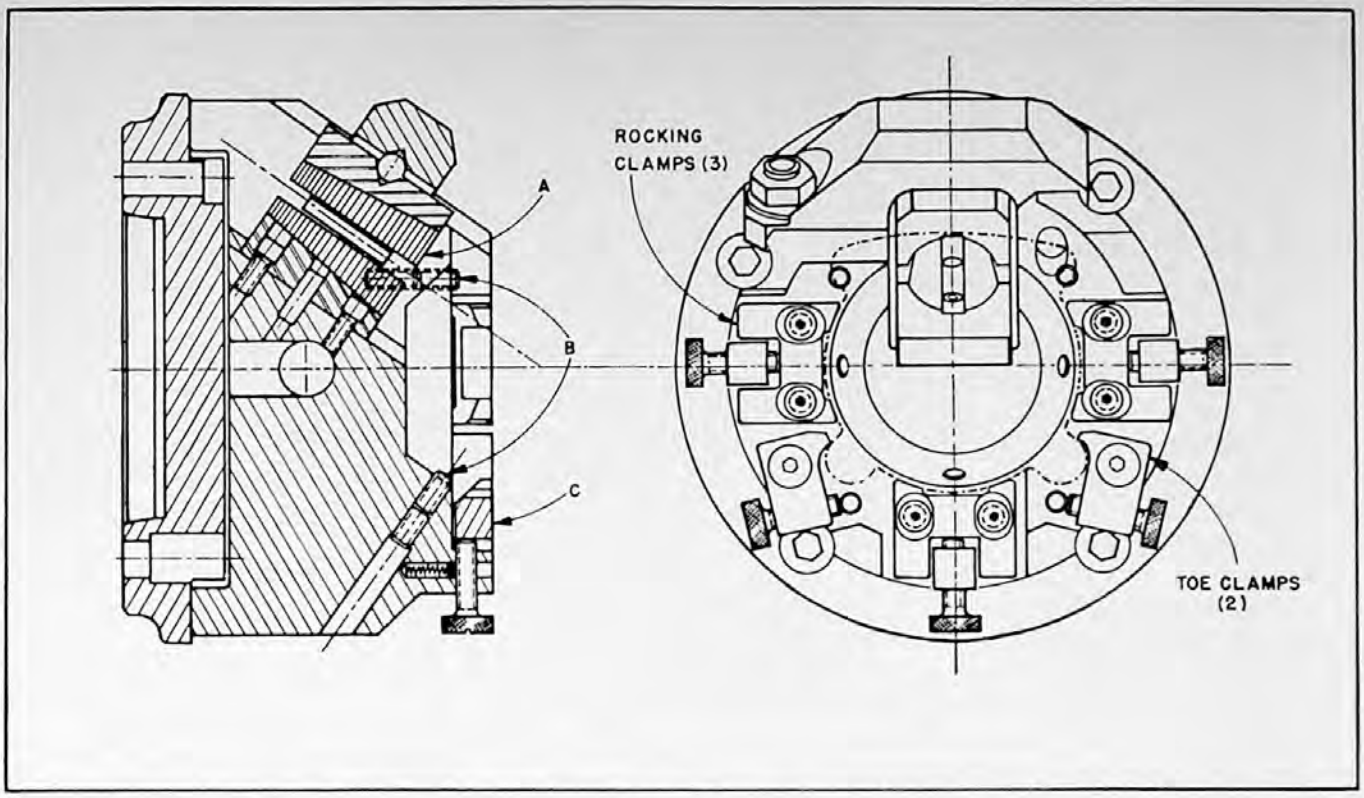
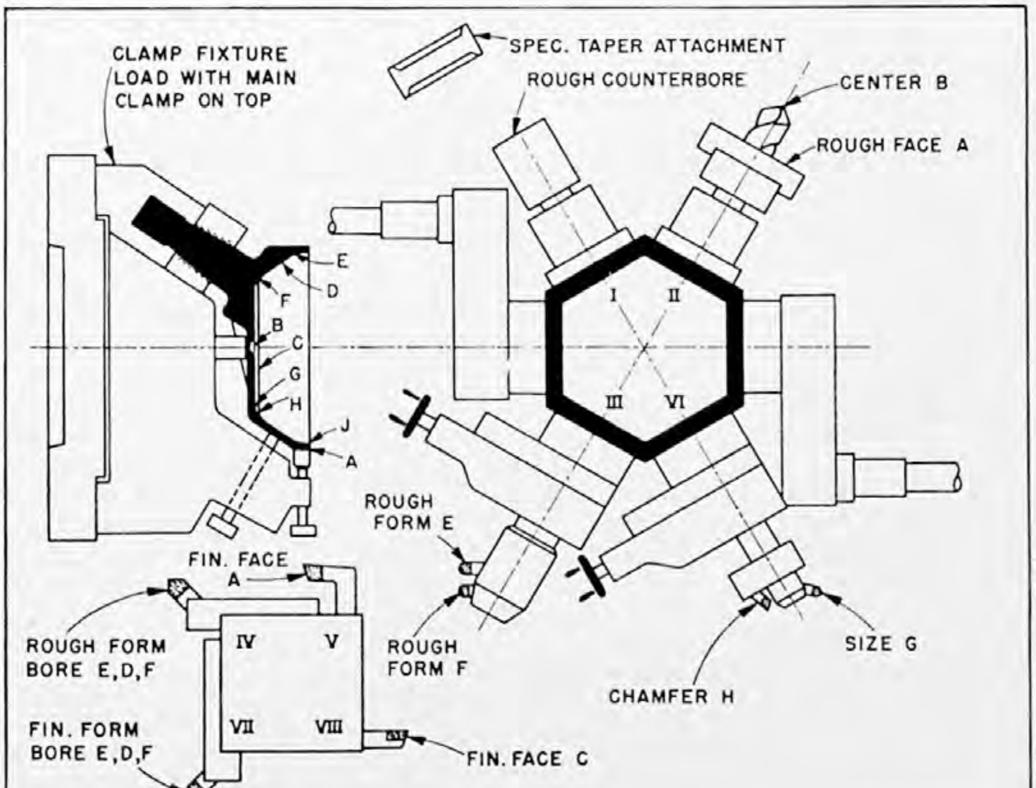


FIGURE 2

power-operated fixture or chuck, and while the manual loading and unloading time is longer, not all of the clamps must be adjusted for each part during the run of the job. That is, for any given lot of castings, the stock runout will be so nearly alike from piece to piece that only those clamps necessary to get each part in and out of the fixture need to be operated.

Figures 3 and 4 illustrate the tooling used to produce this part. The Roman numerals designate the sequence of necessary operations. No tools are mounted in the two multiple turning heads. They are part of the permanent standard



← FIGURE 3

tooling setup applying to other work in the same job series as the motor housing.

A large two-flute end mill is mounted in Station I of the hexagon turret for rough facing Surface C. This is followed by a center drilling and slab facing tool mounted in Station II of the hexagon turret. The center drilling tool serves to relieve the center of the flat bottom for subsequent machining and at the same time supports the slab facing cutter against weaving. In Station III a special two-slot tool block is mounted in a vertical slide tool for rough forming Surfaces E and F. It must be understood that a substantial amount of stock must be removed from the interior of the engine mount housing and this requires a *series* of cuts to reduce the surfaces to finished size.

Operation IV is performed from the square turret in conjunction with a special taper attachment. The tool in Station IV is supported by a special overhanging tool block so that Surfaces E, D and F can be reached. The arrangement of *all* tools in the square turret requires that the tools for roughing and finishing Surfaces E, D and F be used on the rear side of the spindle center line. Thus, the slots in the tool blocks are designed to mount the tools upside down. After the completion of these roughing cuts, the internal surfaces are ready for the final finishing operation.

Operation V consists of facing the rim of the part from a bent nose tool mounted in the indexing square turret.

Operation VI consists of a size boring cut and chamfering cut on Surfaces G and H taken from the respective positions on the hexagon turret.

Station VII is on the square turret and consists of another special tool and block. Surfaces E, D and F are finish form bored in this position, again with the help of the special taper attachment.

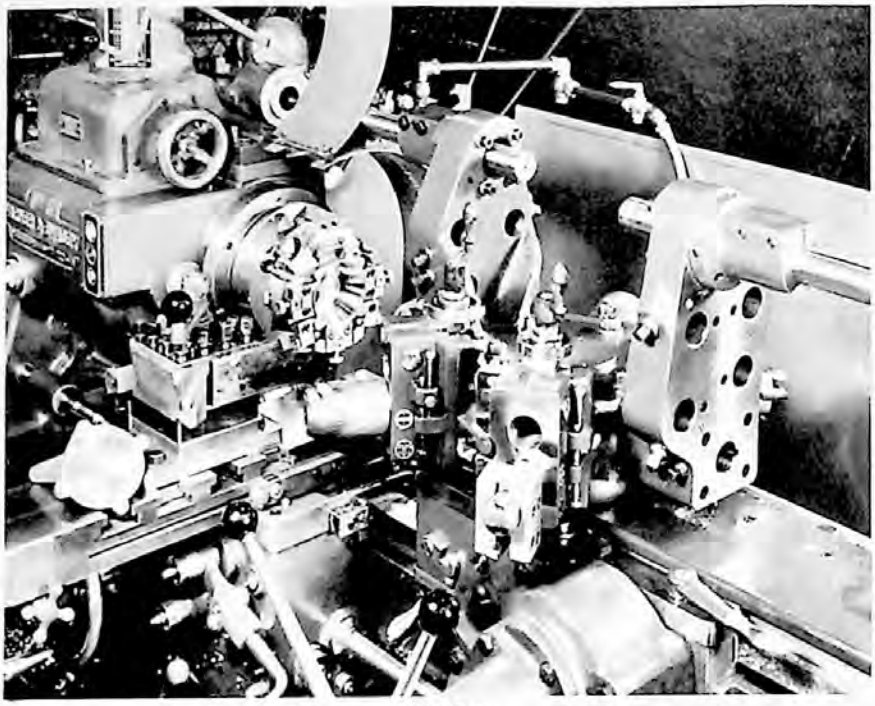


FIGURE 4

The last operation on the part is performed in Station VIII and consists of finish facing Surface C.

All tools, with the exception of the two-flute end mill in Station I of the hexagon turret and the center drill, are carbide-tipped.

Some publicity has been rightfully accorded the value of choosing the proper tools for a given job, depending upon the number of pieces in the run and other factors. The machine itself should be analyzed in like manner. The economics of tool and machine selection are important for any job which can to all intents be done equally well by several methods.

However, the job described in this article is an excellent example of how the hand turret lathe provides superior results through retention of manual control for a long run job which, at first glance, seems adaptable to an automatic. Tool life is extremely critical on a job of this kind, hence the maintenance of work finish, since it is a function of tool life, must be closely watched at all times. When machining under those conditions, the hand-operated machine is normally the best choice.

While an analysis based on the economics of job placement could be made on this part when produced on hand versus automatic machinery, it would be difficult indeed to evaluate for this job the cost of possible scrap and tool maintenance down time on automatic machinery. These latter factors would have a decided effect on the choice between the hand and automatic machine.

SPECIAL TOOLS

PART III

An example of how highly specialized tools may still be economical on small lots

Highly specialized tooling may be economically applied to turret lathe jobs produced in relatively small lots if the jobs are complex and have a large variety of machined surfaces and handling problems.

The two-inch tandem seat valve body *(See Figure 1,)* is an example of such a job. Previous methods of producing this valve body required several operations on vertical turning equipment using standard tooling.

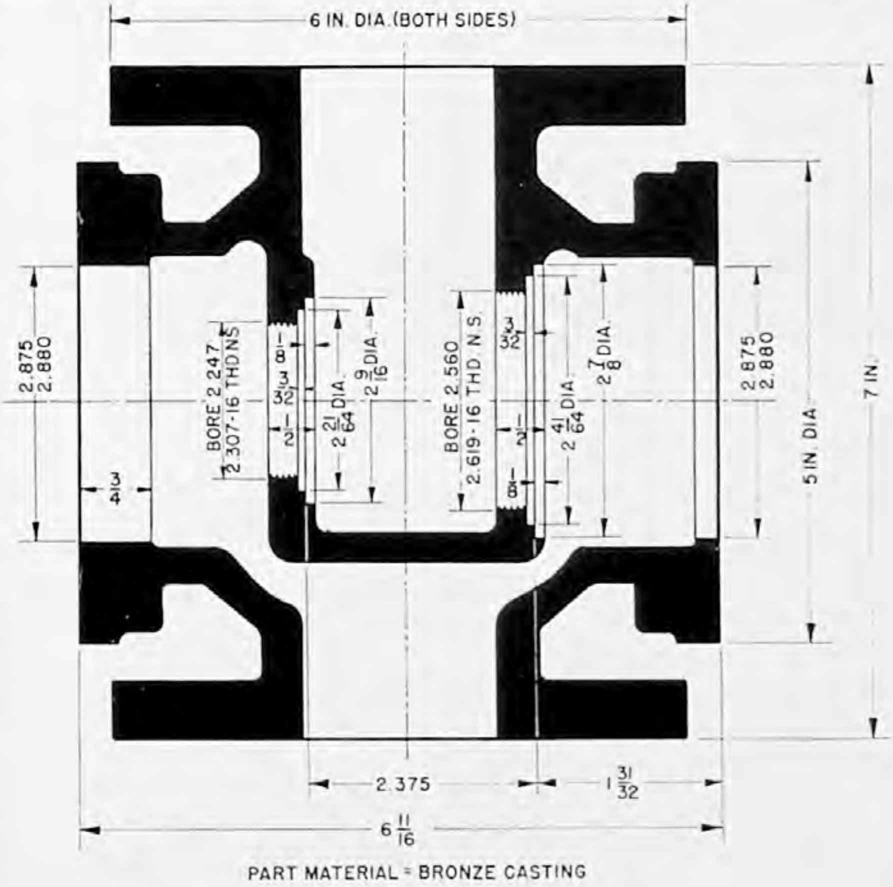
Consequently, a system of tooling on the horizontal turret lathe was proposed which could produce the valve body in one handling. This proved to expedite the flow of work through the shop and to cut machine time by virtue of consolidating many cuts, previously performed in separate operations, into one operation.

The sketch of the flanged valve body indicates machining on all four ends, as well as on the two valve seats after they are assembled to the body, as one of the operations during the turret lathe cycle. The need for holding the close dimension between the valve seats is of utmost importance in machining the valve.

The valve body is gripped in a special two-jaw indexing chuck so that each of the four ends of the part can be presented in turn to the turret tooling. A holding method of this kind allows the surfaces on each end to be maintained in relation to one another, and, in addition, produces a finished part for each cycle of the machine. This expedites production flow. That is, once the rough castings have been completed in the turret lathe operation they may be carted from the machine, thus alleviating storage problems, repetitive handling into the machine, etc.

The basic theory of doing all four ends in the one turret lathe operation, however, complicates the arrangement of tooling due to the increased number of surfaces to be machined.

This requirement was solved by selecting a Warner & Swasey 3A turret lathe equipped with a cross sliding hexagon turret. This permits several different cutting tools to perform boring operations on many different size bores, thus multiplying the end use of each cutting tool



PART MATERIAL = BRONZE CASTING

FIGURE 1

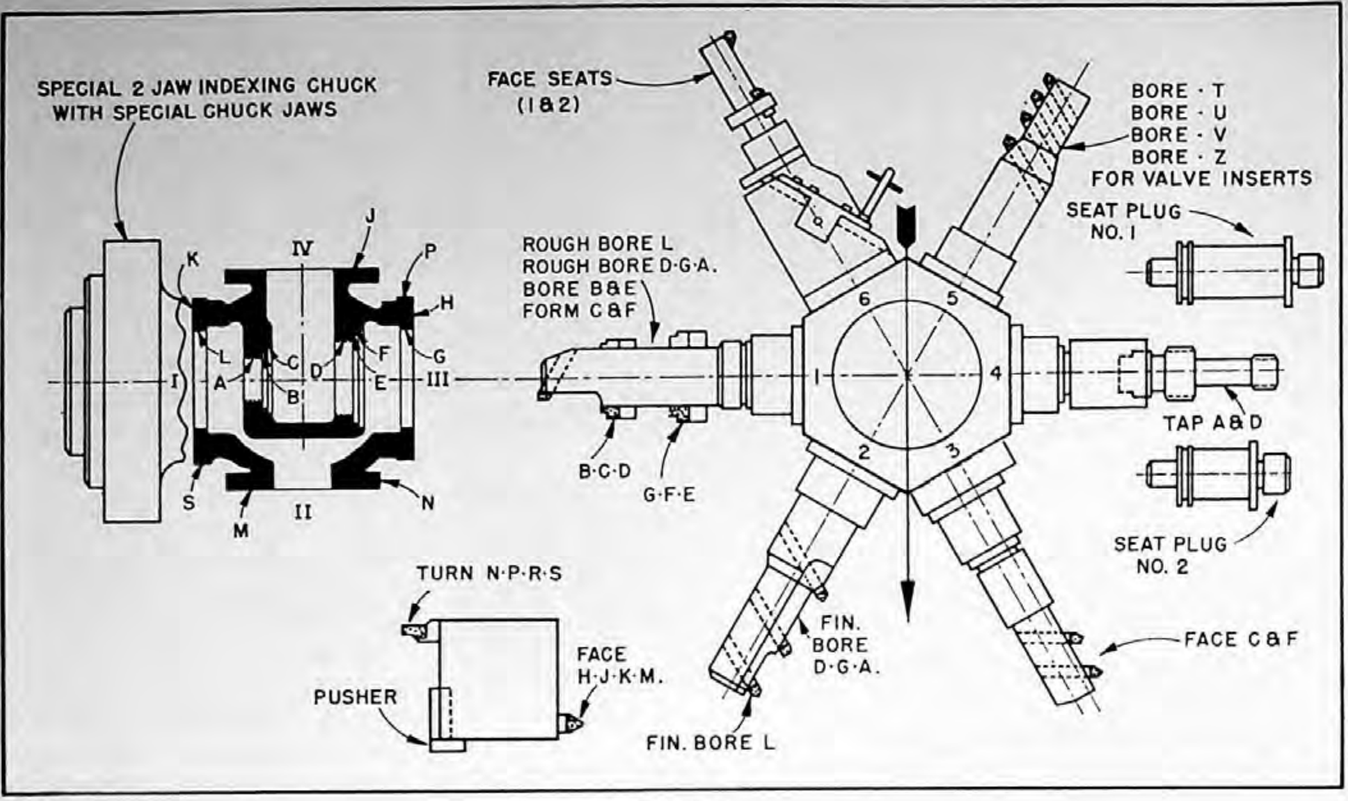


FIGURE 2

and reducing the number of tools or tool stations required.

A schematic sketch of the tooling arrangement is illustrated in Figure 2. In Station 1 of the hexagon turret, *(See Figure 3)* a special boring bar carries a single point tool as well as two flat blades with cutting edges balanced on each side. These turning tools as well as all other tools in the setup are carbide-tipped.

The front bit in the bar in Station 1 is used to rough bore Surface L on Face I of the valve body when that face is presented to the hexagon turret for machining. Surface K is faced from the square turret. The front bit in the bar in Hexagon Station 2 is used to finish bore L. Flange S on Face I of the part is turned with the special carbide turning tool in the square turret as are the other Flange Diameters P, R and F. The square turret cutting tool previously mentioned also faces Surfaces J, K and M on the other sides of the valve body as they are indexed into position.

Face II of the valve body is next indexed to position and the diameter and face of the flange machined with tools held in the square turret as previously described.

Next, Face III of the valve body is indexed into position for machining. This position of the part is illustrated in Figure 2.

When Face III of the part is presented for machining, the special boring bar in Station 1 of the hexagon turret is used once again, this time to rough bore G. Then, the hexagon turret is moved to the spindle center line and the front bit in the bar is used to bore A while the flat blades are used to bore and form surfaces B, C, D, G, F and E.

Next, the boring bar in Station 2 of the hexagon turret is indexed into position and surface G is finish bored after which the turret is moved to the center line of the work and finish cuts are taken on Bores D, G and A. Next, the tandem facing bar in Station 3 of the hexagon turret is indexed into posi-

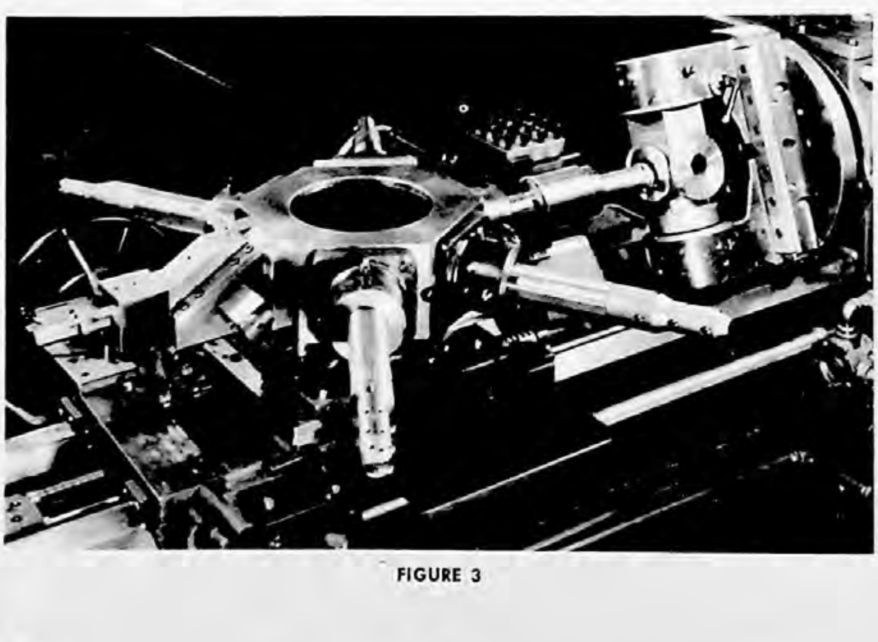


FIGURE 3

tion and advanced into the part so finish facing cuts can be taken on Surfaces C and F. These are the faces against which the valve inserts align themselves and this facing cut is necessary to insure squareness of the seats with the axis of the valve body. Here also is an excellent application of the cross feeding principle of the hexagon turret in that these facing cuts may thus be taken under power feed while the turret feeds away from its normal center line.

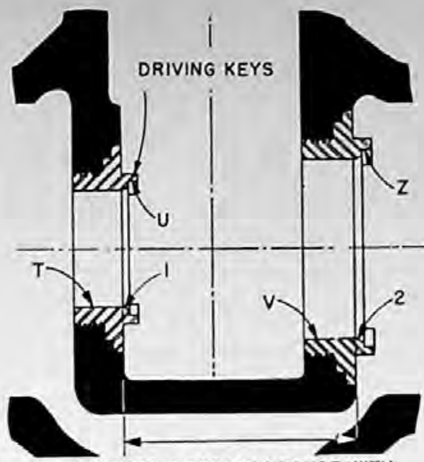
Station 4 of the hexagon turret is then indexed into position. A multiple disc friction-type tool holder is mounted in this station. This tool holder may be adjusted for various driving torques, depending upon the requirements. In this case, a tandem tap is mounted in the tool holder for threading Surfaces A and D. The friction tool holder is also used for driver plugs *(See Figure 2)* which serve to assemble the valve seats that were semi-finish machined in another operation, into the valve body. Once the valve insert threads are machined in this station and the inserts assembled to the valve body, the hexagon turret is indexed to Station 5.

In Station 5 is mounted a special boring bar for finish boring surfaces T, U, V and Z, the bores in the valve inserts themselves *(See Figure 4)*.

The final operation on this face of the valve body involves machining the taper seats, which are spaced to an exceptionally close tolerance.

There are several tooling methods possible, such as the use of a tandem reamer, etc., to hold this extraordinary tolerance but the tool illustrated on the schematic setup and in Figure 4 was selected because it involves simple carbide bits. Individual bits are easier to grind and less expensive to stock, and also permit single point generation of the seat surfaces, which is considered superior to the forming method.

Figure 5 is a closeup view of the angular seating tool used in this



HOLD TO ±.000 TOLERANCE WITH CUTTING TOOLS SPACED TO TOOL ROOM GAGE

FIGURE 4

station of the hexagon turret.

Note that the bar mounted in the fore-part of the tool holds the turning tools for machining the seat. These tools are set in the tool room in the exact position relative to one another and then the bar is transferred to the turret lathe tool holder. It is then a simple matter to move the bar in and out of the tool holder to establish the relation of the two seats to the rest of the valve body.

The part of this tool in which the bar is held constitutes a slide which moves up and down at the same angle as the path of turning tool travel across the seat inserts. The slide is housed in the main part of the tool body, which is bolted to the face of the hexagon turret.

A cam block is fitted at right angles to the tool slide and this cam is pushed from the front of the tool holder by a bumper held in the square turret. The cam track within the cam slide is set at 15 degrees so that, for every .001-inch of feed of the cross slide, the tool slide in the angle tool holder feeds at a rate of .000268-inch per revolution. This means that a very fine feed can be applied to the tool slide which holds the seat cutting tools.

The purpose of the "T" wrench is to permit the operator to lock the tool slide after it has progressed across the face of the seats. Thus, the turning tools can be retracted out of the valve body without marring the seat surfaces. When the tools are withdrawn from the work, the "T" wrench is loosened and the spring in the slide tool returns the bar in its slide to the initial starting position.

The face and flange diameter of Face IV of the valve body are machined with the square turret tools previously described.

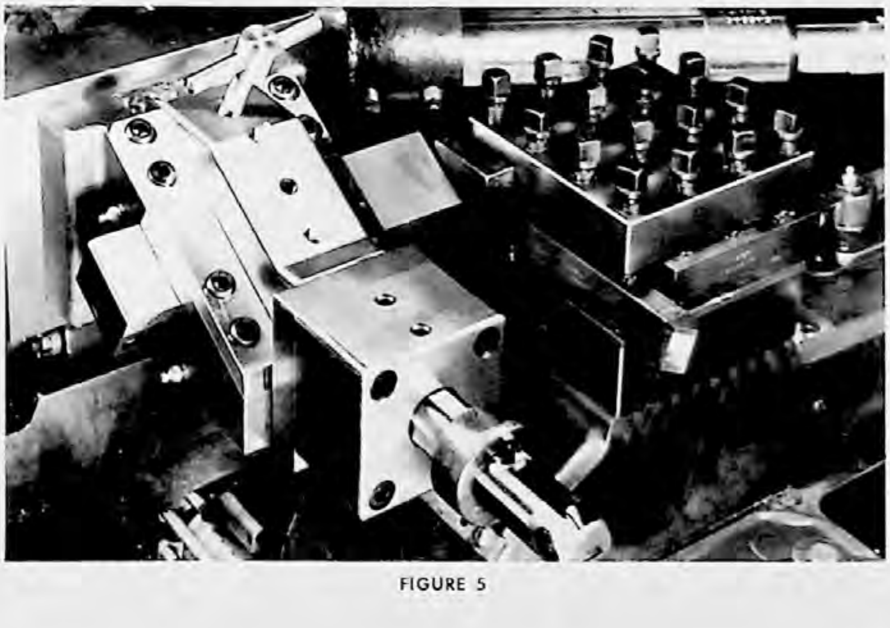


FIGURE 5

SPECIAL TOOLS

PART IV

A unique solution to machining a fragile work piece

SPECIAL precautions must frequently be taken when machining aluminum die castings on turret lathes. Primarily, the problem in machining these jobs concerns the holding device.

Die castings are likely to be quite fragile due to thin wall sections, and usually do not have more than .010 to .015-inch stock to be machined. Therefore, the holding device must grip the work firmly enough for machining but in such a manner that distortion is not introduced into the part through high specific pressures in the gripping areas. Furthermore, due to the scant stock allowances, the work must be gripped concentrically so that all required surfaces clean up.

Since the die casting process normally lends itself readily to intricate shapes, the selection of proper gripping areas must be considered along with the means of overcoming fragility and stock distribution.

One such job is illustrated in Figure 1. Note the extremely thin wall sections, the close tolerances, and the spacing between the 1.175 and 5.625-inch bores. These bores are far enough apart to require close concentricity in gripping if they are to clean up within the stock allowed.

This holding problem is satisfied by the combined air chuck and fixture illustrated in Figure 2. The air chuck is a 10-inch three-jaw chuck fitted with special jaws which grip on the small end of the aluminum die casting. This centralizes one end of the part with the center line of the machine spindle. The outer end of the work is gripped by a pot fixture which aligns the large end to the small end and supports the outer end against cutting thrusts.

The stationary body of the fixture serves as an endwise location for the aluminum casting and a housing into which three spring loaded support pins can be mounted to centralize the die casting on the outer periphery. These pins are actuated by a sliding fixture component attached to the same draw rod which actuates the three jaw chuck.

Since it is convenient to use but one air cylinder on the turret lathe, a specially designed draw rod is necessary to actuate both the three jaw chuck and the pot fixture. That is, the draw rod from the air cylinder is attached to a plunger which in turn is connected to the chuck closing mechanism.

Within the chuck plunger is a secondary draw rod arranged with a suitable spring so when the air cylinder retracts the chuck plunger, the spring in the secondary draw rod first effects the closing of the sliding fixture component. This action closes down the spring loaded support pins and when these pins impinge on the part, further

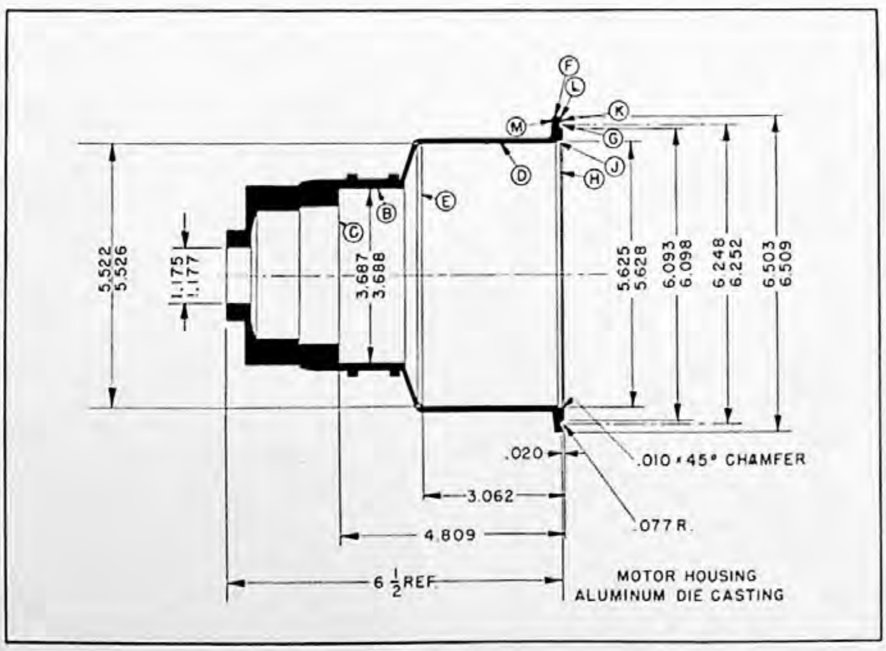


FIGURE 1

motion of the secondary draw rod is arrested. However, the spring in the fixture draw rod allows the chuck draw rod to continue its closing motion on the three-jaw chuck until the jaws are in position on the small end of the casting.

In effect, this fixture design allows a variation in timing between gripping the die casting on the outer periphery and on the small end. At the same time, it provides accurate radial location of the die casting with respect to the machine spindle center line, and by virtue of the spring pressure gripping in the secondary draw rod, a gentle gripping action results on the fragile periphery of the casting.

Heavy pressure on the spring loaded support pins is not necessary because a positive contact is maintained through the solid pins between the taper on the sliding fixture component and the work diameter. The spring around the support pin serves only to retract the pins away from the work when the part is unchucked. The taper ground in the sliding fixture component is sufficiently slight to prevent movement of the pins under cross cutting thrusts.

An anti-friction pilot bushing is provided in the fixture to support cutting tools mounted on the hexagon turret.

Figure 3 illustrates the tooling setup used to produce this part. A special tool block mounted on the rear of the cross slide holds two carbide-tipped tools for producing the surfaces marked in the setup. Note that the bottom of the 5.522-inch bore must be held to a .002-inch tolerance from the front face of the part. Note also that the bottom of the 3.687-inch bore must be held to a tolerance of .004-inch from the front face of the part. This means that some positive relationship must exist between the plane of the facing tool which is used to machine surface "H" and the tools mounted on the hexagon turret which produce the faces at the bottom of the bores.

Although the machine stops on the turret ram slide are normally accurate enough to hold such tolerances in their own right, it was decided that the position of the cross slide for facing "H," the outer face of the casting, might have to be adjusted frequently, depending upon how accurately the part could be fitted to the fixture during the run of the job. In other words, the cross slide of the machine on which the facing tool is held, can be adjusted longitudinally at will so that the tool will stay within the stock allowance on the outer bore. This requires the use of supplementary stops on the cross slide as sketched in the setup, so that Stations 2 and 3 on the hexagon turret can work against the cross slide stops in order to hold the depth dimensions of the bores in relation to any particular longitudinal setting of the cross slide.

Station 2 of the hexagon turret is used for boring "J" and for producing some of the contour surfaces on the outside of the rim. Station 3 in the hexagon turret consists of a piloted multi-cutter boring head for machining the inside surfaces of the part.

A spring is arranged between the hexagon turret and the saddle of the machine so that the hexagon turret will automatically back index to Station 2 after the conclusion of Station 3.

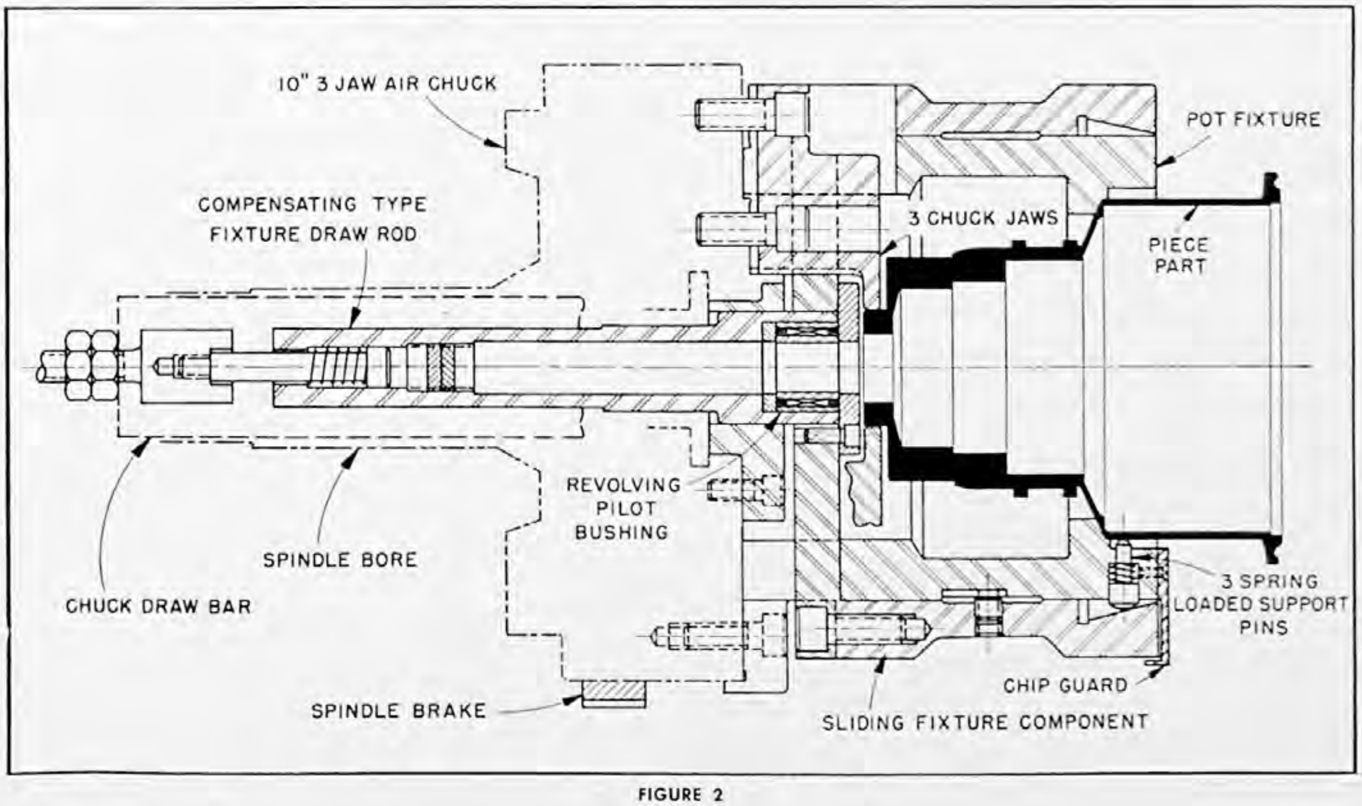


FIGURE 2

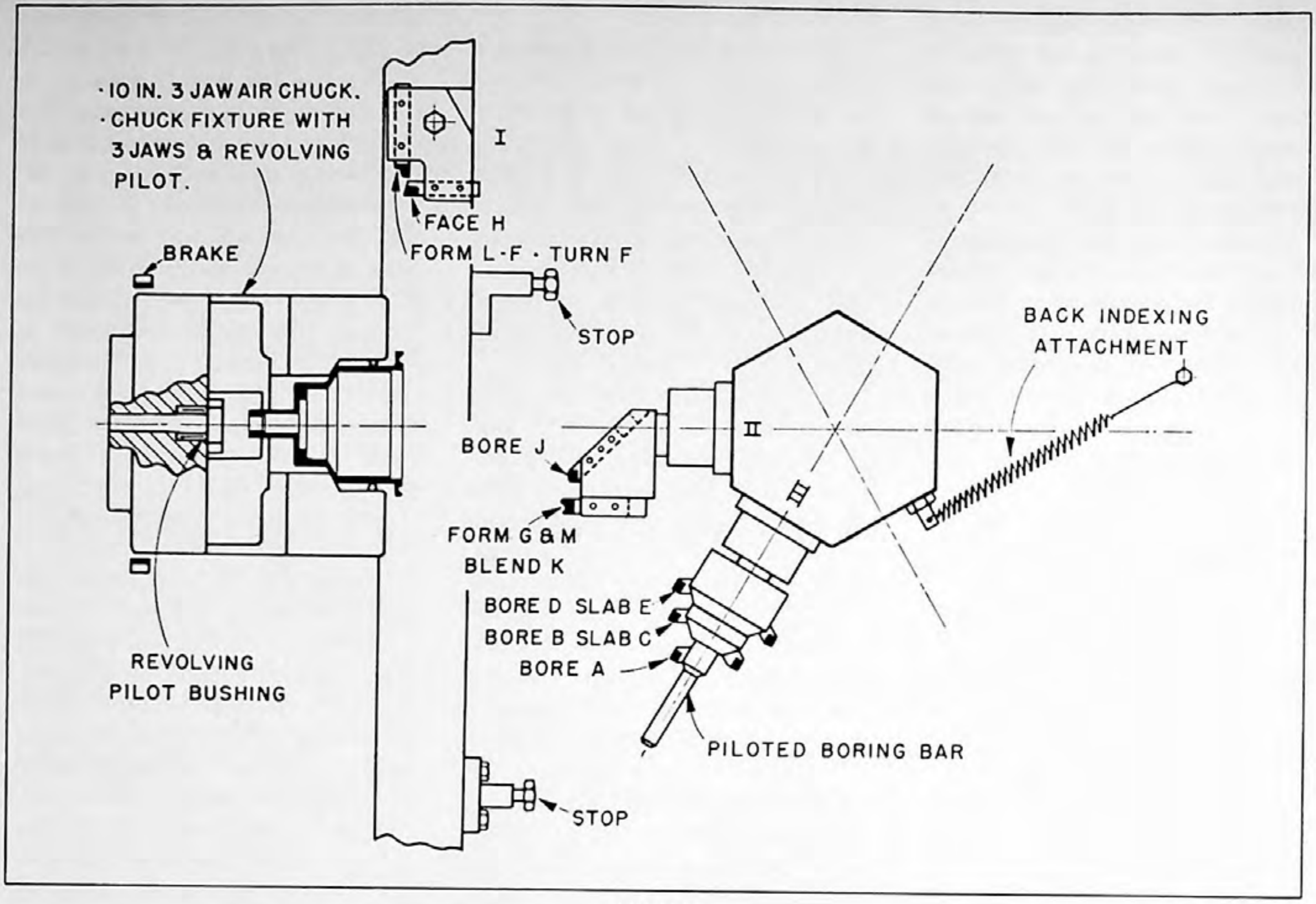

· 10 IN. 3 JAW AIR CHUCK.
· CHUCK FIXTURE WITH
3 JAWS & REVOLVING
PILOT.
BRAKE
I
FACE H
FORM L-F · TURN F
STOP
BACK INDEXING
ATTACHMENT
BORE J
II
III
FORM G & M
BLEND K
BORE D SLAB E
BORE B SLAB C
BORE A
REVOLVING
PILOT BUSHING
PILOTED BORING BAR
STOP

FIGURE 3

HOW TO USE CARBIDES ON TURRET LATHES

Common factors which need attention in applying carbides to turret lathes

Rigidity; power;
speed and feed control;
chip control;
motor selection

IT IS by no means a simple matter to consolidate all facts leading to successful carbide application on turret lathes. The technique of grinding and applying carbide is a subject in itself. Manufacturers of cemented carbide tools have done an excellent job in providing literature on the correct use of this excellent cutting medium.

Equally as important as the correct grade and grind of carbide tooling are the machine tool and the characteristics of the job.

The mechanical condition of the machine tool is undoubtedly of basic importance and, in connection with turret lathes, certain important units of the machine must be corrected or maintained in adjustment before carbide tools can be successfully applied. Headstock clutches, feed clutches and "V" belts in the motor drive must be in proper adjustment if sufficient power is to be transmitted to take cuts at carbide speeds. Preload on spindle bearings, gib adjustment and proper machine lagging are important points to inspect.

FOR carbide application, tool holders must be rigid and close attention should be given to the possibility of piloting tool holders for the heavier cuts if vibration is to be minimized during the cutting operation. Most turret lathe turrets, both square and hexagon, are equipped with binder clamps which need adjustment occasionally and without which the larger strains induced by carbide cutting can seriously affect the accuracy and finish of the part as well as the life of the tool.

A COMMON source of inconvenience when using carbide tools arises from operating the turret lathe at a reduced line voltage. This is a variable, depending upon locality, season and hour of the day. While the majority of power companies attempt to maintain line voltage at rated values, it is impossible in some cases to do so. A turret lathe motor operating at more than 20 percent drop in rated voltage will not furnish its rated power and may overheat under otherwise normal cutting conditions.

If all factors outlined above are controlled, it is possible to analyze power requirements of jobs for the purpose of relating power requirements to the capacity of machine headstock and motor.

The power required to remove a given amount of metal depends upon the time expended in the operation. A convenient unit of power is horsepower per cubic inch per minute. Tests in various metal cutting research programs have revealed that for any given material to be machined, the horsepower per cubic inch per minute remains essentially constant regardless of the combination of feed, speed, and depth of cut used. This fact has made possible the arrangement of the metal cutting nomograph printed in another chapter of this book.

For finishing operations there is seldom, if ever, any need to be concerned about power limitations of the machine. However, when hogging cuts are to be taken, the power limitations must be recognized and considered and it is for this class of work that the power nomograph was prepared.

Choice of cutting speed used on a job is based on custom and experience. It could easily vary over a range of plus or minus 10 to 20 percent of values which have been set up as standards, but seldom varies more than that.

Depth of cut is usually determined by the shape of the part and the amount of stock allowed for finishing. This leaves the feed per revolution as the only factor that can be varied over a wide range and it is in the selection of feed that a knowledge of resulting power required versus power available is needed.

Power, of course, is not the only factor that will limit the feed to be used on a roughing cut. Other factors are (a) rigidity of the part, (b) rigidity and strength of tooling (fixtures, tool holders, etc.), (c) strength of tools, (d) end thrust of drills.

HORSEPOWER is directly proportional to feed, speed, depth of cut and cutting resistance of the material being machined. Feed and depth of cut are usually fixed by part characteristics. Strength of the part, type of holding device, and required work finish can govern the feed and depth. Tool life depends upon speed and—to some extent—feed, for hard and soft materials. Most tables of recommended cutting speeds are expressed in ranges from which a value to give satisfactory tool life can be selected. The effect of speed on tool life is somewhat variable, depending on the type of work material.

Ordinarily, heavy cuts and hard

work materials are not as likely to create maximum power demands because lower cutting speeds are used to obtain efficient tool life. However, softer materials, such as aluminum and bronze, run at higher surface speeds with comparable tool life. Thus power demands are likely to be larger. For example, a ¾-inch depth of cut in SAE 4130 steel at a feed of .027-inch feed per revolution at a surface speed of 110 feet would result in a motor requirement of 20 horsepower. The same cut in aluminum taken at 500 surface feet per minute would require 30 horsepower.

THE AMOUNT of production gained, when speed is increased within a range of practical value, must warrant the decrease in tool life. If, for example, a simple shaft is to be turned in one pass with a carbide tool, obviously the job can be profitably operated at the highest practical speed because it is a simple matter to change tools, and still maintain higher production.

However, another job machined from the same material may be more complex and require more tools. If this job is run at the same speed as the shaft, tool maintenance becomes a factor and the net production gained may not warrant the higher speed, due to both cost of tooling and time lost in changing tools. A lower speed (and reduced horsepower) may in this case result in more finished pieces in a given time than is possible at the higher speed.

In addition, there are many types of jobs where the number of operations which can be performed at higher speeds comprise only a small total of the complete cycle time. For example, if higher speed and horsepower apply to one or two cuts, and save only one-half minute on a 12 minute job, the reduced tool life resulting from higher speed operation hardly seems warranted. There is also a possibility that an increase in cutting speed may prevent combining of cuts, thus reducing the apparent benefit gained by operating at higher speeds.

ANOTHER factor affecting the ultimate power requirement for any job is the matter of chip control. This important factor is frequently overlooked when more speed and horsepower are considered. From a practical operating standpoint, chip form and disposal is a very real problem which requires that speed, feed and tool grind are adjusted to suit various materials. In such cases, it is quite possible that maximum speeds and horsepower are not controlling factors.

Once the condition of the turret lathe has been analyzed and full recognition given to all factors which affect power requirements of a job, it is possible to determine whether the size of the drive motor on the turret lathe must be adjusted. Certain factors may be used to guide this procedure.

THE three-phase induction motor is most commonly used on turret lathes. These motors are ordinarily normal torque, low starting current, and may be obtainable with single speed or two-speed windings. If a two-speed motor is used on a turret lathe, it is usually recommended that it be a constant torque-type motor.

For example, a two-speed constant torque motor may be a 7½—3¾ h.p. 1800/900 r.p.m. motor or, 10—5 h.p. motor, etc. The torque of these motors is exactly the same at either speed range. Hence, this is a good motor to use with a turret lathe headstock because twice the motor output horsepower can be delivered to the drive shaft with no increase in torque by virtue of the doubled motor speed. Thus this motor operates the headstock at twice the speed and can therefore deliver twice the horsepower to the cut without changing the headstock forces.

The three-phase induction motor is a very rugged source of power and can be repeatedly overloaded 50 percent and yet maintain long life. When a motor converts electrical energy into mechanical power, heat is generated, and the capacity of the motor to deliver mechanical power is therefore a function of its ability to dissipate this heat within safe limits. The nameplate rating of the motor specifies the output horsepower which the motor may deliver to the headstock continuously for a given, safe, temperature rise.

THE AVERAGE turret lathe job calls for a series of heavy and light cuts of variable duration. Accordingly, the power furnished by the motor is variable and the average horsepower demand may be calculated. This is known as the root means square horsepower. This R.M.S. horsepower is the equivalent continuous horsepower output of the motor.

In other words, a continuous full load on a motor will generally result in a rated temperature rise. If the motor is overloaded during a portion of the job cycle, it must be underloaded during other parts of the cycle so that the total heat generated will not exceed the rated temperature rise in the motor, which would apply if it were operating under continuous usage at full load.

If the equivalent continuous horsepower output or R.M.S. horsepower of a motor on a variable duty cycle is greater than the full load rating for continuous duty, the motor is overloaded beyond the point of safety.

When selecting a motor for combined low initial and operating cost, it is important to remember that the larger motor costs more because of its own cost and the probable investment in feeder lines, branch circuits and transformer capacity necessary to service it.

Indirect operating costs of the motor are higher when its average load is less than 75 percent of full load because it is not working in the range of high efficiency and high power factor.

Therefore, when initial and operating costs are a consideration, the size of the drive motor should be closely matched with actual job requirements. It is not difficult to do this if the metal cutting nomograph previously mentioned is used to determine the horsepower of the maximum cut, and time study means are employed to determine the relative time during which this cut occurs compared with the total cycle time.

For example, in past years many turret lathe jobs have been checked for power requirements and in almost every case the ratio of peak horsepower to average horsepower required to do the job was found to be about two. Since the motor manufacturer designs the motor to take a 50 percent overload both intermittently and repeatedly, it follows that a motor should be selected that will pull the heaviest cut and not often exceed the 50 percent overload yet still maintain the average motor load in the neighborhood of 75 percent motor rating which is in the high power factor and high efficiency range.

For example: The maximum peak load of the job is 13.5 h.p. What is the best size motor on the basis of low first cost and operating cost?

Answer: Using the rule of thumb, the average horsepower of the cycle is ½ of 13.5 or about 7 h.p.

A 10 h.p. drive motor can safely be overloaded to 13.5 h.p. since this peak is under the 50 percent overload factor. Furthermore, the average horsepower is about 75 percent of the full load rating of the 10 h.p. motor and the motor will operate in the range of high power factor and efficiency.

Equipment costs and operating costs may be of less importance to companies whose work is highly diversified. In these instances, the turret lathe should have the largest motors recommended for the individual machine size. It is a simple matter to refer problems such as these to the lathe manufacturers.

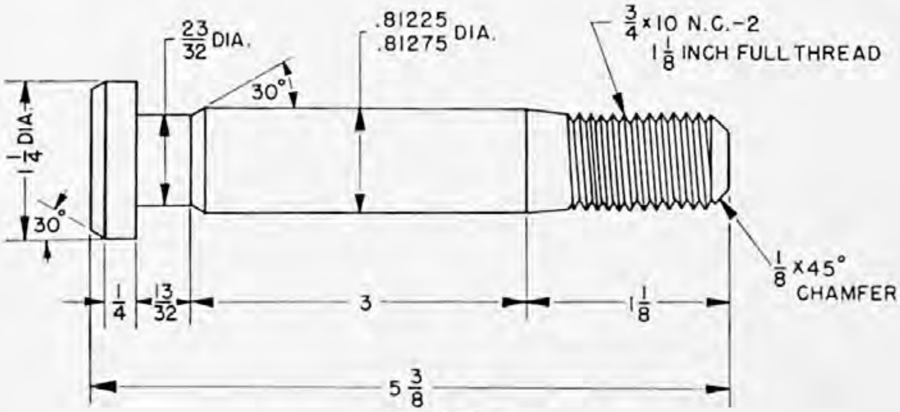


FIGURE 1

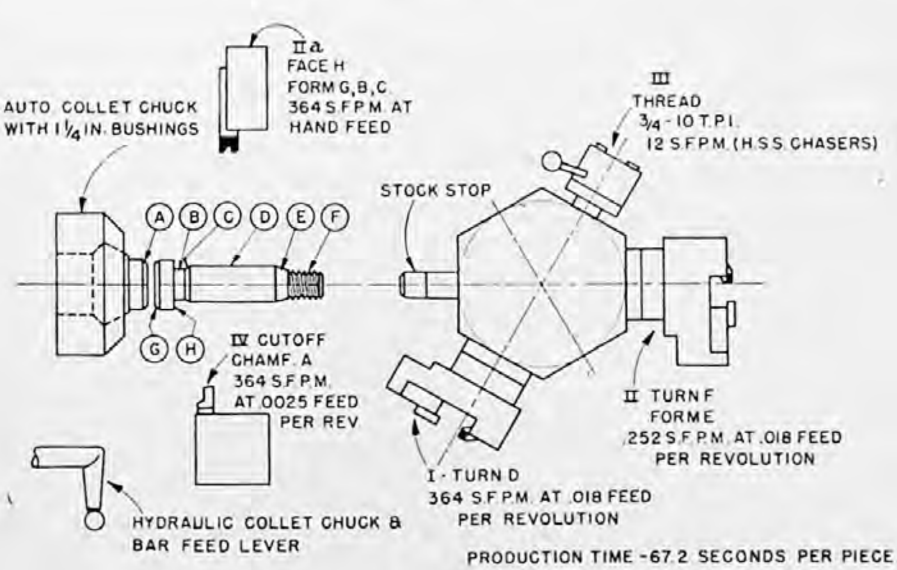


FIGURE 2

FIGURE 1 illustrates a simple bar job tooled with carbide in accordance with good turret lathe practice, so that a cycle time of 67 seconds per part, floor to floor, is obtained. The tooling arrangement used to produce this part is illustrated in Figure 2. Carbide tools are used for the cut-off and forming operation as well as in the two single turning tools. High speed steel chasers are used on the threading operation which, including machine handling time, consumes 18.6 seconds of the total 67 seconds.

The size of machine chosen for this job is a two-inch bar machine. For a fast cycle job of this kind, it is necessary that the turret lathe chosen have ample power to remove the required metal at the fastest rate consistent with acceptable tool life without sacrificing speed of handling and flexibility of other work within its capacity. Because of proper machine and tool selection, the excellent balance between the size of the part and the size of the machine, a reduction of machine handling time to equal only 32 percent of the total 67-second cycle was effected.

Test runs to determine power demands established that practical carbide tool life was found to be about 360 surface feet per minute for turning the .812-inch diameter and 12 surface feet per minute for cutting the ¾-inch—10 pitch thread with high speed steel chasers. Higher turning and cut-off speeds were tested, but due to reduced tool life it was established that 360 surface feet per minute would be most economical if standard stock tools and grinds were used.

In analyzing the power requirements for this job, it was established that one major peak occurred during the cycle. This peak developed during turning the .812-inch diameter and amounted to 13.5 motor output horsepower. The calculated root mean square horsepower of the complete cycle was found to be 7.53 h.p.

Therefore, on the basis of the 360 surface feet cutting speed, it would appear that a 10 h.p. motor would be an economical matching of motor size to the load on a duty cycle basis. That is, a 10 h.p. motor operating under an average load of 7.53 h.p. would be in the range of highest efficiency and power factors. Furthermore, the peak of 13.5 h.p. existing for only 22 percent of the total cycle is also within the 50 percent maximum overload permissible on the motor.

STANDARDIZATION OF CARBIDE TOOLS

Description of how carbides are handled and applied in the Warner & Swasey Shop. Offers practical hints, tool sketches, and shows relation to need for proper machine maintenance

Without doubt, the use of carbides on turrent lathes is now an accepted fact. In view of this, many users of carbide may be interested in how a machine tool builder handles this cutting material in its own machine shop and what it considers to be the basic principles underlying the application of this cutting material to turret lathes.

In the Warner & Swasey shop, the current use of carbides for machining steel is commonplace because it began to play a prominent part in machining operations as long as 20 years ago. By 1939 a Carbide Department had been established with centralized responsibility for the profitable application of this cutting material to "large and small lot production jobs." A section of this department is illustrated in Figure 1. Thus influenced, the design of carbide cutters has been simplified to the point where 36 standard tools cover 80 percent of the work in the shop. This is especially interesting in view of the thousands of special purpose carbide tools also required and in view of the 1,200 to 1,500 single point carbide tools in operation during any one average 24 hour shift.

Some of these standard tools and suggested chip groove dimensions are illustrated in Figures 2 and 3.

It is possible to list several interesting facts which arise out of daily application of this fine cutting material.

1. Except for chip grooves, the grinds for tools to machine cast iron and steel are essentially the same.

2. The grinds on tools for machining steel are the same regardless of the grade of steel.

3. Note the virtual absence of top rake on tools for machining steel.

4. A total of five grades of tips are used for all types of steel and cast iron. Ninety percent of the work is done with two grades; a general purpose grade for steel and a general purpose grade for cast iron. The other three grades are used for special purpose applications. For instance, for precision boring, the hardest grade tip is used and for a less severe job such as forming pulley grooves, a medium hard grade is used. For a severe, interrupted cut, a general purpose grade carbide tip is used and the tool is ground with a negative rake.

5. Tool shanks, with some exceptions, are made from bed iron. In the case of small boring tools or where the tool overhangs as in planer tools, the shanks are made from SAE 1045 steel or equivalent.

6. It is desirable to grind a radius of $\frac{1}{16}$-inch or less on tools which are to machine cast iron or steel in order to promote longer tool life.

7. Where finish is paramount, a drag is ground on the cutting edge approximately 50 per cent greater in length than the rate of feed in inches.

8. The grinding wheel for producing the chip grooves is $\frac{1}{16}$-inch thick and is a steel metal-bonded diamond wheel, 120 grit.

9. Most special tool designs ordinarily originate in the Carbide Department and the tools are then drawn up in the shop tool design department. Frequently, it is a matter of close cooperation between these two departments in designing a tool.

10. Due to the high degree of organization in the Carbide De-

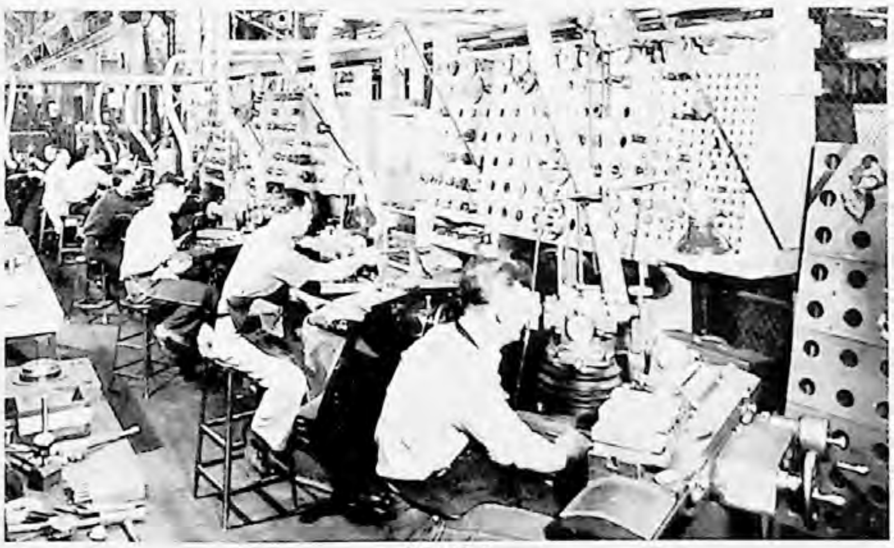


FIGURE 1

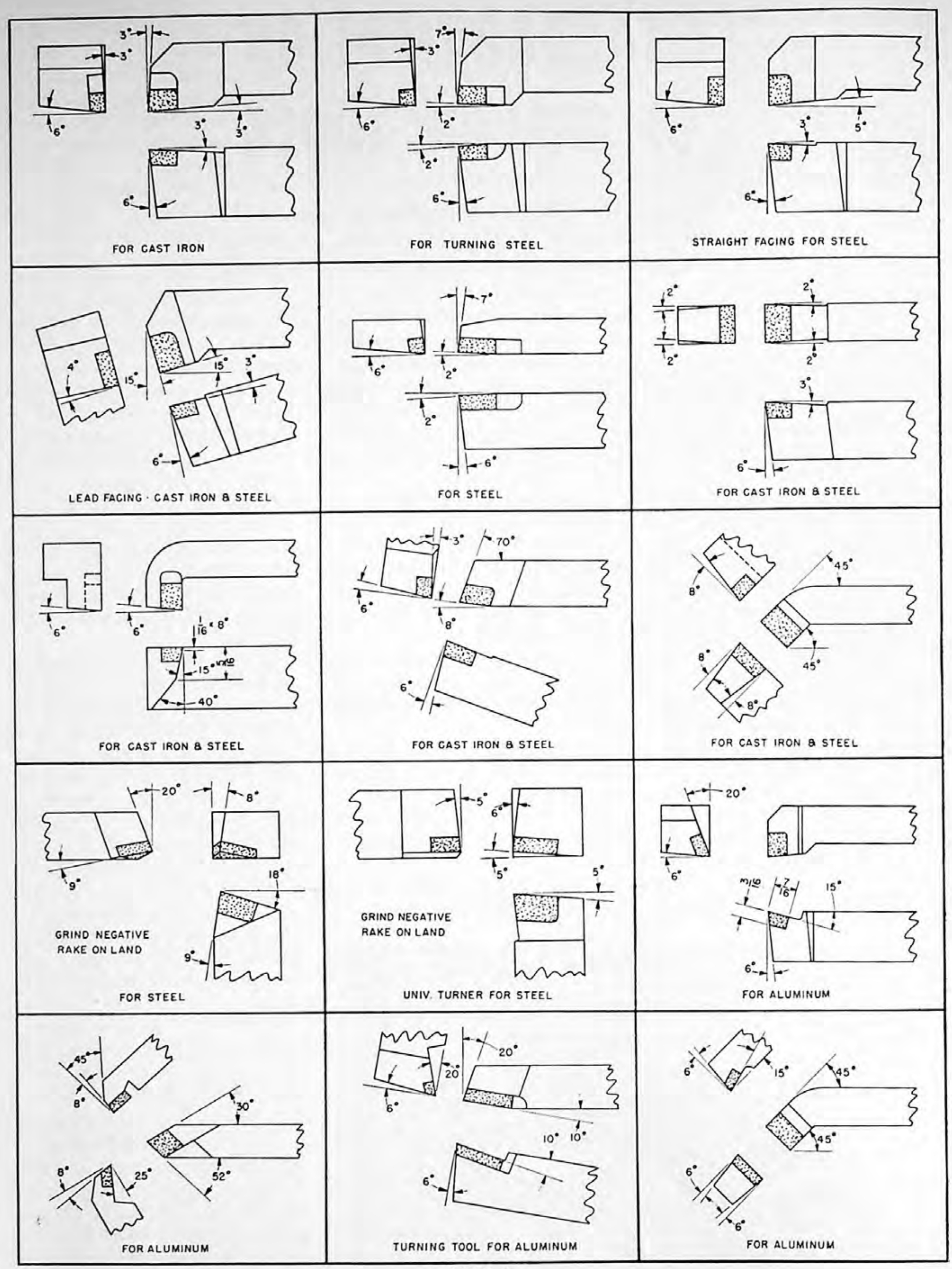

FOR CAST IRON
FOR TURNING STEEL
STRAIGHT FACING FOR STEEL
LEAD FACING · CAST IRON & STEEL
FOR STEEL
FOR CAST IRON & STEEL
FOR CAST IRON & STEEL
FOR CAST IRON & STEEL
FOR CAST IRON & STEEL
GRIND NEGATIVE RAKE ON LAND
FOR STEEL
GRIND NEGATIVE RAKE ON LAND
UNIV. TURNER FOR STEEL
FOR ALUMINUM
FOR ALUMINUM
TURNING TOOL FOR ALUMINUM
FOR ALUMINUM

FIGURE 2

SUGGESTED CHIP GROOVES FOR STEEL TURNING						
	STYLE 1 FOR TURNING	STYLE 1 FOR FACING	STYLE 2	STYLE 3	STYLE 4	OVERHEAD TURNERS
Width of Land	.015"	.025"	.017"	.015"	1/32"	.017"
Width of Groove	5/64"	5/64"	5/64"	5/64"	1/8"	5/64"
Depth of Groove	.005"	.005"	.005"	.005"	.004"	.005"
Head Swung at	10°	10°	10°	10°	15°	10°
	2° Negative Back Rake	3° Neg. Back Rake on Land			Front Must Be Square	2° Neg. Back Rake on Land

	UNIVERSAL TURNERS	STYLE 9	GROOVING TOOLS	5/8" x 1¼" STYLE 4 1/2" x 1" STYLE 4	STYLE 12
Width of Land	.017"	.015"	.020"	.020"	.020"
Width of Groove	5/64"	5/64"	3/32"	5/64"	5/64"
Depth of Groove	.007"	.005"	.005"	.005"	.005"
Head Swung at	10°	10°	10°	10°	10°

FIGURE 3

partment, it is frequently possible to design and make a special carbide tool at less cost than the same tool would cost if made from high speed steel.

Equally as important as the correct grade and grind of carbide tools are the machine tool itself and the characteristics of the job.

Users of carbide must consider the power available in their machine because this cutting material generally permits faster cutting with acceptable tool life.

If a turret lathe is several years old or was purchased during World War II when limitations on motor sizes existed, it is possible that it is equipped with an average duty motor. These motors are usually satisfactory for cutting with high speed steel tools but the use of carbides in many cases requires the installation of a heavy duty motor on the machine.

When there is evidence that the machine is not "pulling" a cut satisfactorily with carbide tools, the following items should be checked.

(a) Are headstock and feed clutches properly adjusted? Reference to turret lathe manufacturers' service manuals will usually indicate the proper clutch adjustments.

(b) Are the V-belts in the motor drive properly adjusted for tension?

(c) Is the line voltage on the drive motor within plus or minus 10 percent of rated voltage? At certain hours of the day and during the winter season especially, it is quite possible that the motor may be operating at an excessive undervoltage, which will definitely affect the ability of the machine to pull heavy cuts. Correcting this problem is a matter for investigation by the plant electrician and may be in some instances beyond control.

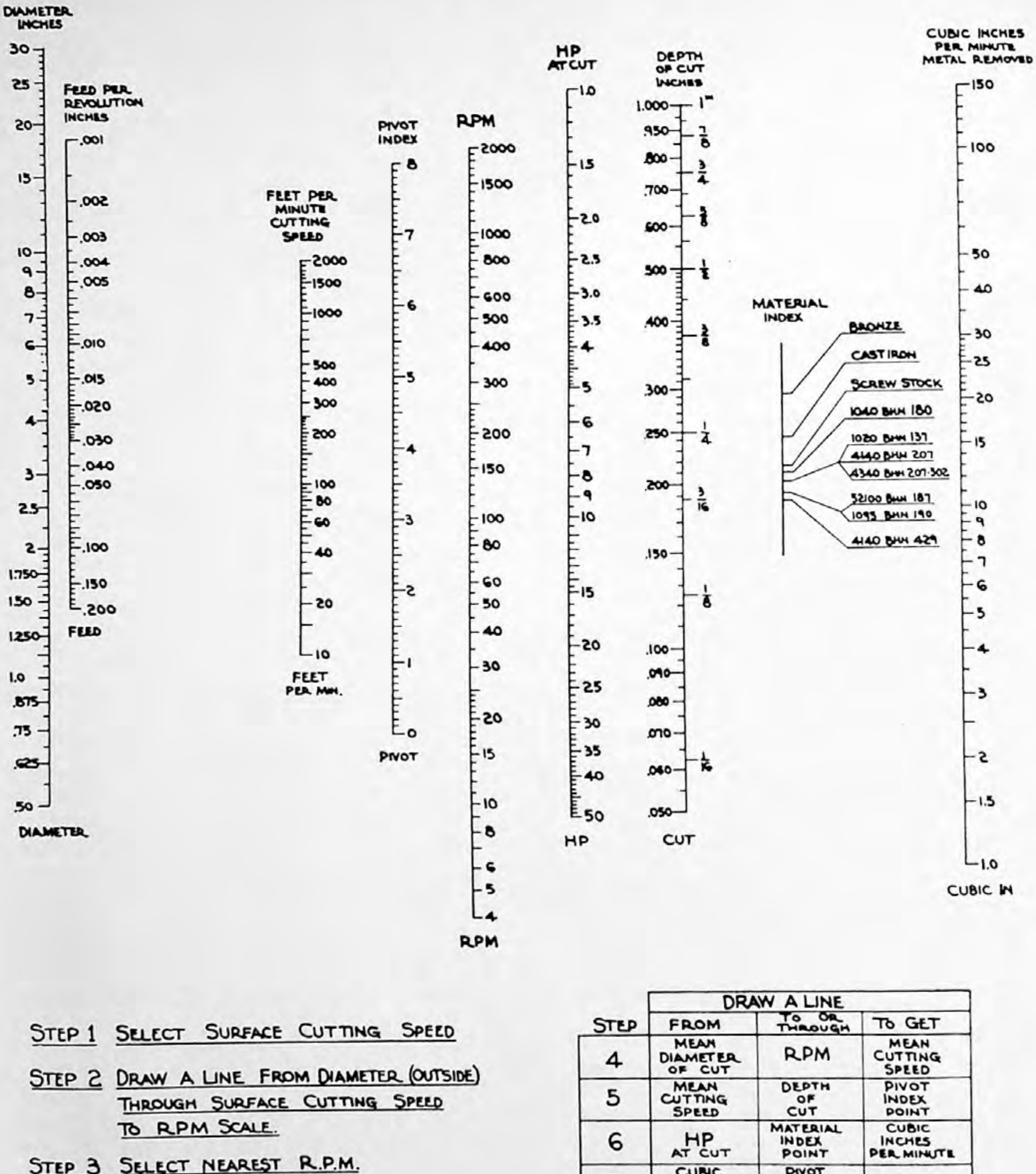
(d) Is the motor on the machine large enough to handle the heaviest cuts with carbide? To help calculate how much power is needed for various cuts, a horsepower chart is included with this article. It should be used for checking the cutting requirements for power against the size of the drive motor.

Note: *The figures of speed, feed and depth of cut for any given horsepower rating make allowance for average turret lathe headstock losses of a size conformable to motor size.*

Many research investigations have been made into the problem of the power required to remove

METAL CUTTING CHART

SHOWING RELATION BETWEEN DIAMETER - RPM CUTTING SPEED - FEED - DEPTH OF CUT - CUBIC INCHES PER MINUTE & HORSEPOWER REQUIRED FOR VARIOUS MATERIALS



STEP 1 SELECT SURFACE CUTTING SPEED

STEP 2 DRAW A LINE FROM DIAMETER (OUTSIDE) THROUGH SURFACE CUTTING SPEED TO RPM SCALE.

STEP 3 SELECT NEAREST R.P.M. ON MACHINE.

STEP	DRAW A LINE		
	FROM	TO OR THROUGH	TO GET
4	MEAN DIAMETER OF CUT	RPM	MEAN CUTTING SPEED
5	MEAN CUTTING SPEED	DEPTH OF CUT	PIVOT INDEX POINT
6	HP AT CUT	MATERIAL INDEX POINT	CUBIC INCHES PER MINUTE
7	CUBIC INCHES PER MINUTE	PIVOT INDEX POINT	FEED

TABLE 1

metal. One such thorough investigation has been conducted by the Warner & Swasey Co. within the last few years primarily to investigate the possibilities of cutting with carbide at much higher rates of speed than are commonly in use. *(See Table 1)*

A by-product of this investigation has resulted in exhaustive data on the power required to cut metal. The power chart in this article is a digest of this material arranged as a check list. Figure 4 illustrates the 1-A Warner & Swasey machine used for these tests. The machine is driven directly through the spindle by a 50 h.p. direct current motor. A 3:1 speed increase between the motor and spindle permitted speeds up to 6000 r.p.m. Some of the extensive instrumentation used in these tests on metal cutting with carbide is shown in the photograph.

It is generally agreed that horsepower required to cut metal is for all practical purposes directly proportional to feed, speed, depth of cut and cutting resistance of the material being machined. Usually feed and depth of cut are fixed by characteristics such as shape of the part, type of holding device, finish required, etc.

Tool life depends upon speed and, to some extent, feed for both hard and soft work materials. However, heavy cuts in hard work material are not as likely to create maximum power demands because lower cutting speeds are used in favor of obtaining efficient tool life. By the same token, soft materials such as aluminum and bronze may run at higher surface speeds with acceptable tool life and thus power demands are likely to be larger.

It is important to consider some other factors when applying carbide tools to turret lathes so that the results will be in accord with the highest efficiency possible.

For example, the production gain obtained, when speed is increased within the range of practical tool life values, must warrant the decrease in tool life obtained at that higher speed. A good example of this is a simple shaft which may be turned in one pass with a carbide tool. Under these circumstances, such a job can be operated with profit at a very high speed because it is a simple matter to change tools and in the meanwhile obtain the benefits of higher production due to high speed.

On the other hand, if a job is complex and thus requires a large quantity and variety of tools, tool maintenance is a definite factor and the net production gained from running at a higher speed may not warrant the use of this speed because of cost of tooling. Time lost in changing tools when dulled may produce less finished parts in a given time than is possible by operating at a more conservative speed.

Chip control is an important factor when considering the speed and horsepower of a job. From a practical operating standpoint, the form of the chip and the direction of its disposal is a very real problem which requires that speed, feed and tool grind must be adjusted to suit various materials, and tooling combinations. In such cases, it is quite possible that maximum feeds and horsepower are not the controlling factors in determining the pace at which the job operates.

The amount of power required to cut metal also bears a very definite relationship to the selection of motor size. The three-phase induction motor is most commonly used on turret lathes and they are ordinarily normal torque low starting current. Usually a choice of motor with single speed or two speed windings may be applied to a machine, depending upon the number and range of spindle speeds used.

The three-phase induction motor is a very rugged source of power and can be overloaded up to 50 percent for short durations. However, it should be remembered that a motor converts electrical energy into mechanical power and thus heat is generated. In that respect, the capacity of the motor to deliver mechanical power is therefore a function of its ability to dissipate this heat within safe limits. The name plate rating of the motor specifies the output horsepower which it may deliver to a machine tool headstock continuously for a given safe temperature rise.

It is a fact that the average turret lathe job calls for a series of heavy and light cuts of variable durations. Therefore, the power which must be furnished by the motor is variable during the cycle and an average horsepower demand may be calculated. This is known as the root mean square horsepower. This may be called the "equivalent continuous horsepower output" of the motor. The r.m.s. horsepower may be calculated by

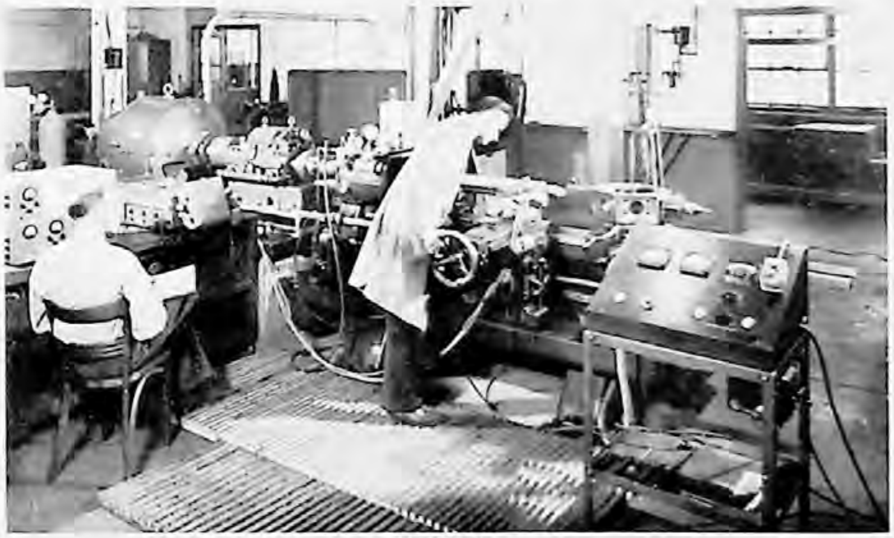


FIGURE 4

mathematical means when it is desired to relate a motor size specifically to power requirements or to check the ability of a motor already on a turret lathe to handle a given production job. If this calculated equivalent continuous horsepower output or r.m.s. horsepower output of a motor on a variable duty cycle is greater than the full load rating of the motor for continuous duty, then the motor is overloaded beyond the point of safety.

It should be remembered that if a motor must be selected on the basis of low initial cost and operating cost, it is important that unnecessarily large motor sizes must be used with discretion because large motors result not only in greater initial cost but also in indirect costs in feeder lines, branch circuits and transformer capacities necessary to service them.

Furthermore, the indirect operating costs of a larger-than-necessary motor are higher when its average load is less than 75 percent of full load because it is not operating in a range of high efficiency. Thus, this motor contributes to an over-all shop loss in power factor which may penalize the user of carbides depending on his contract with the public utilities company.

Most manufacturers of turret lathes are competent to analyze job requirements as they relate to the customer's work, and they invite discusion on this important phase of tooling so that the full effect of carbide efficiency may be realized. Experience has shown that the inefficient use of carbides on turret lathes has resulted in part from lack of persistency in analyzing the requirements of such applications and in part to the various additional factors surrounding the machine and tool conditions which must be in proper order before carbides may be applied successfully. However, once all of the various factors have been considered, there is definitely no reason why carbide cutting materials may not be used successfully on all lot sizes ranging from one part upward.