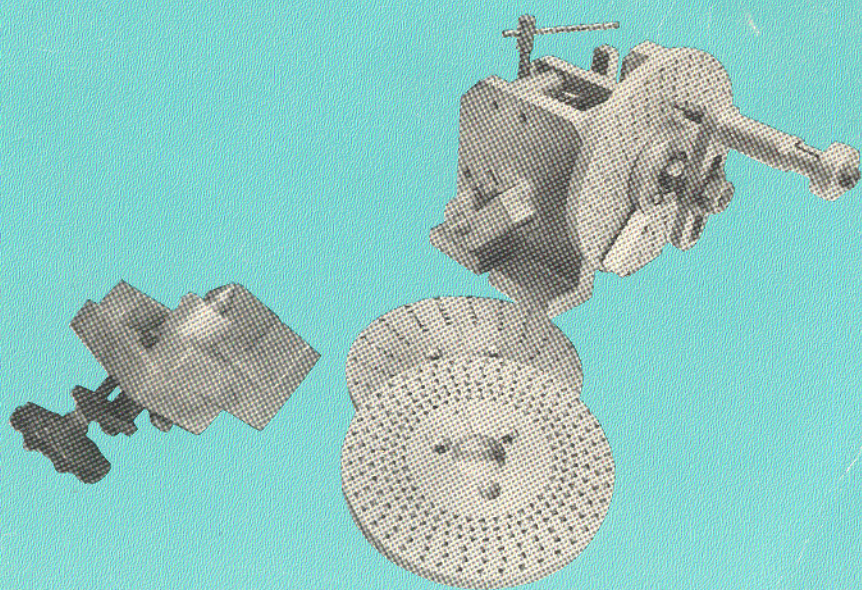

BUILD YOUR OWN
METAL WORKING SHOP FROM SCRAP

6

The Dividing Head & Deluxe Accessories



Written and Illustrated by David J. Gingery

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THE METHODS AND MATERIALS THAT ARE SUGGESTED IN THIS MANUAL WERE DEVELOPED BY A NON-PROFESSIONAL. THE AUTHOR IS NOT AN ENGINEER OR SCIENTIST. NO LIABILITY IS ASSUMED FOR INJURY TO PERSONS OR PROPERTY THAT MAY RESULT FROM THE USE OF THIS INFORMATION.

The main object of this manual is to provide the means to produce spur gears so that we can add change gears to the lathe. While we can hardly expect to produce a perfect involute gear tooth in the home shop, we can certainly make a set of change gears for the lathe that will mesh nicely and provide the accurate and positive drive to the lead screw that is needed for cutting screw threads on the lathe. The work is much easier than you may have imagined, and the cost is so slight that it just doesn't make sense to deny yourself the advantage of this improvement to your shop.

Few of us could bear the expense of a set of formed gear tooth cutters for the miller, but it is an easy job to grind a simple fly cutter at a cost of about half a dollar. Mine has cut something over 200 gear teeth with no sign of blunting. The gears are uniform and mesh nicely with each other and with commercially made gears.

There would be no problem in gathering enough data to write an entire volume on gear technology alone, but most of the information would be of little value in the home shop. Don't be concerned with the inability to produce a perfect involute gear form because such a thing hardly exists except in theory. Modern equipment can come very close to perfection but they still miss by a little bit. You can come so close with these simple methods that only an expert with very exotic equipment could find the error.

A worm wheel dividing head is a simple and fascinating device. It is the only practical way to provide a broad range of dividing capability to the shop, and its versatility will amaze you. It not only enables you to make accurate gears, but it will handle any other dividing or indexing chore that you may assign to it. Its accuracy will be more than adequate for the broad and general class of work, and you will have a piece of equipment that most home shop operators must do without.

If you have completed any of the earlier projects in the series you won't find these projects difficult. The first chapter is largely a review of simple methods and devices from earlier manuals, and these provide what is required to build the dividing head and add change gears to the lathe.

The castings that are required are all within the one quart capacity of the charcoal foundry, and the simple methods for producing the castings have been well covered in the earlier manuals. Most of our discussion will be on finishing and fitting the parts.

The necessary equipment for these projects is the lathe, the drill press and the miller. If you have built these, or any one of them, you will be well trained in the required skills.

A good drill press is vital to making the fraction plates for the dividing head and some of the more demanding drilling jobs. Building one is worth the effort if only for the machining skill that is gained, but you can buy an adequate machine for less than \$200.00 if you are anxious to get started on these projects.

The dividing head is primarily a milling machine accessory, but this one is designed to serve as a rotary table as well. It can be used in the vertical or horizontal position, and it's not just for making gears.

If you happen to own one of the vertical mills with an R-8 spindle this dividing head will easily adapt to it.

The design can easily be scaled down in size for some of the smaller vertical mills that are now so popular. You need only select a finer pitch worm and wheel and reduce the size of the parts in proportion.

A sturdy drill press can serve as a miller if properly modified. An X-Y table can be purchased or built, and the spindle is given extra support at or near the chuck. A speed reduction will be needed to give spindle speeds below 300 RPM, and this is easily done with a countershaft. If the chuck is not held with a screw collar or draw bolt you are not safe to use the drill press as a miller. The home made drill press that is described in book #5 is not adequate for milling because the quill bearings are too light and the chuck is held only by the spindle taper. This project would destroy the drill press, and you may get hurt in the bargain.

The change gear set can be adapted to fit any lathe, though the pitch of the gears and the ratios will have to be changed if the machine is much larger or smaller.

It may seem a bit strange that the four jaw chuck is presented so late in the series. While it is a great accessory for the lathe, a part of the object has been to demonstrate the broad range of capability of the simple lathe equipped with no more than a pair of centers and a face plate. You can still delay building the four jaw chuck until later, though it will be an aid in a few of the operations in this manual.

It tries the patience to stop and build a simple fixture to machine a part when you really want to get on with the main project, but all of these devices add to your equipment and skill, and your shop is growing even though you may feel that you are experiencing a delay. Each device and new skill will find many uses in future projects, so take the time to make them well and train yourself thoroughly.

In most cases only one method is described to handle the operation at hand, but there are almost always alternate methods that may work better for you and your equipment. You can't fail to gain from trying out an idea. At the very least you will learn what does not work, and new ideas that come out of the experience will be more sound.

It is mere myth that people that have an unusual level of skill are specially endowed either mentally or physically. A thorough understanding comes from study, and skill is developed by practice. If you view a complex project in its entirety it may overwhelm you, but you can surely grasp some elementary principle, and that's the key. Take it at the level of your present understanding and begin to build on it. Soon you will see it clearly as a whole, and you will have made a permanent improvement to your mind as well. A first attempt at anything is likely to be clumsy, but both your speed and the results of your effort improve with only a few repetitions. When you have repeated any exercise often enough it becomes automatic, and then your mind is free to tackle the next step. This is the way that skill is developed. First you understand what you want to do and then you do it. When your mind has trained your hands they will do it without being told how. As your level of skill increases, so does your capacity for acquiring new skills. The process expands so quickly that problems become adventures instead of burdens. You are potentially a master mechanic, and all of the means are at your disposal.

Now you should go out and temper your sand. Riddle it once and cover it up so that it will be ready when you go out to use it next week end. Make sure that you have plenty of charcoal and melting stock on hand, and be ready to enjoy some really great projects as you finish building your own metal working shop from scrap.

TOOLING UP

SUPPLY SOURCES

Cutting tools, stock and supplies are a serious problem in many areas. Most of us have to rely on mail order for at least a portion of what we need, so a catalog and a clear understanding of ordering procedure is vital.

Some houses are geared to supply only large industrial users and they will not respond to individuals with small needs, but many will fill an order if properly sent. All have some minimum order amount and it will be clearly stated in their catalog. You may be able to pool an order with a friend to make up the minimum order. Use a blank if one is furnished, and otherwise make the order very clear. Use catalog numbers with your description and follow all of the ordering directions. Make it easy to fill your order. It is a good idea to include an extra dollar or two with your payment to allow for price changes and shipping costs above your estimate. I always do, and have never been beat out of a penny.

Campbell Tool Co., 2100 Selma Rd., Springfield, Ohio 45505. An excellent source for much of what you need. A very fast and reliable house offering personal service to home shop operators. Catalog fee is \$1.00. I was able to get my gear tooth pitch gauge and several other items from them, and all at very fair prices.

Wholesale Tool Co. has four outlets. The main office is at 12155 Stephens Dr., Box 68, Warren, Mich. 48090. Catalog fee is \$1.00. A very large stock, and service is very good. I've had several orders filled to my complete satisfaction.

Penn Tool Co., Inc., 1776 Springfield Ave., Maplewood, N. J. 07040 is one I've only recently learned about. I've not ordered yet but will give them a try soon. I don't know if they charge a catalog fee, but it's fair to send a dollar for postage when you request a catalog.

McKilligan Industrial and Supply Corp., 435 Main St., Johnson City, N. Y. 13790 offers thousands of items in a catalog of about 700 pages. Foundry equipment and supplies and many items that can hardly be found elsewhere, and they

do sell to individuals. Minimum order amount is just \$15.00 and they provide a special order blank for small cash orders. The catalog fee is \$5.00, which can be refunded with an order of \$100.00.

Stock Drive Products, 55 south Denton Ave., New Hyde Park, N. Y. 11040 has a large offering of gears and small standardized components. Their complete handbook/catalog is available at \$5.95 post paid. Many items you may have thought were not available. A valuable reference.

Small Parts, Inc., 6901 N. E. Third Ave., Miami, Fla. 33138 has a broad listing of fasteners, bearings, collars and small mechanical components that all of us have need for. The catalog is free.

Both Boston and Browning gears are available through industrial supply houses. Special orders are filled fast and accurately. I got my Browning worm and wheel through a local house in less than a week.

None of these listings are adds or offerings. I do not receive any fees, discounts or considerations from any of these companies.

THE HOME SHOP BOOK SHELF

Experience is the best teacher, but reading gives you the knowledge and experience of others as a guide. These books guided me as I built my shop and prepared these manuals, and they should be a help to you as well.

The Complete Handbook of Sand Casting by C. W. Ammen. Done by the meanest sand crab of all time, and written so you can understand it. It was this book and Bill Ammen's personal guidance and encouragement that made this series possible.

Foundry Work For The Amateur by B. Terry Aspin. An excellent English publication. Very useful and highly recommended.

How To Run A Lathe by South Bend Lathe Co. Nothing can compare with this classic. First printed in 1907 and still going strong. I wouldn't be without mine.

Jig and Fixture Design by Edward G. Hoffmann. The best ideas for holding work pieces and guiding tools are devised by working machinists. These are clearly illustrated and explained in this text book. Jigs and fixtures are not only for mass production. Difficult machining jobs become easy with Ed Hoffmann's clear guide.

The Home Shop Machinist is a new magazine published by the same people that publish "Live Steam". Excellent photography, and the magazine is project oriented. Fills a long neglected need, and it's your line of contact with advertizers that can fill your home shop needs. One year subscription is \$17.50 for 6 issues. The Home Shop Machinist, PO Box 968, Traverse City, Mich. 49684

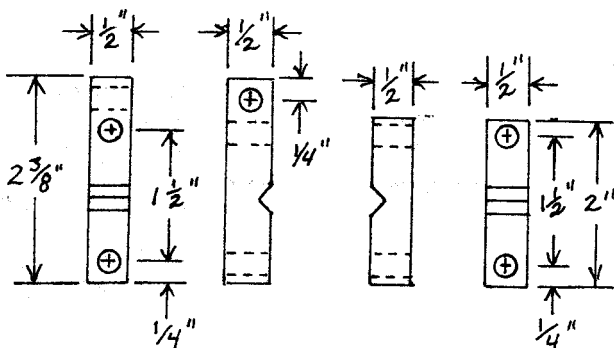
FITTING OUT THE LATHE

Most of what is needed will be on hand if you have built the lathe and the milling machine, and the simple lathe will again do most of the work. A few minor modifications and additions will be required. The four jaw chuck and the steady rest will be dealt with in separate chapters because they are rather complete projects in themselves.

THE CLAMP DOG

Much of the work will be done between centers, and for this you need the slotted face plate and a driving dog. The one described in book #2 is too large for some of the work in these projects.

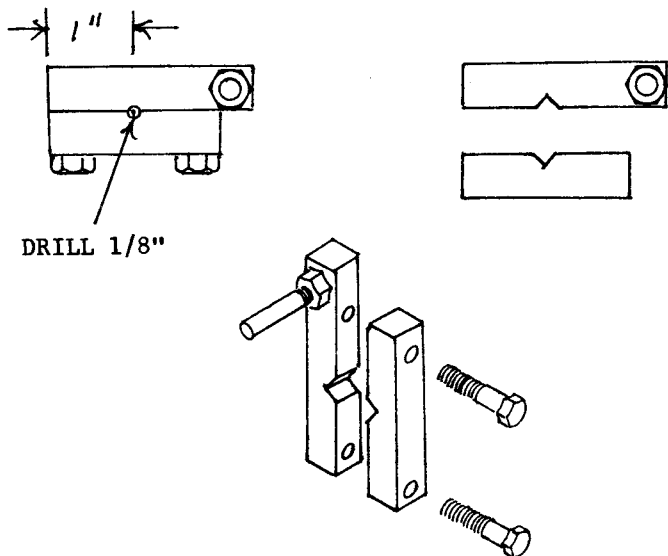
Two pieces of 1/2" square key stock or cold rolled steel provide the material for the clamp.



It will be best to step drill both clamp bolt holes to 1/4" with the parts clamped together. Then separate them to enlarge the holes in the shorter part to 21/64". Use the enlarged holes to guide the tap as you cut 5/16"-18 threads in the longer part.

The single hole in the longer part is drilled $1/4"$ and tapped $5/16"-18$ for the drive pin. This is a $5/16"-18 \times 2"$ cap screw with the head cut off, and it's locked in place with a jamb nut.

Draw the two parts together with short bolts and drill a $1/8"$ hole on the joint centered between the draw bolts. Then separate the halves and file each half to a V.



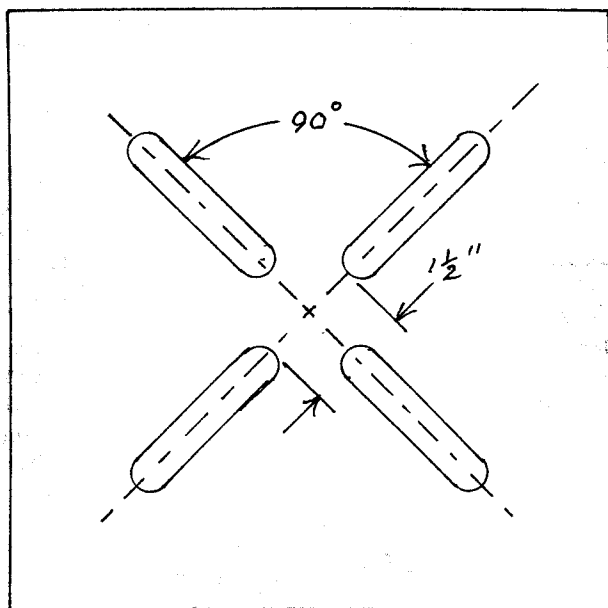
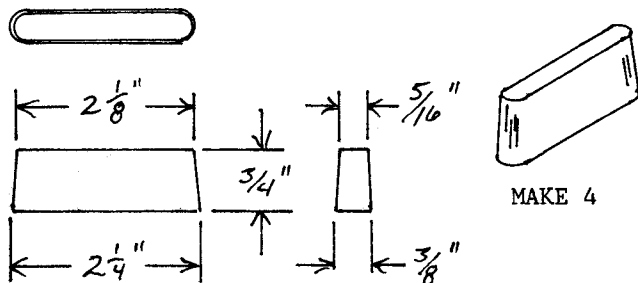
This dog will drive work up to $1"$ diameter, and it is compact enough so that you can run the carriage up close to the drive end of the work. It will also be used with the dividing head for cutting the gears.

THE FACE PLATE

The original face plate described in book #2 is a bit too light for some of the work in these projects. It's an easy job to cast a heavier one, and you have the existing face plate on which to machine its bore.

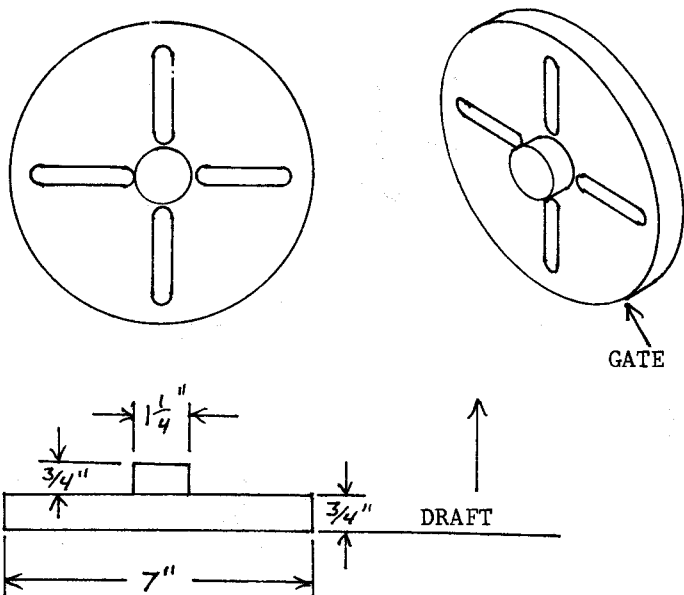
I made mine a full $3/4"$ thick with no recess in the back. A larger hub is a temptation, but the slots need to extend close to the center for some of the work, so a $1 \ 1/4"$ diameter hub proves adequate.

The slots in the face plate must be well centered and at 90 degree intervals, and this is difficult to form in a plywood pattern. I cut my slots oversize and molded them to true size and position over a waxed wooden pattern using auto body putty. Make four slot patterns very smooth, and mount them carefully on a flat board. Rub both the board and the patterns with parafin so that the body putty won't bond to them.



The pattern, of 3/4" plywood with oversized slots, is carefully centered over the slot patterns and the space is filled with the auto body putty. When the putty has set you can lift the pattern from the board and clean up the edges and check for flaws. The inside surface of the slots must be very smooth and free of undercuts, so you will likely have to fill the flaws and again set it on the core patterns. Clean up the core patterns and re wax them before each use.

When the slots are well formed you can fasten the hub pattern with glue and brads and mount the finished pattern on the existing face plate to true up the rim and the hub.



Molding is routine, but don't ram the slot cores any harder than the rest of the sand, or the cores will break off when you draw the pattern. Vent well with the wire and feed at the rim with a 1 1/4" sprue and a short runner.

Mount the casting on the existing face plate with spacers so that the boring bar can pass through, and bore to fit the spindle nose. Install the set screw in the hub and mount the new face plate on the spindle nose to true up the rim and face it off. The slots can be cleaned up with a coarse file.

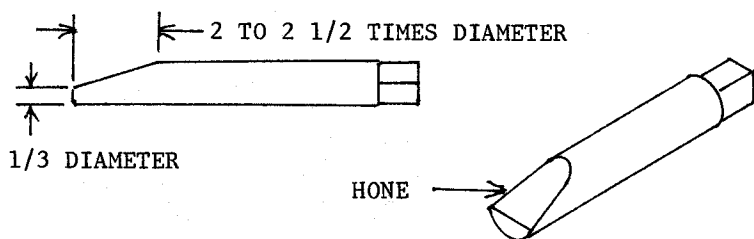
HAND REAMERS

It is difficult to bore to exact size, and time consuming too. It's much faster and easier to drill or bore to near size and finish with a hand reamer.

Reamers are quite expensive, and it's hard to justify their cost for occasional use in the home shop. Fluted reamers are a bit technical for home shop production, but there is a simple type that works very well.

You can make these out of drill rod and harden them and temper them for use on iron or mild steel, but cold rolled steel, untreated, works very well on aluminum, brass and pot metal.

Simply cut a bevel on one end of a length of cold rolled steel and square the other end for the wrench. Hone the cutting edges very sharp and clean.



From 4" to 6" long is adequate for most jobs. I've made them longer and used them as aligning reamers for use on re-bushing electric motors, and they work nicely. They cut to a very snug fit on the shank size of the reamer, so you need to do a bit of scraping with the three cornered scraper for a proper running fit. A set that includes 1/4", 3/8", 1/2", 5/8" and 3/4" will do all of the work in this manual, and it will be a handy set for future use.

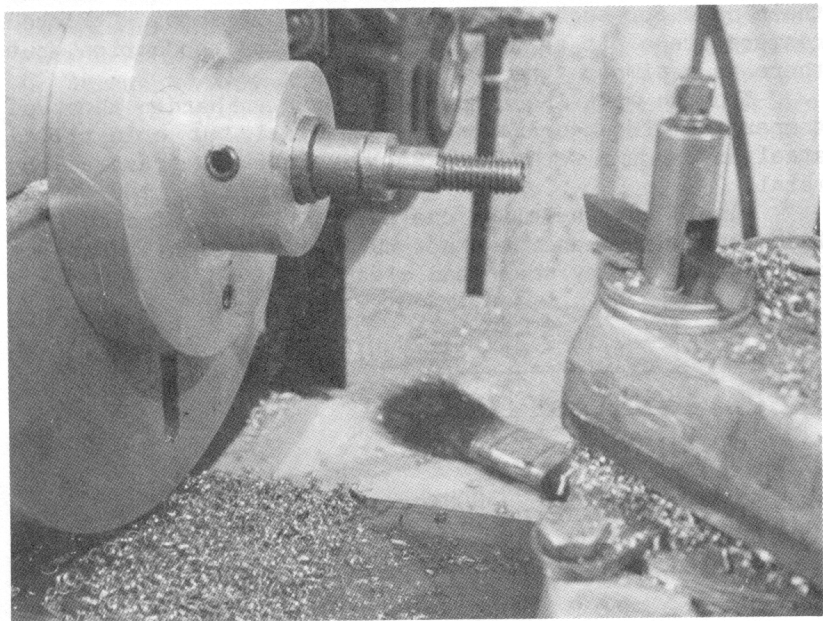
They require slow speed and lots of power, so they are not suitable as chucking reamers on light power equipment.

A SET SCREW CHUCK

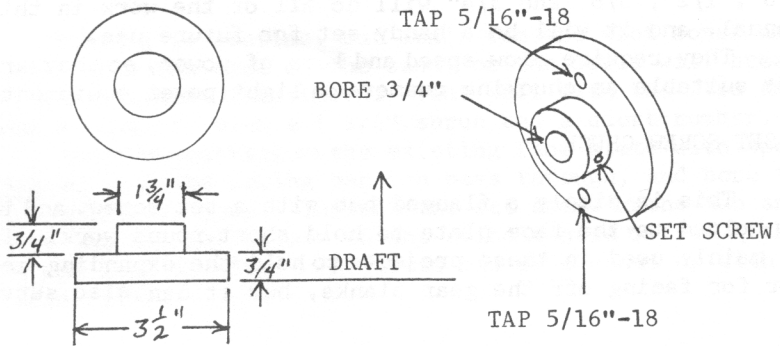
This is simply a flanged hub with a set screw, and it is bolted to the face plate to hold short round work. It is mainly used in these projects to hold the expanding arbor for facing off the gear blanks, but it can also serve

in place of a three jaw chuck for some jobs. The bore can be made larger or smaller, and split pulley bushings can be used to hold work that is smaller than the bore.

It's shown in use in the photo below to make a shoulder bolt from a scrap of 3/4" cold rolled steel.



It's a simple casting job, and the machine work is as simple. A length of stock the same size as the bore is tapered at about 45 degrees on one end, and it serves to center the fixture as it enters the mouth of the spindle nose taper when you bolt it to the face plate.



The casting is first bored to size and the set screw is installed in the hub. It can then be mounted between centers on an arbor to face off the back side and true up the outside diameter. When it's bolted to the face plate the bore will be at right angles to the face plate, and the tapered gauge will center it on the turning axis.

AN EXPANDING ARBOR

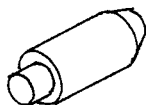
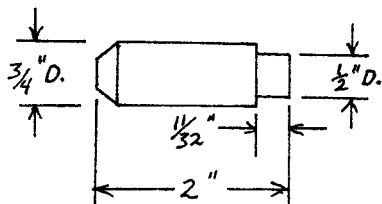
This type of fixture is normally made with a taper shank to fit the spindle nose, and it's held in place with a draw bar. Blank taper shank arbors are expensive, if you can find one, and they are time consuming to make. I made my expanding arbor to fit the set screw chuck, and its tapered back end is also the centering gauge for the chuck.

The gear blanks will be mounted on the expanding arbor to face them off to finished thickness.

Slip the finished set screw chuck over a straight $3/4$ " arbor and mount the arbor between centers. This will center the chuck as you bolt it to the face plate. Then remove the arbor and knock out the spindle nose center, and the chuck will be in position to machine the expanding arbor.

Prepare a $2\ 1/4$ " length of $3/4$ " cold rolled steel with a flat for the set screw to seat against and mount it in the set screw chuck. Machine the exposed end to a blunt taper of about 45 degrees. Invert the stock in the chuck so that the tapered end enters the mouth of the spindle nose taper and again lock the set screw. Mark the rim of the chuck so that you can return it to the face plate in the same position each time it is used, and the tapered end will center the chuck for future jobs.

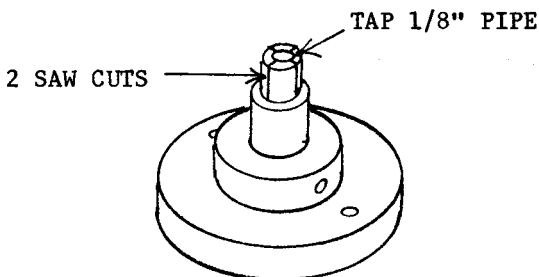
Machine the opposite end of the stock to a diameter of $1/2$ ", leaving a shouldered stub $11/32$ " long after the end is faced off square.



Cut a small center in the faced off end with the facing off tool, and use the tail stock chuck to drill a $21/64$ " hole about $3/4$ " deep in the end of the arbor.

Hold a standard $1/8$ " pipe tap in the tail stock chuck as you run it into the tap hole as far as you can while you turn the face plate by hand to start the tap true. Then you can remove the entire face plate and clamp it in the vise as you continue to tap by hand to a depth of about $1/2$ ".

Carefully make two hacksaw cuts nearly to the shoulder to divide the stub into four equal segments, and run the tap in again to clean up the threads.



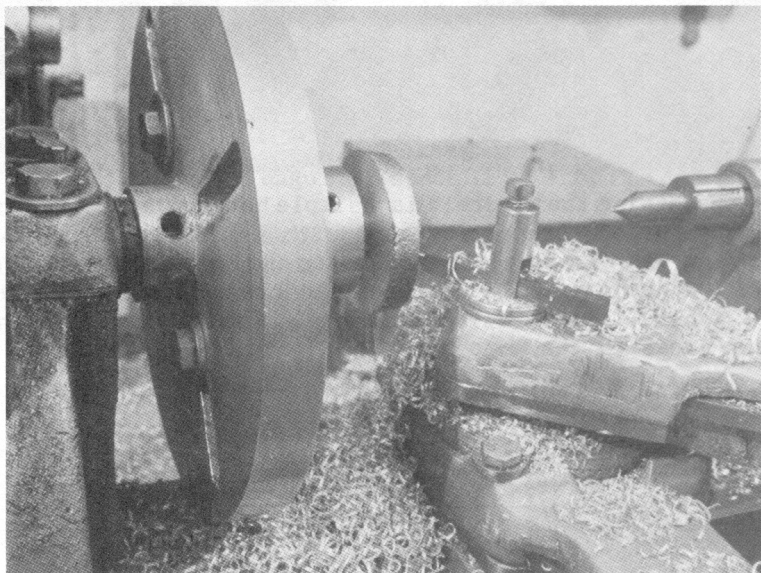
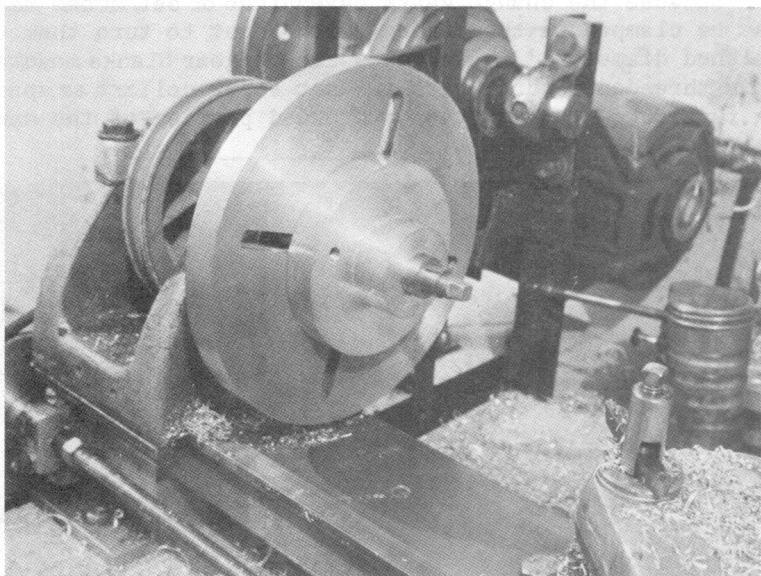
Turn a $1/8$ " pipe plug into the hole until it just begins to get snug. Then mount it on the lathe to lightly clean up the stub with a file.

Being tapered, the plug will expand the arbor when it is turned into its tapped hole. The finished stub should fit the bore of the gear blanks closely when it is relaxed. About one turn of the plug should hold it securely. The $21/32$ " length of the stub will permit facing the blanks to a finished thickness of $3/8$ " without damaging the arbor.

The gear blanks are first drilled and reamed to $1/2$ ", and the prepared blank is mounted on the arbor with its back surface not quite in contact with the shoulder. The exposed surface is faced off clean and the blank is removed to lightly chamfer the bore on the faced off side. Then the blank is again mounted on the arbor with its faced off side snug against the shoulder of the arbor. The second side is then faced off to bring the blank to its finished thickness of $3/8$ ".

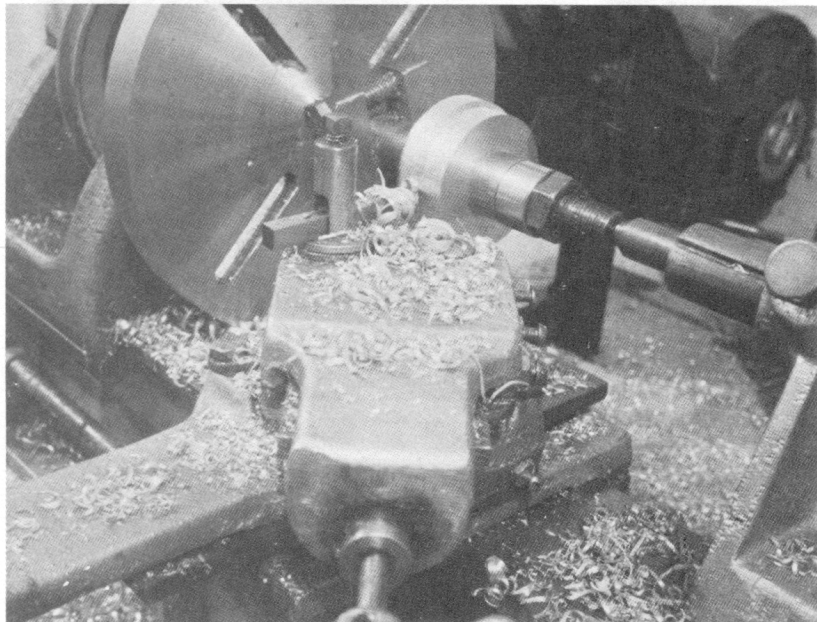
This type of fixture will never be precisely concentric, so the blanks will later be machined to diameter on the threaded mandrel.

The completed fixture is shown below. I've since replaced the plug with one that has a hex socket.



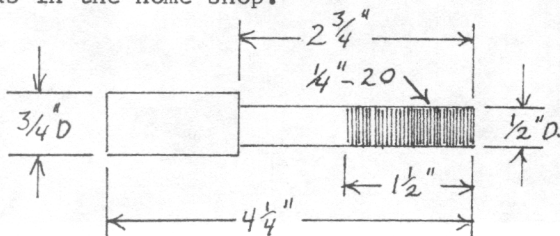
THREADED MANDRELS

Because the change gears have no hub or set screw they must be clamped on the mandrel with a nut to turn them to finished diameter. Shown below are two gear blanks mounted on the threaded mandrel with two set screw collars as spacing furniture to take up the unthreaded portion of the mandrel.

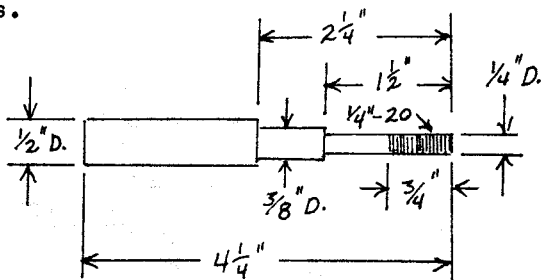


Machining the mandrels is a simple between centers job, and the threads are cut by hand with a guided die stock.

You'll need one of $1/2''$ diameter and one with both $1/4''$ and $3/8''$ diameter. The between centers capacity of the dividing head limits the length, which is still ample for the usual needs in the home shop.



The 1/4"-3/8" mandrel will find use when you are making the gear for the threading indicator and for several other small parts.



HAND THREADING

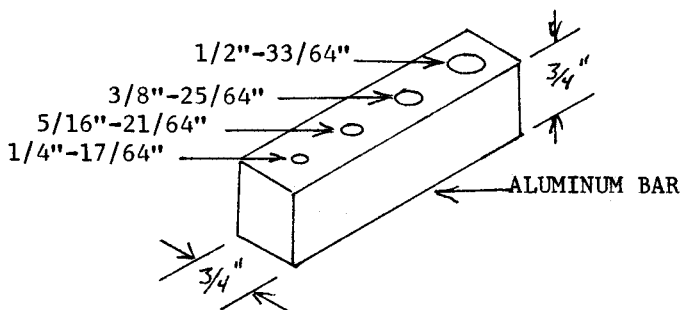
The main reason that we are adding change gears to the lathe is so that we can cut screw threads that are true to center. We'll have to rely on the hand threading die until the gears have been added.

A guided die stock will cut threads that are true to reasonable limits if you use it properly. The common type has three jaws that are adjusted by turning a ring, and it will not center accurately unless you help it.

Just install the die in the stock and run a cap screw into the die. Now adjust the guide so that it bears on the threads of the screw. Lock the guide, remove the screw, and you are ready to cut accurate threads.

You can start the threads with the guided stock, and then finish with an unguided stock if you need to cut right up to a shoulder.

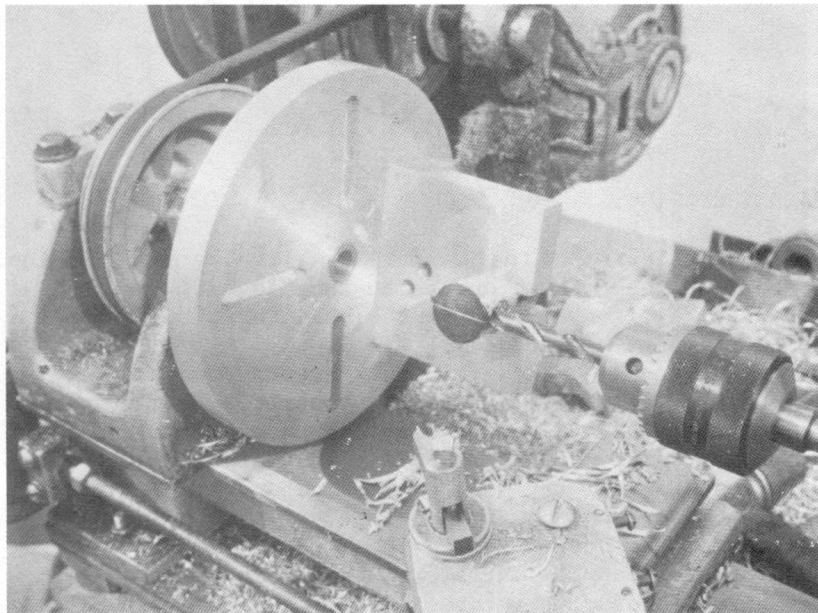
A guide for tapping holes that are truly perpendicular is made by drilling a true hole 1/64" over the bolt size in a piece of stock. A single tapping jig with a row of holes for the most often used sizes is a handy tool.



ANGLE PLATES

When an accurately made angle plate is bolted to the face plate it presents a mounting surface that is at right angles to the face plate. Then you can mount work on the plate to machine it on a line that is parallel to its base.

The angle plate is in use below to drill the tap hole in one of the nuts that is needed for the four jaw chuck.



Detailed directions for making angle plates are given in book #5. They will find plenty of use in this project.

DESIGN YOUR OWN JIGS AND FIXTURES

When you have the ability to make a casting, and the equipment to machine them, you can produce just about any tool or fixture that you can dream of.

Just envision the work piece suspended in position for the required machining operation. Then imagine the size and shape of what is needed to hold it there. Simple castings along with scraps of stock and standard fasteners will usually be all that you need. You will soon see that a simple lathe is really a universal machine tool.

CHUCK BUILDING

A chuck is a holding fixture that supports either the work or the tool. There are some jobs that can be done by using a chuck, and others for which a chuck is a hindrance. If I had to choose between a chuck and a face plate I would have to say that the face plate is far more valuable for a home shop operation, while a chuck might be ideal for some repetitive chores in a commercial shop.

There has to be a bit of sour grapes in my philosophy because I simply couldn't afford a chuck for many years. I managed without one well enough to build my entire shop, so I can only grant grudging respect for a pretty nice gadget.

The design for the four jaw chuck that is presented in this manual is something of a breakthrough because it is so easy to build and the cost is so slight. I would have built one years ago if I'd known how, and then I'd be telling you that you just can't run a shop without one.

If you were to consider buying a chuck you would have to choose between a three jaw self centering chuck or one with four independent jaws. The self centering chuck is the obvious choice for repetitive round work because it saves set up time, while the four jaw chuck is more adaptable to the variety of work that is done in the home shop.

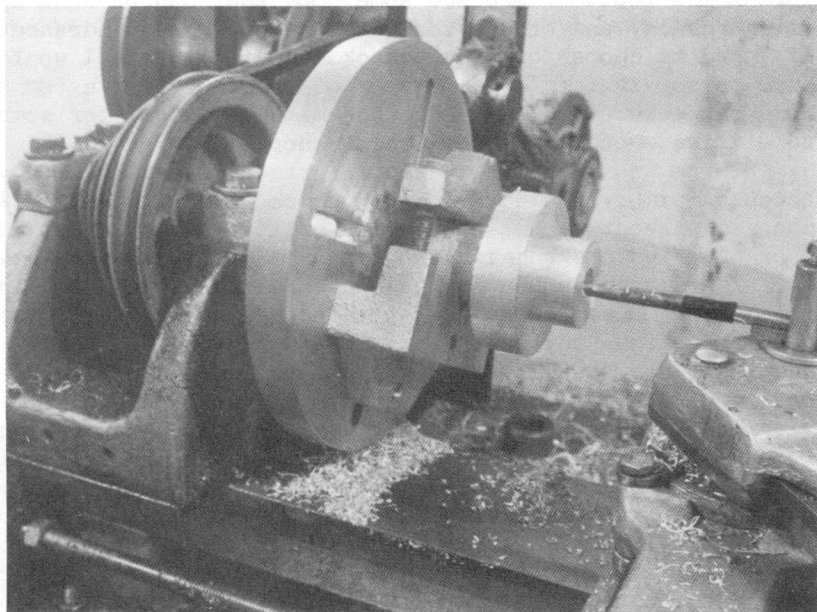
A three jaw self centering chuck is beyond the scope of our home shop at its present level because it requires a scroll to close the jaws, but a two jaw chuck is easy to build, and it can be self centering for repetitive work of the same diameter once the first piece has been centered. Only one jaw is moved to release the work, and new work is located on the same center when the same jaw is closed on it. A four jaw chuck can perform in the same way if only one or two jaws are released.

The four jaw chuck can be fit with jaws of any shape to suit the problem at hand. A pair of V block jaws can be very useful for round work, either centered or eccentric, and a pair of angle iron jaws will support most rectangular work in just about any position.

The two simple chucks that are described in this chapter will fill all of your needs that have not been handled by simple fixtures that have been described in the earlier manuals in this series.

THE TWO JAW CHUCK

This fixture is so simple and versatile that it just doesn't make sense to do without it. It's shown below in a boring operation where a portion of the sprue was left on the casting to provide a grip for the chuck.



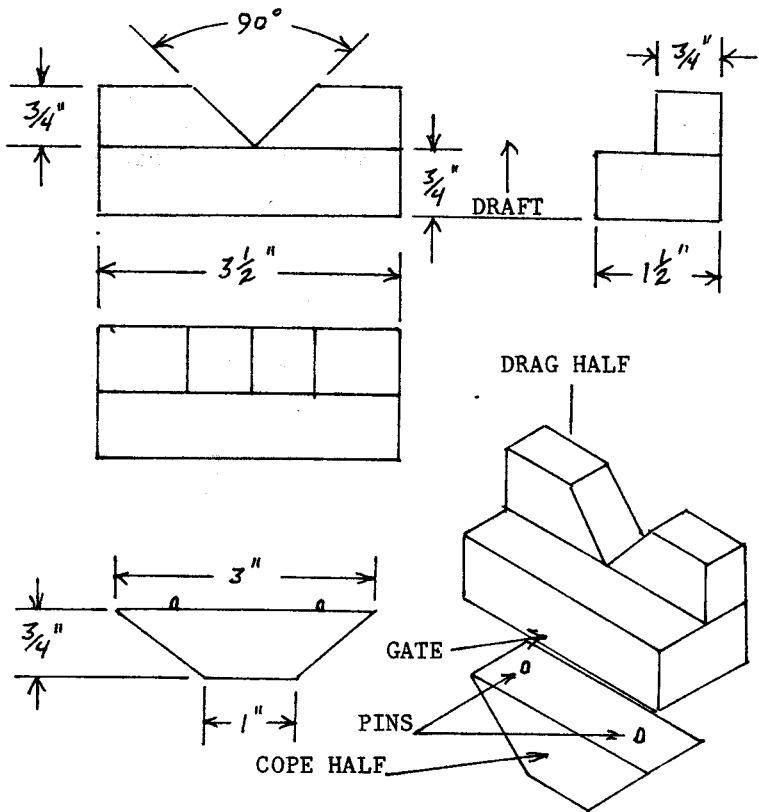
Its V block is either filed or milled smooth, and the clamp is installed with two 5/16"-18 cap screws. Then it is clamped to a true arbor that is mounted between centers and the base is faced off. A single 5/16"-18 cap screw is used to mount the finished fixture on the face plate, and two or more holes can be tapped in the flange for mounting either on or off center.

An arbor the same size as the work piece can be mounted between centers to guide the mounting for centered work. Repetitive work of the same size can be done very fast.

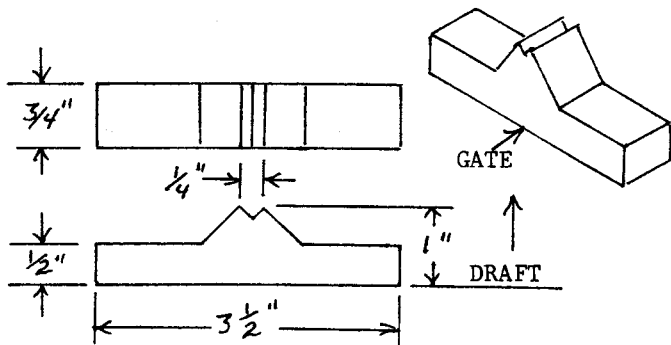
It is faster and easier to set up for off center work than the four jaw chuck.

Its design provides clearance for boring through, and the front surface can be faced off to provide a mounting surface that is parallel to the face plate for some types of plate and disc work.

The patterns are simple, and molding is routine. Feed both molds with a 1 1/4" sprue and a short runner.



CLAMP PATTERN



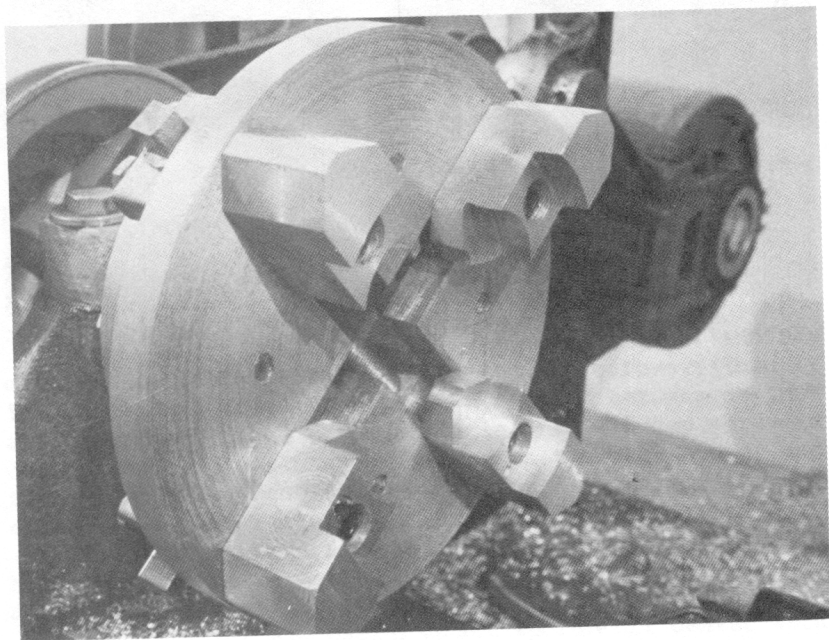
THE FOUR JAW CHUCK

Only two castings make up the main body, and the jaws require just one split pattern. A bit of key stock, standard fasteners and some cold rolled round stock furnish the remainder of the material.

I purchased a 3/8"-16 left hand tap and die from Wholesale Tool Co. to make the screws and nuts, but you can do it with a standard right hand thread if you don't mind the screws turning backwards as you tighten the chuck.

I finished the slots by hand with a 16" double cut file even though the milling machine was at hand. It was less labor than fitting out and setting up the miller to do it with an end mill.

The remainder of the work was done on the lathe and the drill press, so you can easily build this chuck even if you don't have a milling machine.



The patterns are simple and molding is routine. The machining consists of basic turning, boring and facing off, and the hand operations require no special skill. It is a delightful exercise in metal working that you should do even if you don't want the chuck.

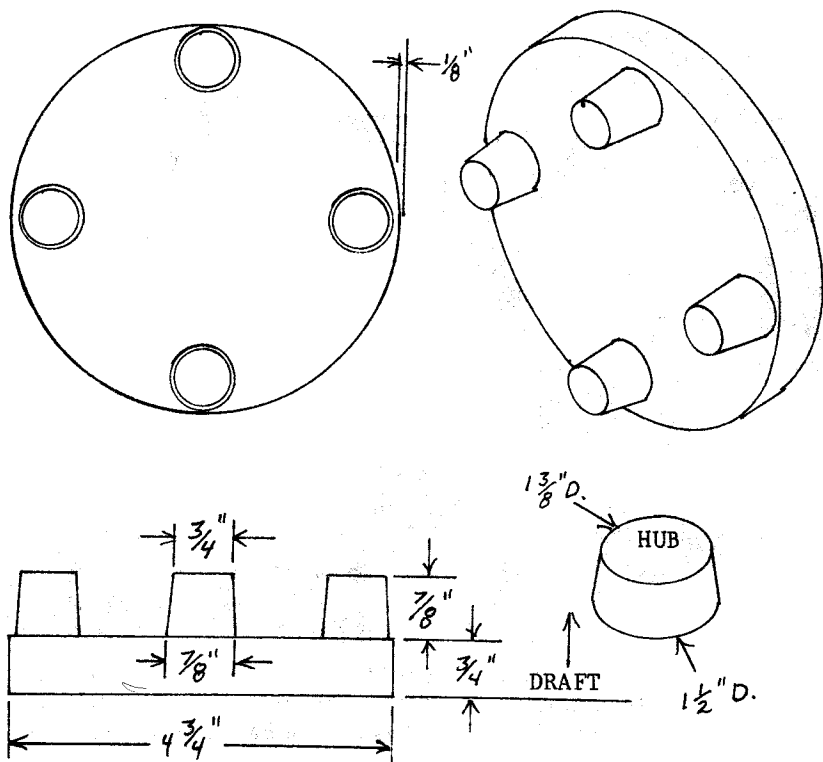
THE BACK PLATE PATTERN

Notice that the four round pads taper from $7/8$ " at the base to $3/4$ " at the top. They are located equally spaced, $1/8$ " from the rim, and fastened with brads and glue. Wipe a small fillet at the junction.

The hub pattern forms the cope half of the split pattern, and it is located in the center of the plate by a pin in its base that enters a hole in the plate.

Ram up the main body carefully and vent generously with the wire. Roll over the drag and set the hub pattern in its place and set a $1\ 1/4$ " sprue pin in the center of the hub pattern. A small pin in the center of the sprue pin will center it on the hub.

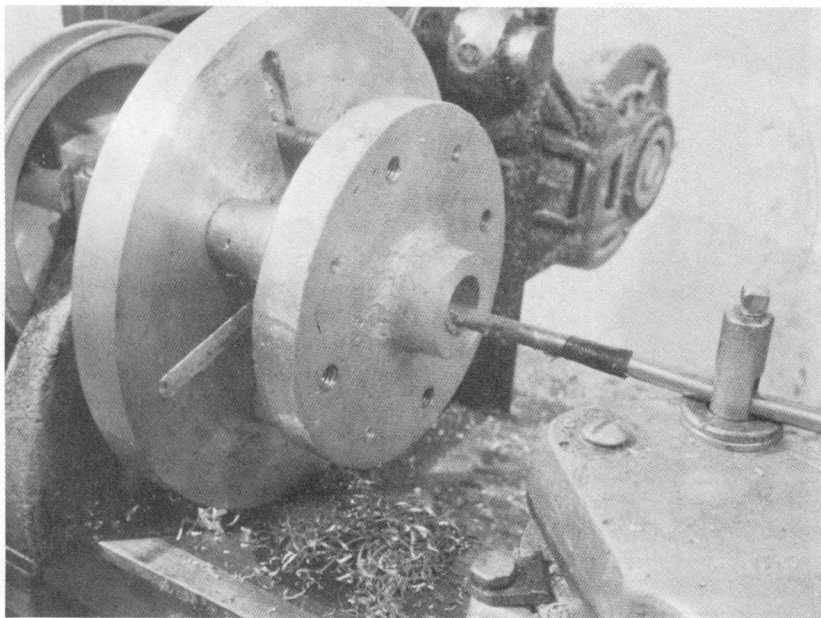
Swabbing the edge of the cope cavity will form a fillet at the hub. Clean up the sprue opening and the cavity very carefully to avoid sand inclusions in the casting.



The sprue is cut off at the hub and eight 1/4" holes are drilled through the casting. Four are drilled through the center of the pads, and the remaining four are drilled exactly centered between them on the same circle. This work should be done on the drill press so that the holes will be truly perpendicular.

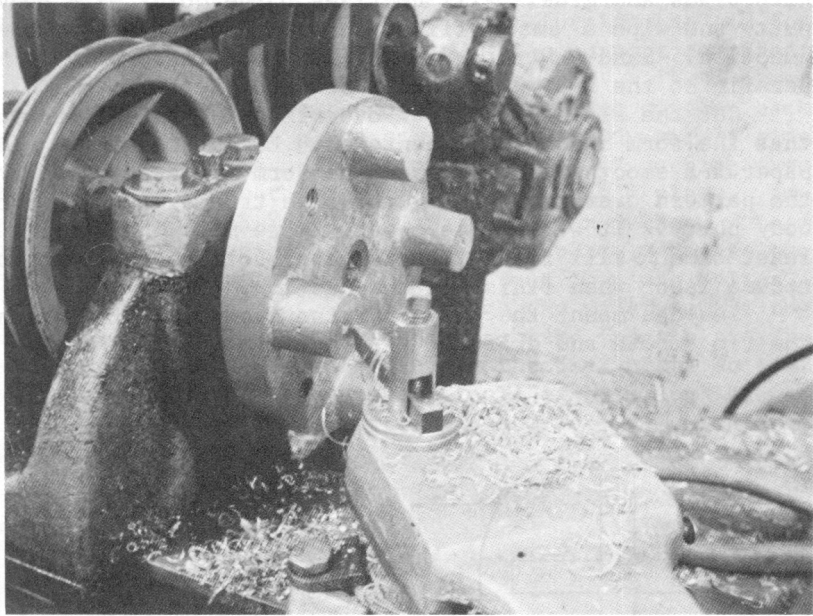
Tap the four holes between the pads 5/16"-18. Two of these will be used to mount the casting on the face plate, and they will all find use later.

The photo below shows the casting bolted to the face plate with the pads resting on the plate, but this is not the best way to do it. A stack of set screw collars or other spacing furniture should be used so that the pads do not contact the face plate. Then the mounting surface of the casting will be more truly parallel to the face plate for a more accurate boring job.



Center the casting carefully, bore it for a close fit on the spindle nose, true up the diameter of the hub and face off the exposed side. You can bore to near size and ream to fit the spindle.

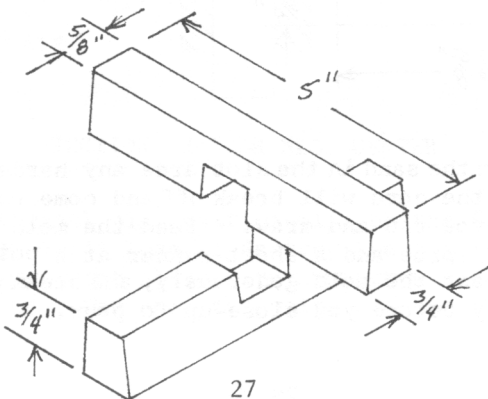
Install a 5/16" set screw in the hub and mount it on the spindle nose to face off the pads. Their finished height can be from 3/4" to 13/16", but not less than 3/4".



THE FRONT PLATE PATTERN

A simple plywood disc with rectangular slots for the jaw nuts. The slots must be well centered and cross at exact right angles for the best jaw alignment.

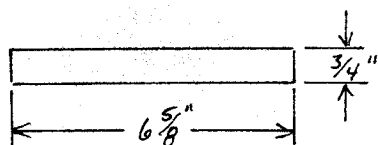
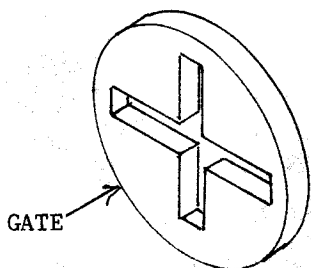
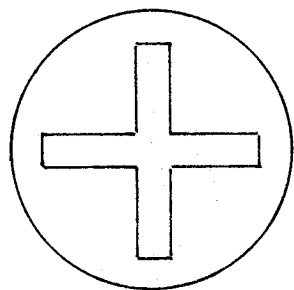
I made a crossed form and molded the slots with body putty just as we discussed for the heavy duty face plate.



Note that the end section measures $3/4$ " at the base and $5/8$ " at the top. This is for draft, and the ends must also be drafted. Assemble the half lap true square and fasten with brads and glue. Fill any flaws at the joint with body putty and wipe a small fillet in all four corners at the junction. Sand very smooth all over and rub thoroughly with parafin so the body putty won't bond to the form.

Cut the slots about $1/8$ " oversized in the pattern so that the form can be well centered. Lay a sheet of waxed paper on a smooth board and brad the form to the board. Lay the pattern over the form and mold the true slots with the body putty. It will be necessary to re-mold the slots at least once to fill flaws. Finish the slots very smooth to reduce labor when finishing the casting.

You can mount the pattern on the face plate to finish the rim smooth and drafted.



Don't ram the sand in the slot area any harder than the main body, or the core will break off and come out with the pattern when you rap and draw. Feed the mold at the rim with a $1 \frac{1}{4}$ " sprue and a short runner at a point between two slots. Vent the mold generously, and clean up the cavity thoroughly before you close up to pour.

MACHINING THE FRONT PLATE

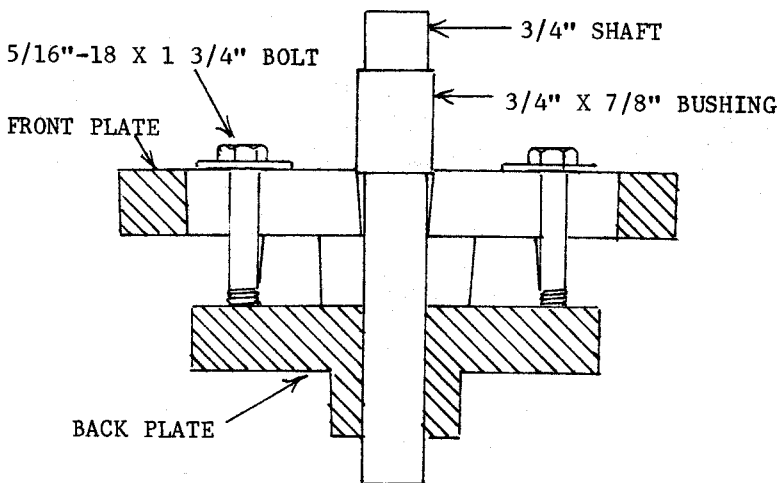
The front plate will be fastened to the back plate with four 5/16"-18 X 1 3/4" cap screws through the pads. The machined and drilled back plate will furnish the jig for drilling the front plate, and it will also support the front plate as you face off both sides parallel.

Slip a 3/4" shaft through the 3/4" bore of the back plate. Lay the front plate on the pads with the widest side of the slots facing up. Slip a 3/4" X 7/8" bushing over the shaft to center the front plate on the back plate. Install two 5/16"-18 X 1 3/4" cap screws through the slots and into two of the tapped holes in the back plate. Locate the pads equally between the slots and snug down the bolts.

Use the four 1/4" holes through the pads to guide the drill as you drill 1/4" holes through the front plate.

Mark both the front plate and the back plate so that you can return them to this original jig position later.

Tap the holes in the front plate 5/16"-18, and enlarge the holes through the pads to 5/16".



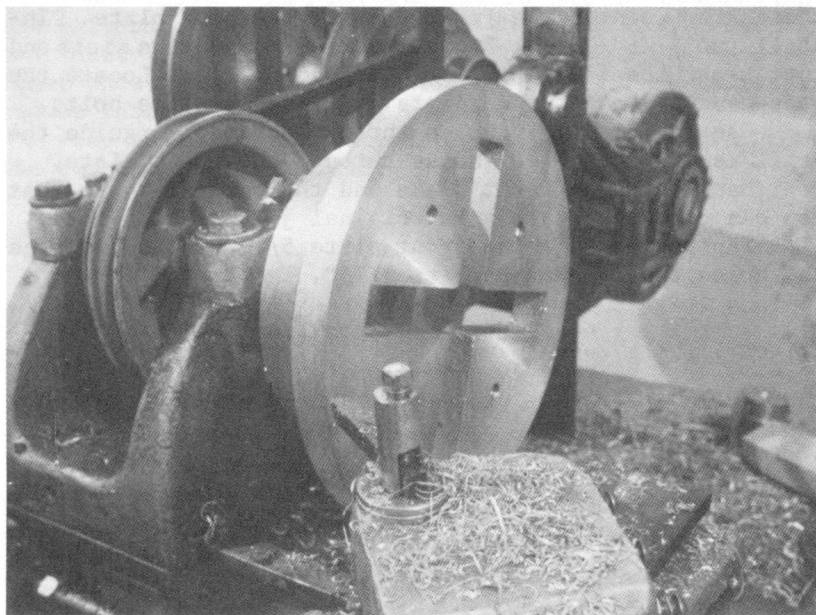
SECTION THROUGH SLOT CENTER

The original jig position will be the final assembly position, so don't lose or destroy the jig marks.

Mount the front plate with the narrow side of the slots exposed first. Use only two bolts because the holes will

not align with the parts reversed. Make sure that all four pads contact the plate, and use shims to give an even bearing if necessary. Face off the exposed surface until it is clean and smooth.

Now you can mount the front plate in the original jig position, using all four bolts with flat washers and lock washers, to face off the second side. If all is done carefully both sides will be parallel, and the face of the chuck will be at right angles to the turning axis of the lathe.

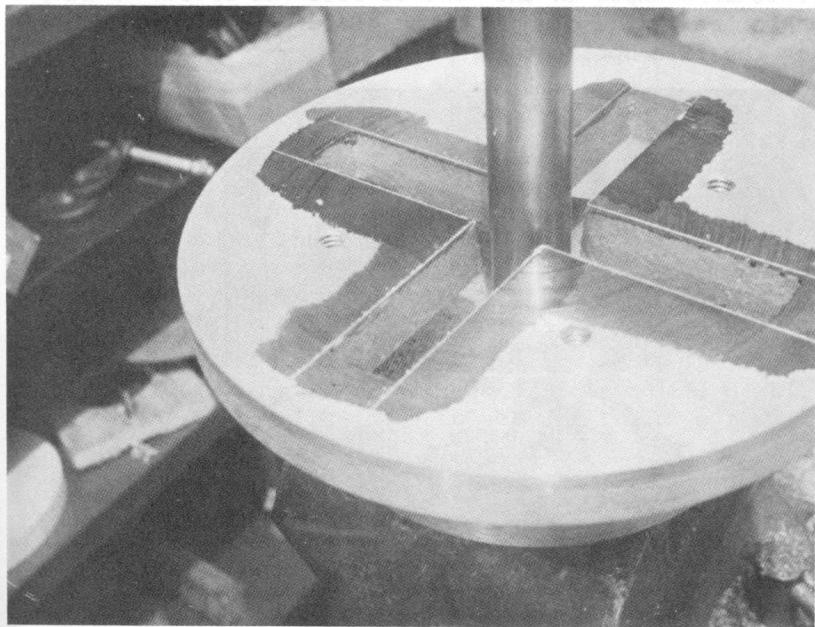


Machine the outside diameter of the front plate true and make a new reference mark before you remove the front plate to finish the slots.

If I were going to make several chucks I would fit out the miller and machine the slots with an end mill. It took less than an hour to file them with a 16" double cut bastard file, which I got at a bargain from Wholesale Tool Co. It would have taken at least a day to fit out the miller so I took the easy way.

Blue layout die makes it easy to work to a scribed line and it only takes a moment to dry to touch. Paint the area around the slots with the layout die.

A 3/4" shaft through the bore of the back plate will center the layout, and it is also a gauge to mark the width of the slots to exactly 3/4".



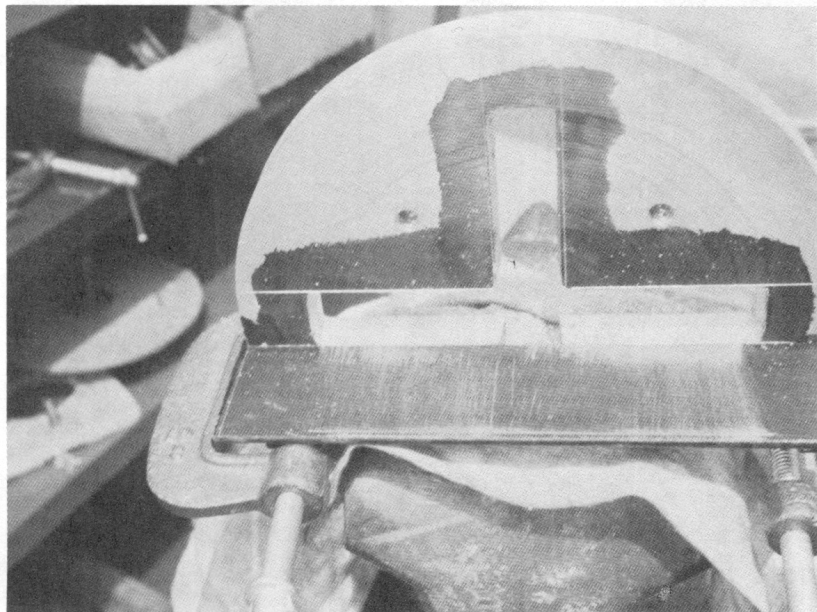
FINISHING THE SLOTS TO SIZE

The object is to cut the slots to a uniform 3/4" width, and they should cross at as near exactly 90 degrees as possible. The blue layout die will show a very clear mark if you use a sharp scriber. One or more short lengths of 3/4" wide cold rolled stock will be a help with the layout, and an accurate straight edge and try square are vital.

Clamp a straight edge to the front plate so that it rests against the 3/4" diameter center shaft, and align it carefully with one of the slots. Use scraps of 3/4" wide stock to space a second straight edge on the opposite side of the same slot. Scribe lines against both straight edges and remove one of them.

Use an accurate try square against the first clamped straight edge to align a straight edge on the edge of the second slot at exactly 90 degrees. Clamp it securely and remove the first clamped straight edge. Now you have a guide against which you can lay out the second slot as you did the first.

It is difficult to file to a line, and maintaining the work angle at exact right angles to the plate is even more difficult. The front plate is removed from the back plate and clamped in the vise to file the slots. A simple angle iron guide clamped to the plate will aid you in holding the file horizontal.



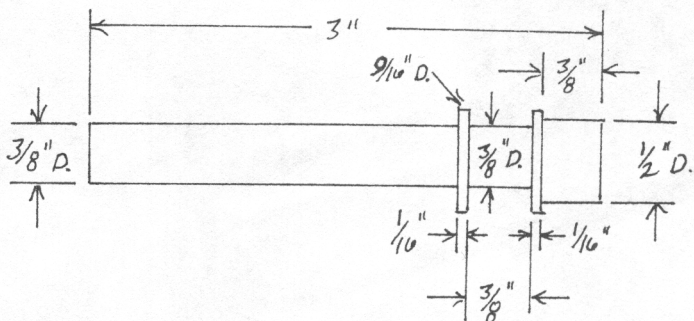
The finished width of the slots is to be $3/4$ ", but it is not critical. The important thing is to have them of uniform width. When you get near to size you can use a scrap of $3/4$ " cold rolled shaft for a gauge, and do the final fitting with the three cornered scraper. The chuck will work well even if the slots are a bit loose, but you don't want any tight spots to bind up the jaw nuts.

THE JAW SCREWS

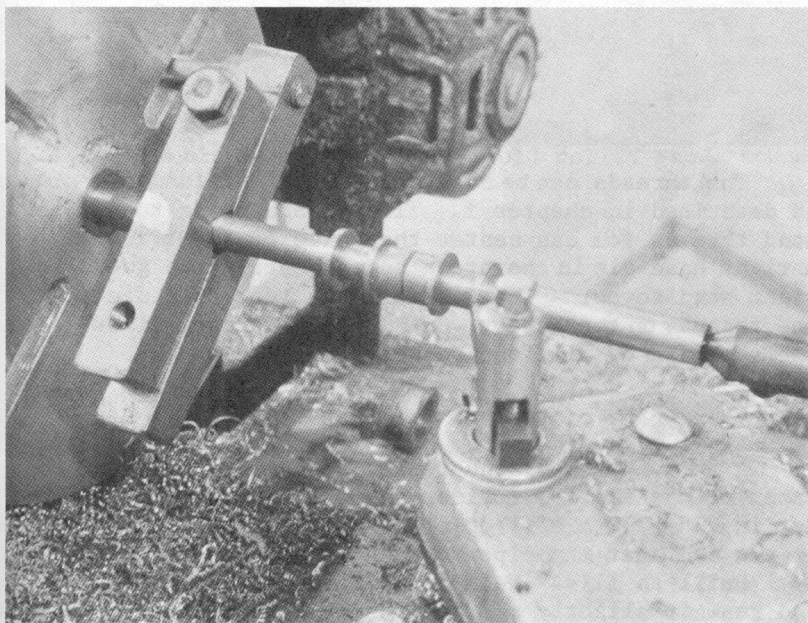
This is a simple between centers lathe job. Four of them are needed, and it will be easiest to make them two at a time and then cut them in half.

You can't cut such grooves in a shaft by plunge cuts on a small lathe. You make multiple passes to depth with a turning tool, which cuts a V shaped notch. Then you face

off the sides of the slot to leave the straight sided shoulder. By making two at once you can turn the work end for end to face off the shoulders so that all of the work can be done with a right hand tool.

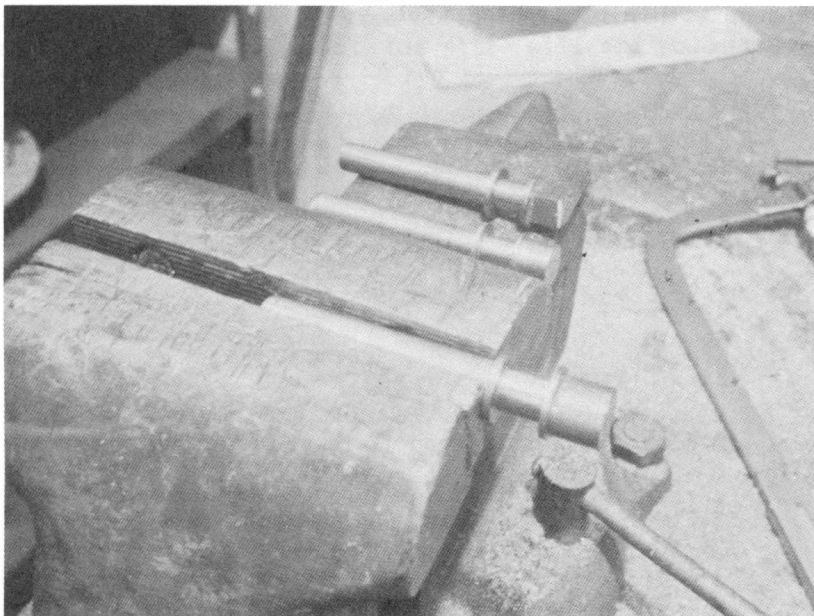


Prepare 6" lengths of $5/8"$ cold rolled steel with centers and make two pairs, head to head, as shown below.



Cut the heads partially in two with a hack saw while the work turns in the lathe but don't try to cut all the way through. Finish the cut off in the vise.

It's a simple job to file the 1/2" round heads to 3/8" square with the large double cut file.



The threads can be cut by hand with a guided die stock as described in chapter I. If you are going to cut left hand threads you can center the guide by first installing a right hand die in the stock and adjusting the guide to a right hand screw. Then install the left hand die to cut the threads on the screw. Cut 3/8"-16 threads right up to the shoulder of all four screws.

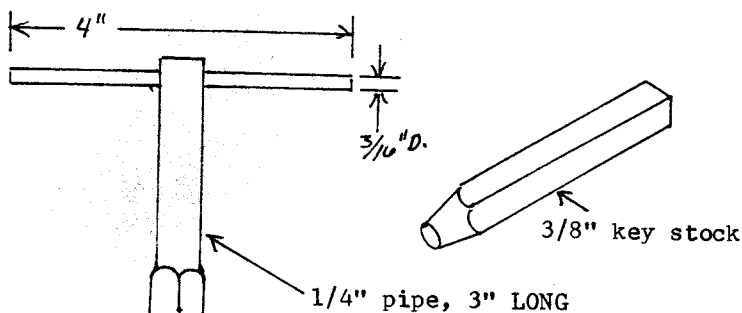
THE CHUCK WRENCH

A piece of 3/8" square key stock can be ground to a taper on one end to provide a die for swaging a square socket in a 3" length of 1/4" pipe. The job can be done cold or you can heat the pipe to make it easier.

Drill an 11/64" hole through the top end of the pipe and ream it slightly so that you can force in a 4" length of 3/16" rod to form the handle.

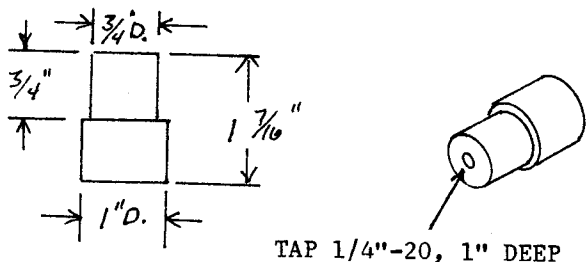
16 pitch threads are much finer than usual for a chuck screw, so the leverage is greater. You will have ample power with the small wrench, and it will help you to avoid over tightening the jaws.

A 7/16" 12 point socket or box wrench will fit the 3/8" square head of the screws, and there are 3/8" square socket wrenches that are made for welding gas tanks that will serve as a chuck wrench.



THE JAW NUTS

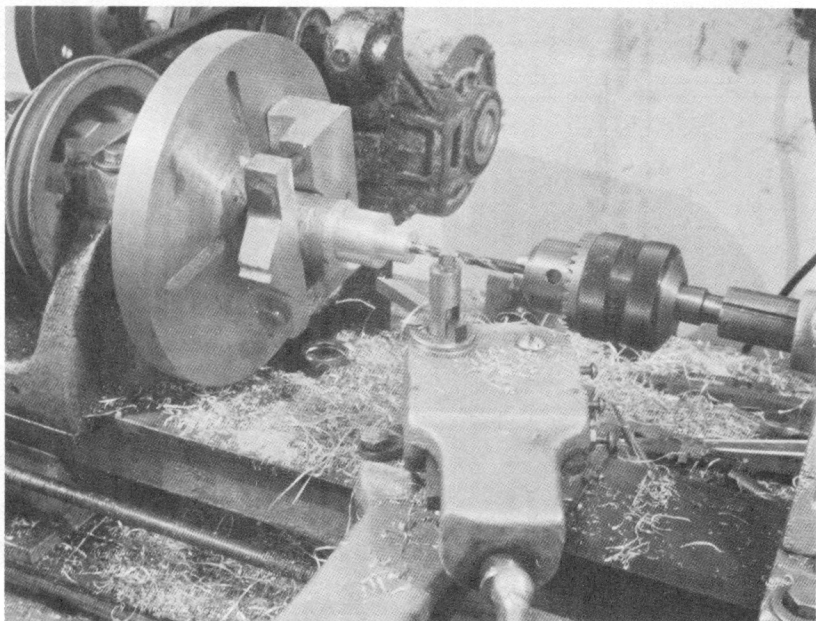
These can be made of either aluminum or cold rolled steel. I made a set of both, and the steel ones greatly improved the feel of the chuck, though the aluminum ones seem to be strong enough. I used sprues to provide the stock for the aluminum ones, and 1" cold rolled steel round stock for the steel ones.



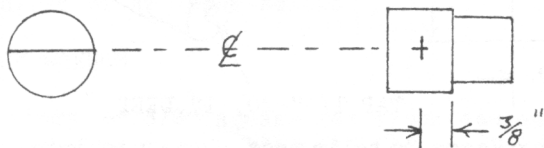
The photo on page 36 tells most of the machining story. All machining operations are done before cutting off so that the tapped hole will be concentric. Machine the diameters and face off the end and the shoulders. Then drill the tap hole 13/64" and start the 1/4"-20 tap with the tail stock chuck before cutting off. Finish cutting the threads with the nut held in the vise.

You can cut off with the hack saw, but be very careful.

Work that is not supported at the tail stock can be cut all the way through with the hack saw while turning, but there is obviously danger of injury, so be very sure of what you are doing.

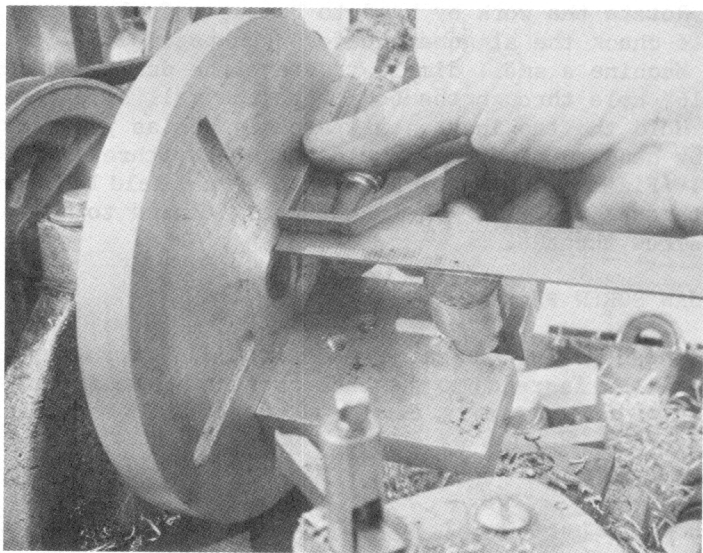


The jaw screw hole must be well centered and aligned so that the nut won't wobble on the screw. By marking out very carefully and aligning the nut on the angle plate you can do the work with the tail stock chuck.

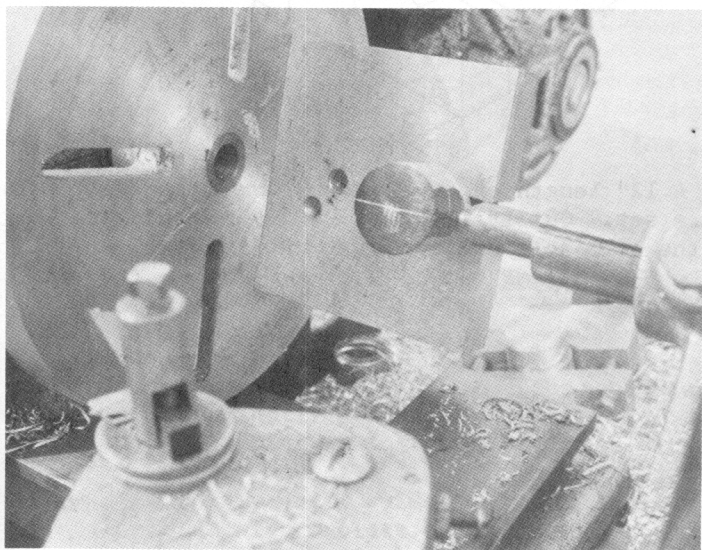


Blue the nut and very carefully scribe a center line on the base. Extend the center line up the side and mark the center $\frac{3}{8}$ " below the shoulder. Punch the center exactly on the mark. This will be the center for the jaw screw, and the scribed line on the base will serve to align the nut true to the turning axis of the lathe. Prepare all four nuts in the same manner.

Use an accurate square to align the base at exact right angles to the face plate.



Then use the tail center to align the punch mark with the turning axis of the lathe.



I cut a slot in the angle plate so that I could mount work very close to the edge. A 1/4" cap screw with a flat washer holds the nut to the angle plate.

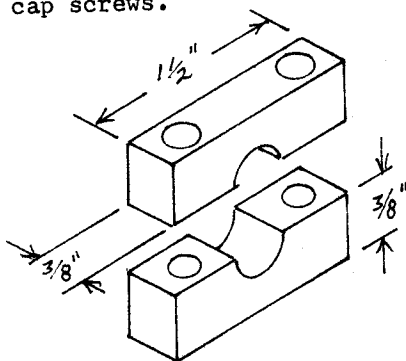
Rotate the work by hand to be sure of clearance, and double check the alignment before you begin drilling.

Machine a small dimple to start the drill, and drill a 5/16" hole through the body with the tail stock drill.

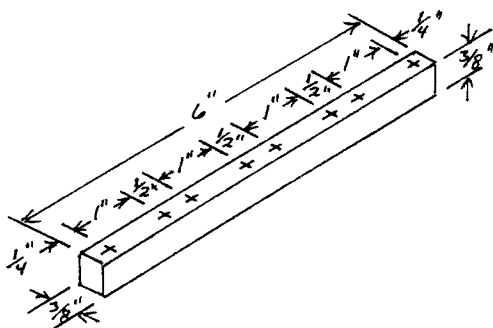
Hold the tap in the tail stock chuck as you start to tap by hand turning the face plate so the threads will be true. Finish tapping by hand with the nut held in the vise. The threads are 3/8"-16, right or left hand to match the jaw screw threads.

THE JAW SCREW BEARINGS

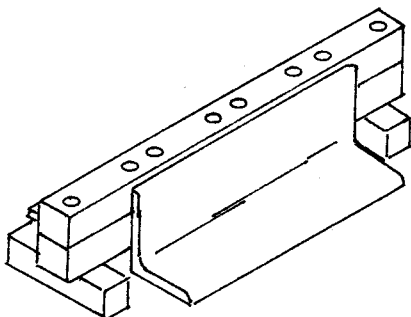
These are split bearings made from 3/8" key stock, and they will be fastened to the back surface of the front plate with 1/4" cap screws.



A 12" length of 3/8" square key stock will make the entire set. Cut it into two 6" lengths and carefully lay out the bolt hole centers on either half.



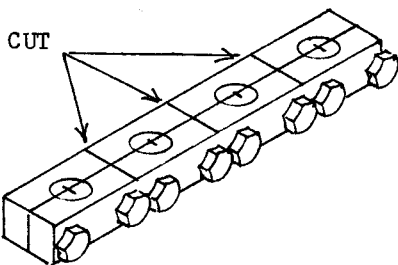
Clamp both halves together in the drill press vise or between two angle irons with leveling furniture and drill eight 13/64" holes through both halves.



Mark the halves so that you can return them to the original position, and separate them to enlarge the holes in one half to 1/4".

Use the enlarged holes to guide the tap as you tap the other half 1/4"-20. Clean up the burrs on both halves and assemble with eight 1/4"-20 X 3/4" cap screws.

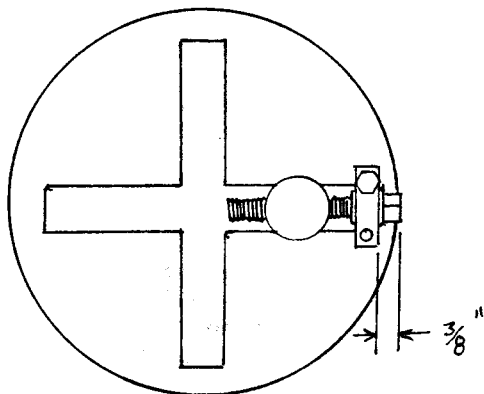
Carefully mark and punch the center between each pair of bolts. Step drill to 3/8", and chamfer each side of the holes slightly with a countersink.



Cut into four separate bearings with the hack saw, and grind the corners slightly rounded.

Separate each bearing and install a jaw screw with just one cap screw in each assembly. In this form they will be a locating jig and a tap drill guide for installing them on the back side of the front plate.

Run a jaw nut onto the screw to about mid way, and lay the assembly on the back side of the front plate. Align carefully so that the screw runs parallel to the slot, with the bearing about $\frac{3}{8}$ " from the edge of the plate.



Clamp securely and drill a $\frac{13}{64}$ " hole through the plate, using the open hole in the screw bearing to guide the drill. Then remove the bearing to drill out the threads in the open hole so the mounting bolt will pass through. Tap the hole in the plate $\frac{1}{4}$ "-20 and install the bearing with a $\frac{1}{4}$ "-20 X $1\frac{1}{4}$ " cap screw with a lock washer. Re-check the alignment carefully before you remove the screw from the other hole to drill the second tap hole. Install the second cap screw in the same manner. Repeat all for the rest of the screw bearings.

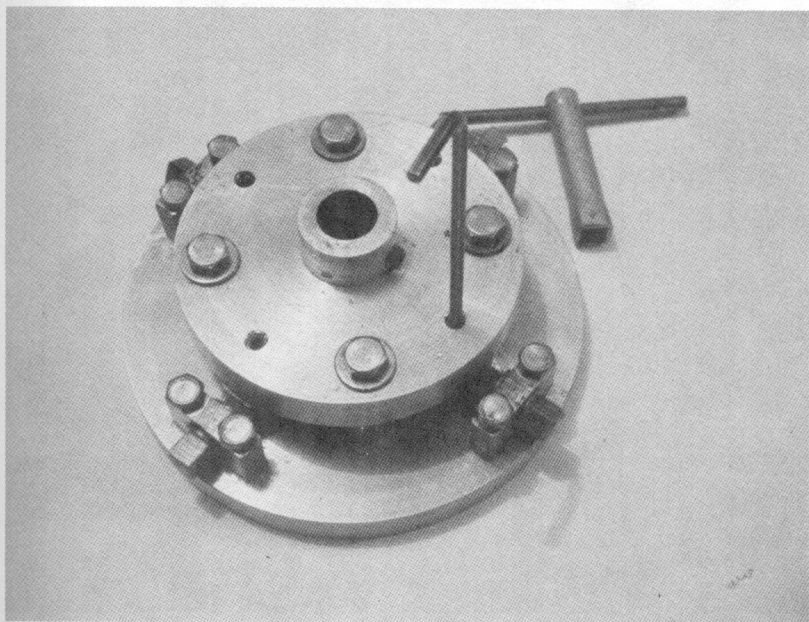
The screw should run the nut over its full length with no binding. It may be necessary to ream the bearings or add shims if the nut binds as it runs near the bearing.

TRIM THE JAW NUTS

The shouldered portion of the nuts will be too long, and they must be trimmed off.

Assemble the front and back plate in the original position, and install four $\frac{5}{16}$ "-18 socket head set screws in the four tapped holes in the back plate. Position the jaw nuts in line with the set screws and snug down the screws to hold them firmly against the back side of the front plate

while you face them off. Don't over tighten the set screws and distort the assembly.



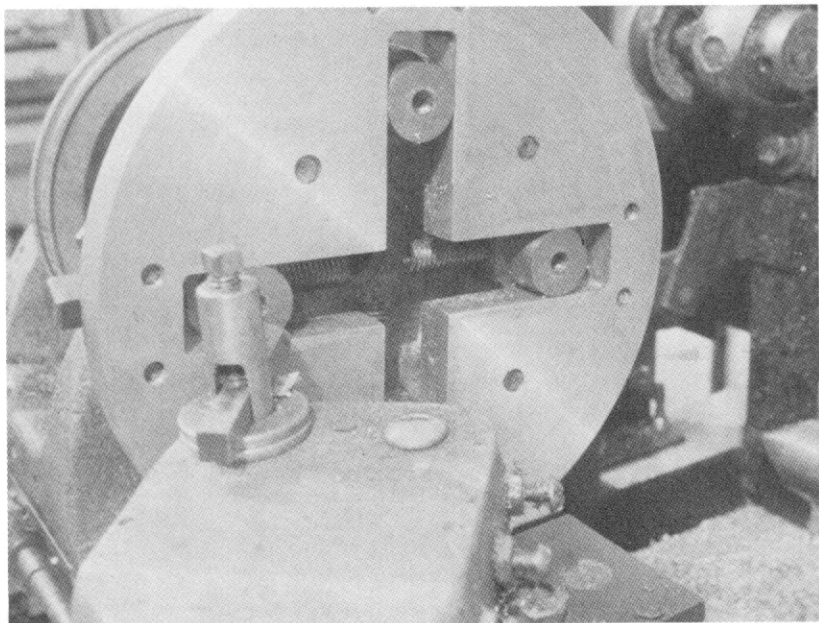
Mount the assembly on the spindle nose and proceed to face off the front surface of the nuts until they are even with the front surface of the plate. Then make at least one full pass across the entire surface.

The finished thickness is not critical, so you can make as many passes as needed to true up the front end. 5/8" is adequate for the finished thickness of the front plate.

The jaws will be fastened to the nuts by 1/4"-20 socket head cap screws, and there must be a tiny bit of clearance between the jaw backs and the plate. Remove the set screws when the front has been faced off and run the nuts to the outside of the slots. Make a very light facing pass across the front of the plate until you come near to the nuts, and stop the lathe before the tool touches the nuts. Then run the nuts to the inside of the slots and finish the facing pass. The object is to leave the nuts protruding about .002" beyond the front surface of the plate.

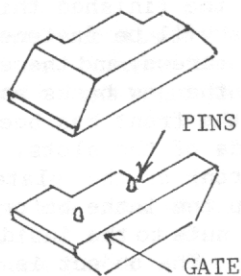
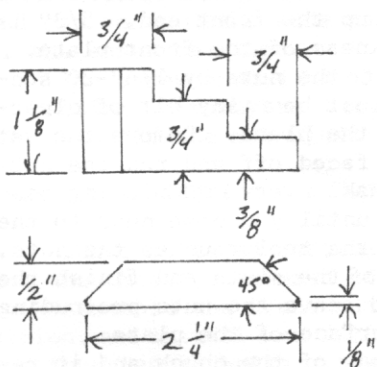
This completes the main body of the chuck and it remains only to add the jaws and the job is done. If all has been done carefully the nuts should run in and out smoothly.

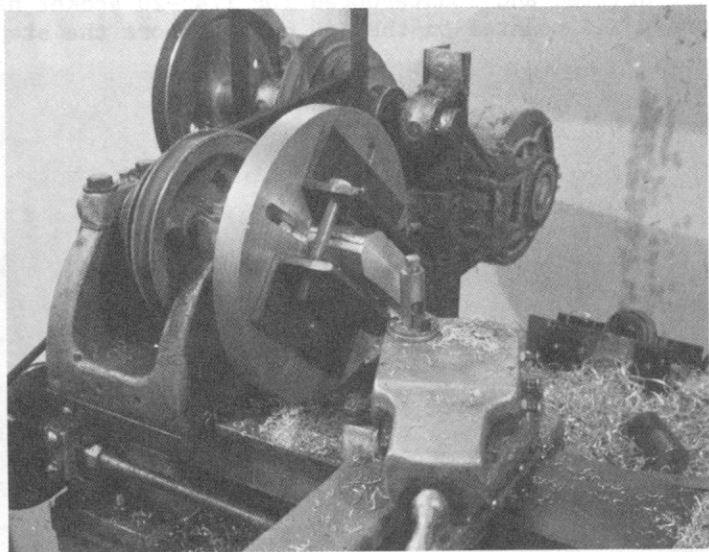
The photo below shows the front of the chuck being faced off.



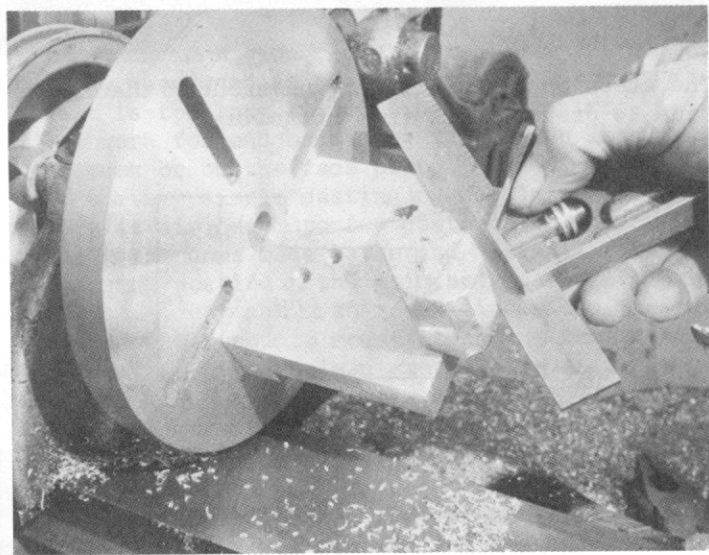
THE JAW PATTERN

It's a very simple split pattern, and easy to mold. Feed with a 1 1/4" sprue and a very short runner at the heaviest part of the casting.



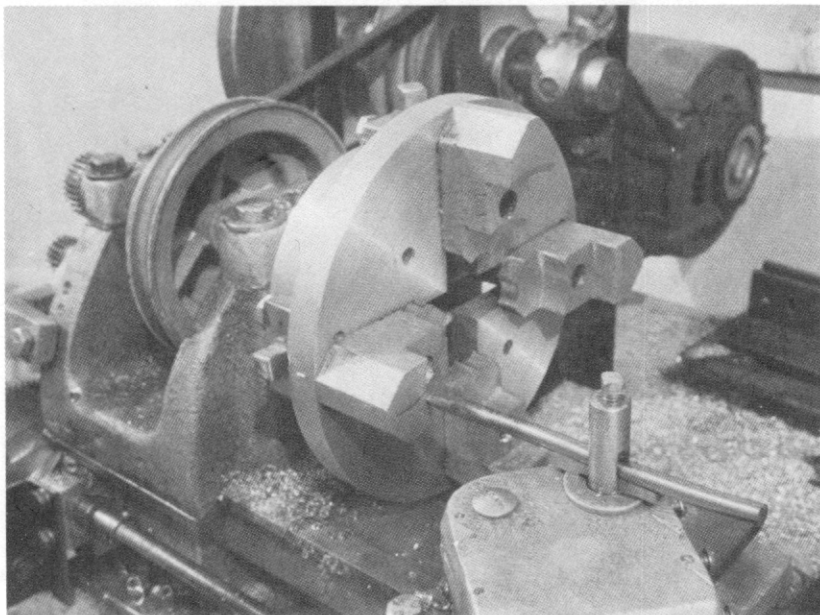


CUT OFF THE GATE AND FACE OFF THE BASE

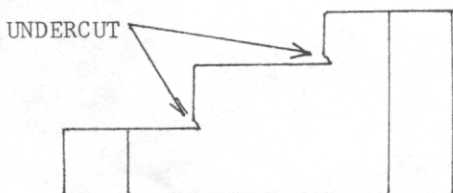


MOUNT ON THE ANGLE PLATE AND FACE OFF THE ENDS

When the jaws have been machined to their general shape they are drilled and counterbored for 1/4"-20 socket head cap screws and mounted on the jaw nuts to bore the steps.

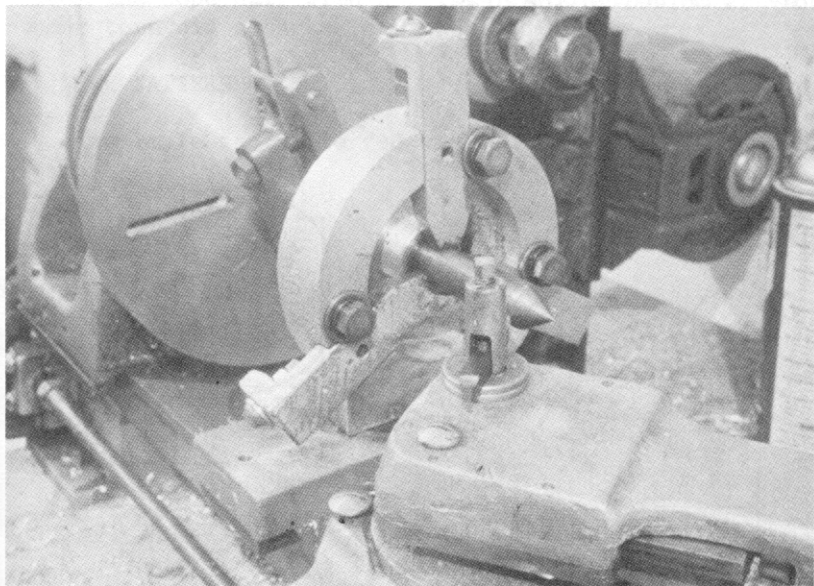


The steps should be slightly undercut so that there is no radius to prevent work from bottoming.



I've found that the single cap screw holds the jaws in position very securely. Special jaws of near any shape can be made and easily installed. Steel or iron jaws can be cut to general shape with the hack saw and finished in the same manner as the aluminum jaws. Now that you have a four jaw chuck you are bound to find plenty of work for it.

THE STEADY REST



This accessory can more than double the capacity of your lathe when used in place of the tail stock to support work that is too long to mount between centers. It also supports work for end machining that is too long to be done in the chuck or on the face plate.

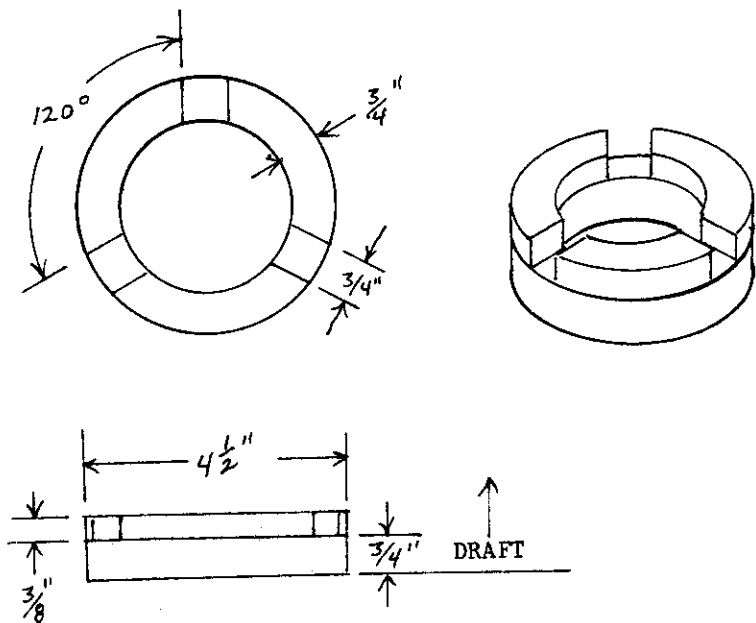
It's a very simple casting and machining project. The main body is divided into two castings to stay within the capacity of the home made lathe and to simplify the pattern.

The ring portion of the main body pattern is best made on the lathe. Just cut it to rough dimensions and screw it to a piece of plywood to mount it on the face plate. In this way you can make a clean smooth bore and a concentric pattern.

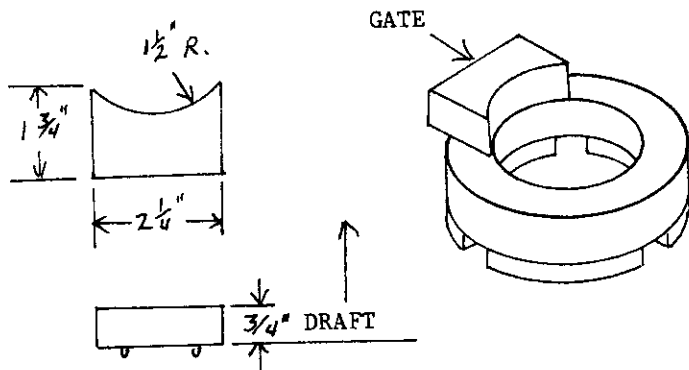
Make all of the patterns as neat and smooth as possible. The slots in the main body pattern should be near to finished width to reduce filing on the casting. The depth of the slots should be uniform because it would be quite difficult to file them to uniform depth in the casting. Space the slots carefully at 120 degree intervals so that the jaws will be well aligned.

THE MAIN BODY DRAG HALF PATTERN

The pattern is split for easy molding, and the main body is molded in the drag.



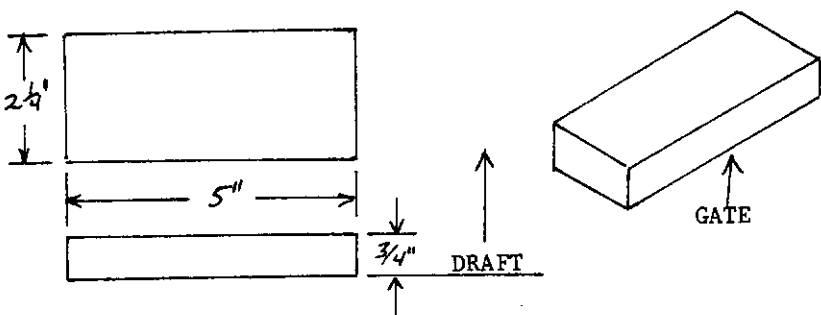
THE MAIN BODY COPE HALF PATTERN



The cope half pattern forms the base of the main body, and it is located exactly between any two slots. A pair of small pins register the cope and drag half. Feed at the base of the cope half with a 1 1/4" sprue and a very short runner to avoid a shrink cavity at the heavy area.

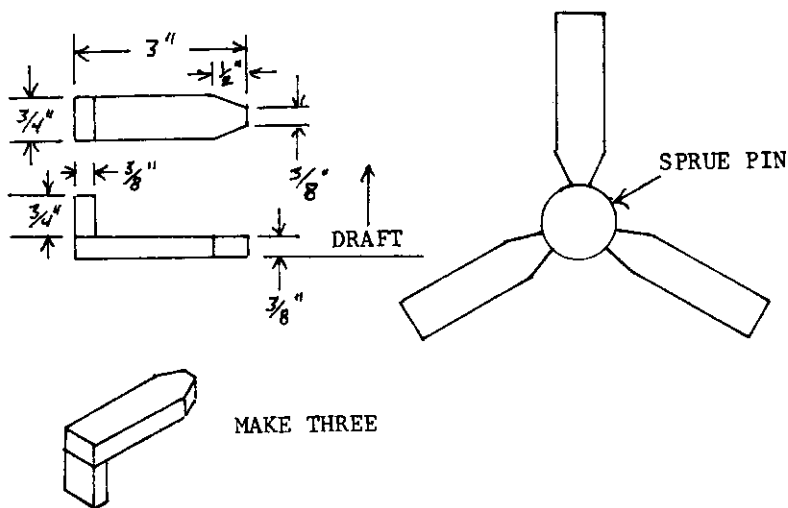
THE BASE PATTERN

A simple rectangle fed with a 1 1/4" sprue.



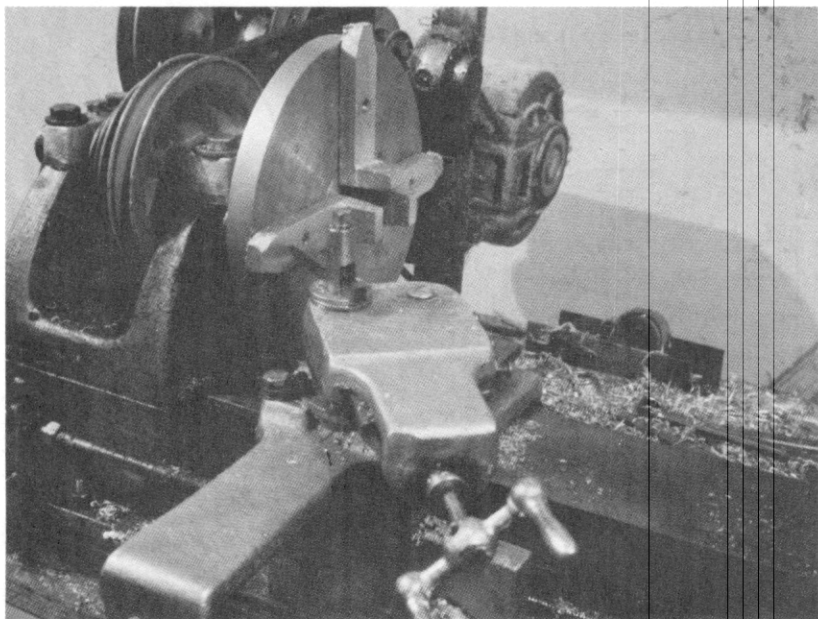
THE JAW PATTERNS

All three are alike. Mold in a "spray", and feed all three with a single 1 1/4" sprue.



MACHINING THE JAWS

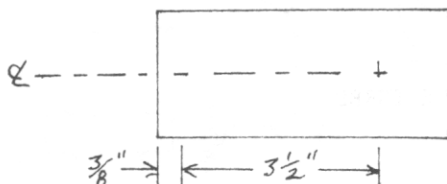
File the front surface clean and flat so that they will rest on the face plate without wobble. Drill and tap each one in the center $5/16''$ -18 and mount them on the face plate as seen in the photo below. Face them off so that front and back surfaces are parallel.



The sides must be parallel too, and you can do it by filing, milling, or by bolting them to the angle plate and facing them off.

MACHINING THE BASE

The mounting holes will serve to mount the casting on the face plate to face off both sides. Drill and tap two $1/4''$ -20 holes as shown below.

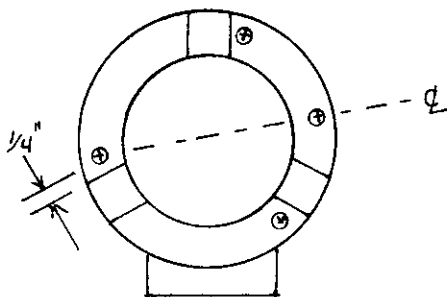


FIT THE JAWS

The finished jaws provide a gauge for filing the slots in the main body. File them for a close sliding fit on the jaws, and so that all three jaws meet nicely in the center. It's a good idea to fit them individually and mark them for later assembly.

FACE OFF THE MAIN BODY

The jaws will be locked with 5/16"-18 cap screws and flat washers. Three holes will be tapped beside the slots, and a fourth hole is tapped for mounting on the face plate.

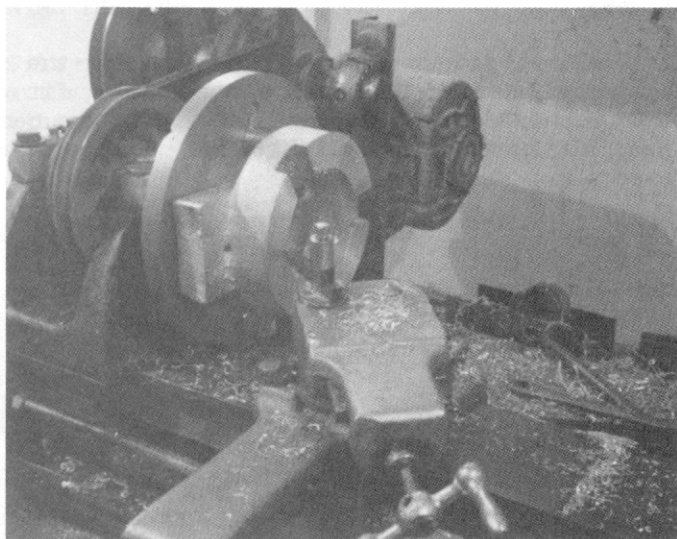


The finished thickness of the jaws will determine the depth of the slots. The object is to face off the front surface of the main body until the jaws extend just a bit beyond the surface when they are well seated in the slots.

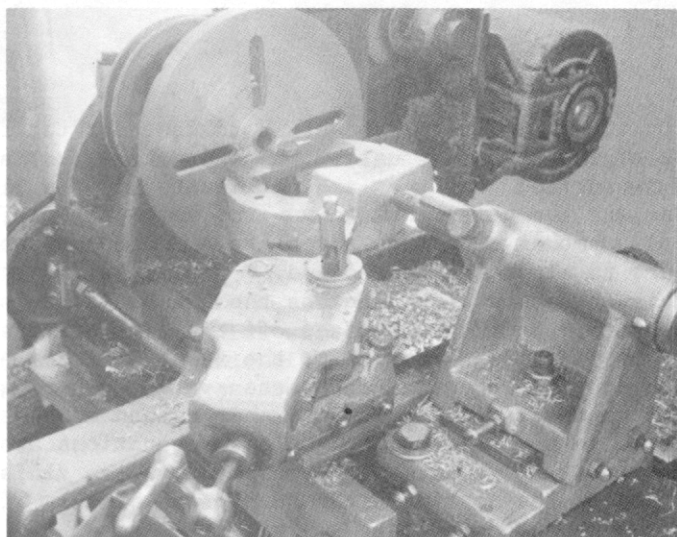
Use the two holes that cross the center line of the main body to mount it on the face plate, with enough spacing furniture to clear the base stand.

This operation also prepares the front surface for the next operation, which is to face off the base stand so it will be at exact right angles to the front surface.

You could also make a few passes with the boring bar to clean up the inside diameter, and you can machine the outside diameter as well, though these operations are not necessary unless you are not pleased with the finish as cast. Center the casting on the face plate closely if you plan to do these operations.

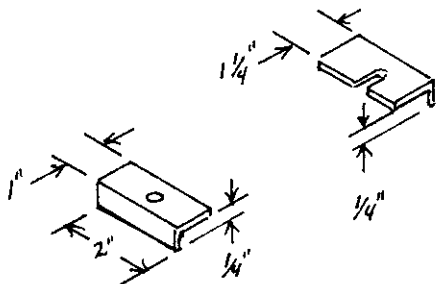


The faced off front surface is clamped to the angle plate to face off the base stand, and it is best to support the stand with the tail center for this relatively heavy job.



THE BASE CLAMPS

Two 2" lengths of 1/8" X 1 1/4" angle iron are modified to form the clamps that hold the steady rest to the lathe bed. The tapped holes in the base accept the clamp bolts. The front clamp has a 1/4" hole, while the back clamp has a slot for easier installation and removal.



INSTALL THE BASE

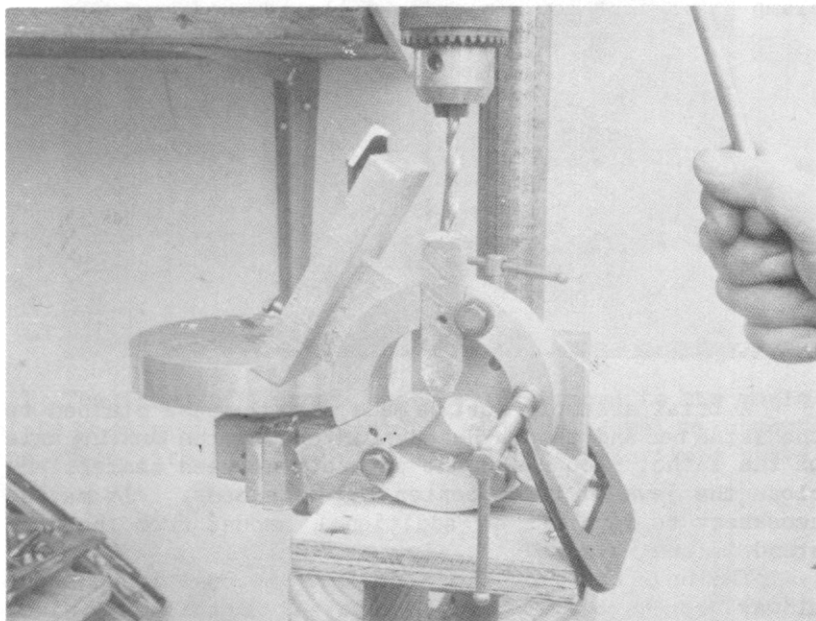
A trial assembly must be made with the base clamped to the lathe bed and the main body centered on the turning axis of the lathe. You can mount an arbor between centers and close the jaws on it to center the main body. It may be necessary to face off an additional amount from the base stand if the main body stands too high.

The base stand of the main body is positioned about midway between the head stock side and the tail stock side. When all is well positioned you can scribe a mark on the base and remove the parts from the lathe. Clamp together securely and mount on the angle plate to drill two 13/64" holes through the base and into the base stand. Separate the parts to enlarge the holes in the base to 1/4" and tap the holes in the base stand 1/4"-20. Counterbore the holes in the base to accept socket head cap screws and assemble the main body and base.

THE JAW SCREWS

Screws to close the jaws are not absolutely necessary, but they greatly improve the steady rest. You could prepare shouldered blanks between centers and thread them by hand, but I found 1/4"-20 X 2 1/2" round head machine screws to be satisfactory. A pair of nuts jammed together form the shoulder.

The tapped holes in the main body must be parallel to the jaws and in line with the bearing hole in the jaw. You can mount the steady rest on the angle plate to drill the 13/64" holes through both the jaw and the main body. Then enlarge the hole in the jaw to 1/4" and tap the hole in the main body 1/4"-20.



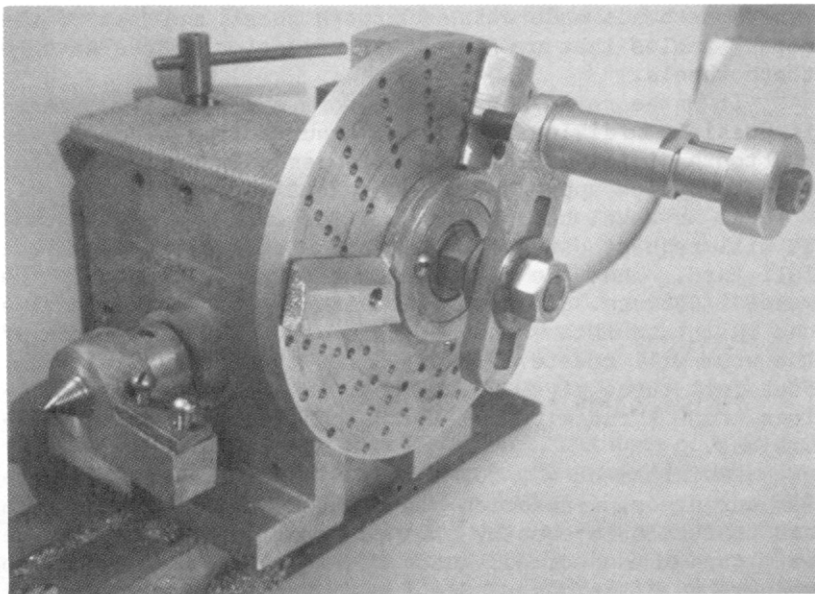
USING THE STEADY REST

Its main use is to support work for end machining if it is too long to be supported only by the chuck. Boring, drilling or tapping a hole in the end of a shaft, or machining a cone nose are examples.

It can provide center support for a slender shaft, or it can replace the tail stock to support work that is too long for the between centers capacity of the lathe.

Work to be machined on the end should be centered and driven by a dog rather than mounted in the chuck. A thrust collar to bear against the jaws of the steady rest will hold it against the spindle center, or the dog can be lashed to the face plate with a leather thong. It will be found nearly impossible to properly center work that is held in the chuck.

THE DIVIDING HEAD



When you become really serious about machine shop projects there are many jobs that require accurate dividing of a circle. Gears, sprockets, splines, index plates and graduated collars are only a few examples.

Those jobs that require only a few divisions, such as taps, reamers and splines can be done with an index fixture. A spur gear or a drilled plate can provide the index, and it is a simple matter to provide support and a latch pin to lock it on the desired division. A 36 tooth gear or an accurately drilled plate will provide most of the needed divisions. 2, 3, 4, 6, 9, 12 and 18 divisions can all be had with a 36 hole plate.

When you set out to make gears and other items that require finer divisions, and in great variety, you need a dividing head. A worm wheel dividing head is the simple device that will do the job.

The patterns and castings are simple. The machining operations are basic, and construction is so simple that it will present no serious problem to those who have completed any of the other projects in this series.

THE WORKING PRINCIPLE

Nearly all dividing heads are now made with a 40 tooth worm wheel and a single thread worm. In earlier years there were some heads made with a 60 tooth wheel, and most of the rotary tables that are fitted with fraction plates have 90 tooth wheels.

It is the ratio between the worm and wheel that makes it possible to divide the circle accurately. Since this is a 40 tooth dividing head we'll discuss only that ratio, but the same rules apply to any other ratio.

As the wheel has 40 teeth and the worm is single thread it will require 40 turns of the worm to rotate the wheel one full turn. Thus one full turn of the worm will rotate the wheel $1/40$ turn. To cut a gear with 40 teeth would require one full turn of the worm for each cut. Two full turns of the worm will rotate the wheel $1/20$ turn for 20 divisions, four full turns give 10 divisions, five turns give 8 divisions, eight turns give 5 divisions and ten turns give 4 divisions.

Divisions of 40, 20, 10, 8, 5 and 4 are not adequate for our needs, so fraction plates are used so that the worm can be turned in equally divided fractions of a turn. One half turn of the worm advances the wheel one half tooth, so we have 80 divisions. One fourth turn of the worm gives 160 divisions. The worm is fitted with interchangeable fraction plates that have equally divided circles of holes. Each circle has a different number of holes so that different fractional turns can be made up. The worm crank has a latch pin to engage the holes in the plates so that combinations of full turns and fractions can be made.

The accuracy is amazing, and near perfect divisions are possible. It is the principle of the diminishing distance between two converging lines that accounts for it.

If you will envision radial lines drawn through the center of each hole, and all converging on the center of the plate you will see that they are radial lines like the spoke in a wheel. As the space between them diminishes as they near the center, so does any error that may have been near the outside of the circle. A barely perceptible error at the outside of the circle will reduce to a minute fraction near the center. The same principle is repeated from the outside diameter of the worm wheel to its center, so any error that is made on the plate is reduced to a tiny fraction at the center of the worm wheel.

DIVIDING CALCULATIONS

A brief study of the ratio between the worm and wheel will show that all calculations can be expressed in the form of fractions. The simple formula for all dividing heads is the same.

$$\frac{\text{NUMBER OF TEETH IN WORM WHEEL}}{\text{REQUIRED DIVISIONS}} = \text{NUMBER OF TURNS}$$

As this head uses a 40 tooth worm, all calculations are expressed with 40 as the numerator of the fraction. To do 8 divisions the fraction is expressed as $40/8 = 5$. Thus five turns of the worm gives eight divisions.

The answer will not always be a whole number, but may be a fraction or a combination of a whole number and a fraction. To do 36 divisions is expressed $40/36 = 1 \frac{4}{36}$. This means that you would turn the worm one full turn plus four holes in a 36 hole circle.

There are three plates in the set, but none of them has a 36 hole circle, so the fraction must be converted. Reduced to its lowest terms; $4/36 = 1/9$.

There is no 9 hole circle in the set either, but there is a 27 hole circle of which $1/9$ is a factor. $1/9 = 3/27$.

The answer to 36 divisions is one full turn plus three holes in the 27 hole circle.

By these simple calculations you can determine if there is a plate in the set that will give the required divisions. The suggested set of plates give all numbers through 50 and all even numbers and multiples of 5 through 100. A great many numbers beyond the basic range are available, and it is no great problem to make a special plate for any need that is not covered by the basic set.

Angular divisions are easily calculated as two holes in the 18 hole circle give one degree. $40/360 = 2/18$.

OPERATING THE DIVIDING HEAD

In general use the dividing head will be mounted on the work table of the milling machine. Work will be mounted between centers of the head and its tail stock. When the proper plate has been selected it is mounted on the head and the worm crank is adjusted so that the latch pin falls in the proper hole circle.

The plate is fit with a pair of sector arms that can

be adjusted to expose the required number of holes for each division.

Work can begin at any hole in the circle, and the first hole is called the " zero " hole. It is never counted unless the division requires one full turn or more, and then it is counted as the last hole in the full turn. If the division calls for six holes in the 18 hole circle you will ignore the starting hole and adjust the sector to expose the next six open holes adjacent to the starting hole. If it calls for one full turn plus six holes you adjust the sector in exactly the same manner, so the starting hole becomes hole number 18 in the full turn, but it is never number 1.

When the work is properly positioned and the depth of cut is set, the worm is turned some amount to take up any backlash and the latch pin is seated in the starting hole. The spindle clamp of the dividing head is locked and the first cut is made. Then the spindle clamp is unlocked and the worm is advanced the required amount and the spindle is again locked for the next cut. The procedure is repeated for each cut.

ACCURACY IN DIVIDING

Given a perfect worm wheel and perfect plates you can expect perfect divisions. Since perfection exists only in theory and dreams, you will realize that there is potential for error.

My plates are noticeably less than perfect, and the errors become very apparent when accumulated over a number of holes. Even so, I cut all of my gears in pairs, and there is no apparent error in the gears. This is because the error is diminished through the plate and the worm wheel, and the commercially made worm and wheel are very near perfect. The only real potential for error is in the back lash between the worm and wheel or poorly fitted bearings in the head.

Error from back lash is eliminated by always turning the worm in the same direction for any given job. If you accidentally move past a hole you must back up beyond the hole so that back lash will be taken up when you advance.

The dividing chart in the appendix will give you the required plate and the number of turns and holes for the basic range, but you should master the basic calculations in order to get the broadest use of the head. You will be able to master it with ease.

THE DESIGN CONCEPT

It is likely that some may want to scale up or down in size to match available equipment. The elements that dictate the final size of the castings are the worm and wheel.

I selected a Browning # CWG 1240-1 worm wheel and a # W 12-1 worm because they have a convenient finished stock size that meets the requirements. It's quite a chore to re-bore finished gears, and I wanted to avoid that.

The worm is a 12 pitch with a 1" diameter and a 1/2" bore. The worm wheel is a 12 pitch 40 tooth with a 5/8" bore. The wheel has a convenient hub size which is used for the clamp brake drum to lock the spindle. I ordered them through a local industrial supply house and had them in less than a week. The cost for both was less than \$30.00 including shipping.

Other brands can work as well, but dimensions may vary and you will need to make changes for them. In any case you should have the worm and wheel on hand before you begin.

If you are going to build a larger head you should keep in mind that the section thickness is already heavier than is required. While the frame members would be larger they need not be thicker unless you scale up more than 50%.

If you are scaling down you can use a 16 or 20 pitch worm, and reducing both section thickness and size by as much as 1/3 should cause no serious problem.

As detailed in this manual, some of the castings are just barely within the swing capacity of the home built lathe.

The lettering that you see on the main frame castings was done with a hand label maker. Simply stick the embossed label on the pattern and the lettering will stand out very nicely if you have fine sand.

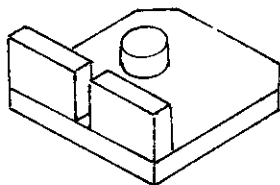
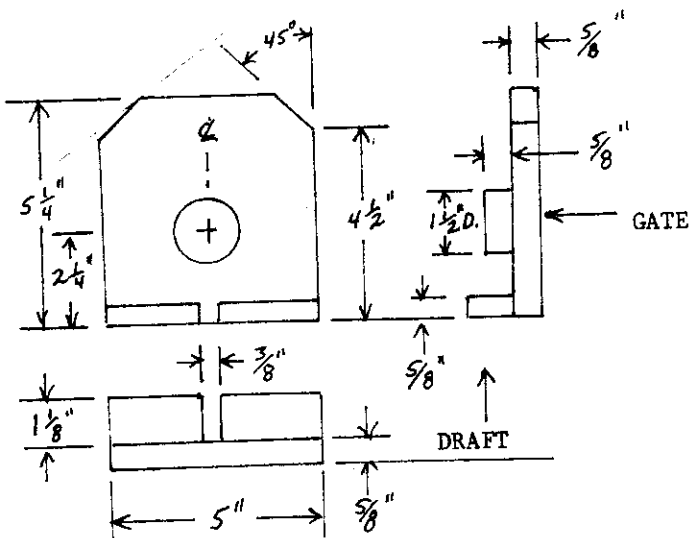
THE MAIN FRAME PATTERNS

The entire main frame is made up of just three castings. Both the front and back frames are molded with the same pattern, but the spreaders are added when the front frame is molded.

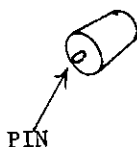
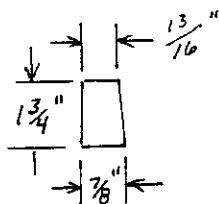
The spreaders are easily made on the lathe from any scrap of broom handle or dowel. They are fit with small alignment pins that register in the holes in the main body pattern.

Mold all pieces carefully, vent generously, and clean up thoroughly before closing up to pour.

Though plywood is not the best pattern material it is satisfactory for this simple pattern if you fill the edge grain and sand very smooth.



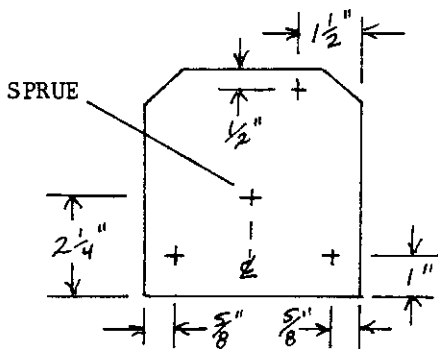
MAIN FRAME - MAKE ONE PATTERN



SPREADERS - MAKE THREE PATTERNS

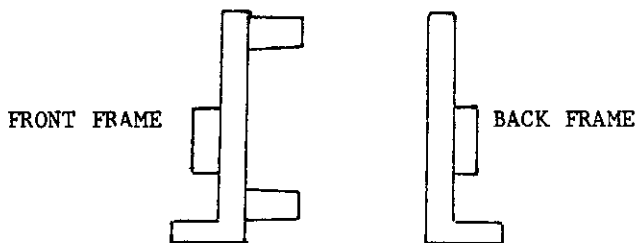
MOLDING THE FRAME CASTINGS

The face of the frame pattern is prepared with holes for the guide pins of the spreaders and a guided sprue.



The back frame is molded without the spreaders, and the spreaders are set in the guide holes when the cope is rammed up for the front frame. Both molds are fed at the center of the hub area to prevent a shrink cavity because of the extra thickness of the hub. Use a $1\frac{1}{4}$ " sprue.

The resulting castings will make an opposing pair.

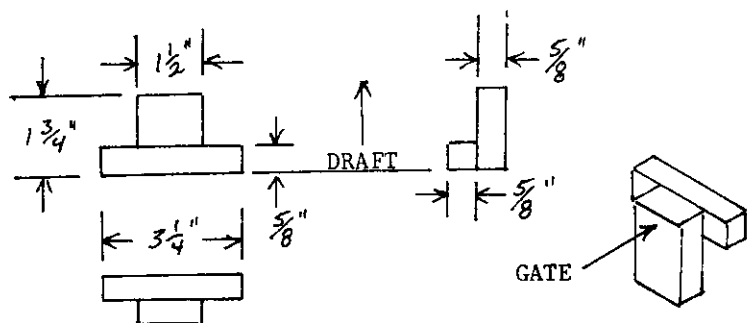


The center sprue is not the handiest place to gate the mold, but an 18 tooth hack saw blade will make short work of cutting them off.

When machined and joined together these two castings make up the entire main body of the dividing head. A foot is added to the back frame, which is a great aid during the machining operations, and it also converts the body for vertical mounting as a rotary table.

THE FOOT PATTERN

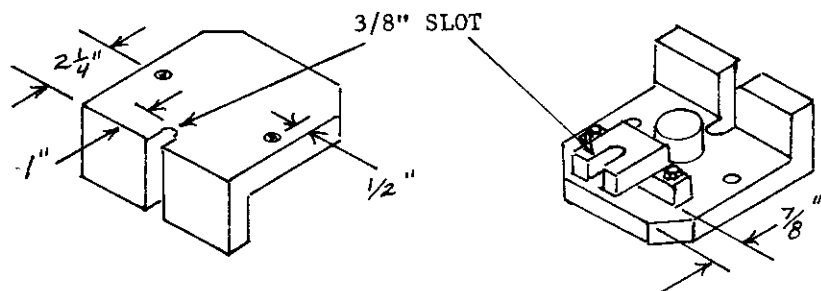
A simple shape, feed with a 1 1/4" sprue



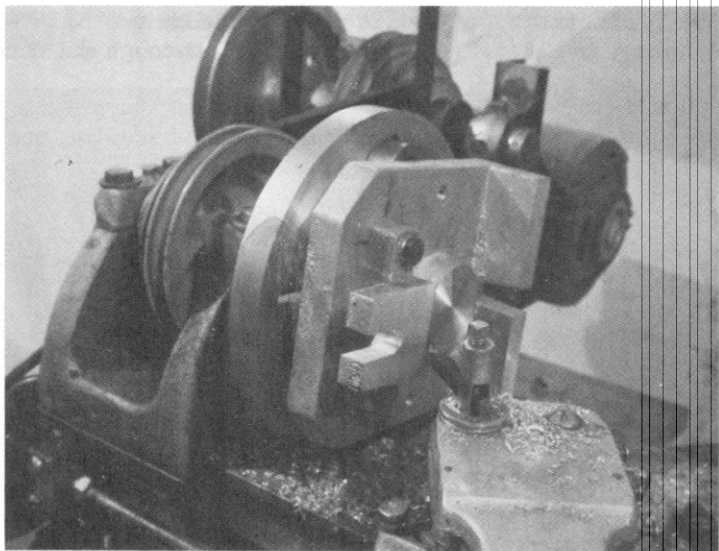
MACHINING THE BACK FRAME

Two 5/16"-18 holes are tapped in the back frame casting for face plate mounting. A 3/8" hole is drilled as shown below, and the slot is cut with a hack saw.

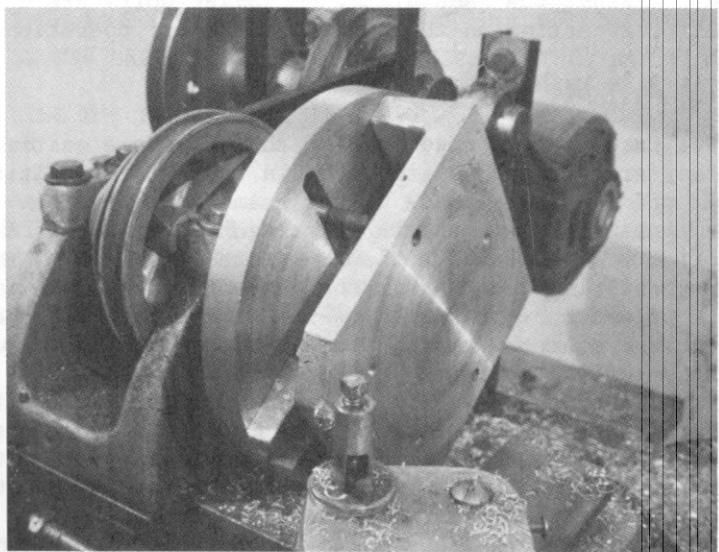
The mounting ears of the foot casting are filed flat and it is fastened to the back frame with two 1/4"-20 X 1" cap screws after cutting the 3/8" slot.



In the first machining operation the back frame is mounted to the face plate with two 5/16"-28 cap screws with set screw collars as spacing furniture. The hub portion is faced off clean, and the foot and the base angle of the frame are faced off parallel. It is then inverted on the face plate and the broad flat surface is faced off clean. The finished thickness is not critical.



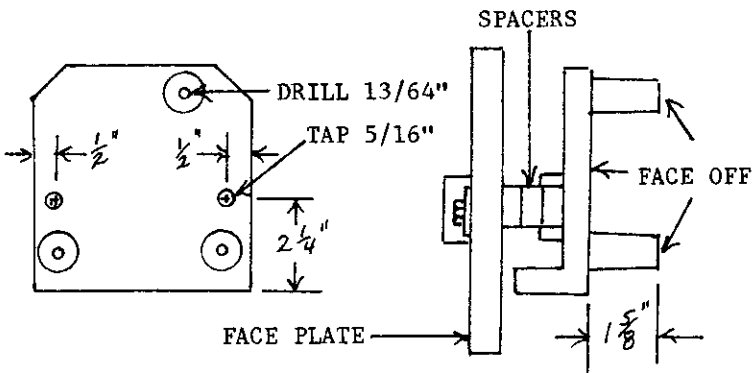
FIRST FACING OFF OPERATION



SECOND FACING OFF OPERATION

The front frame casting is prepared with two 5/16"-18 tapped holes, and 13/64" holes are drilled through all three spreaders.

Mount it on the face plate with spacing furniture to face off the spreaders and the center area where the sprue was cut away.



Then invert the casting on the face plate to face off the hub area and the edge of the base flange. The spreaders rest against the face plate, and longer bolts are used to mount the casting on the second facing off operation.

JOIN THE MAIN FRAME CASTINGS

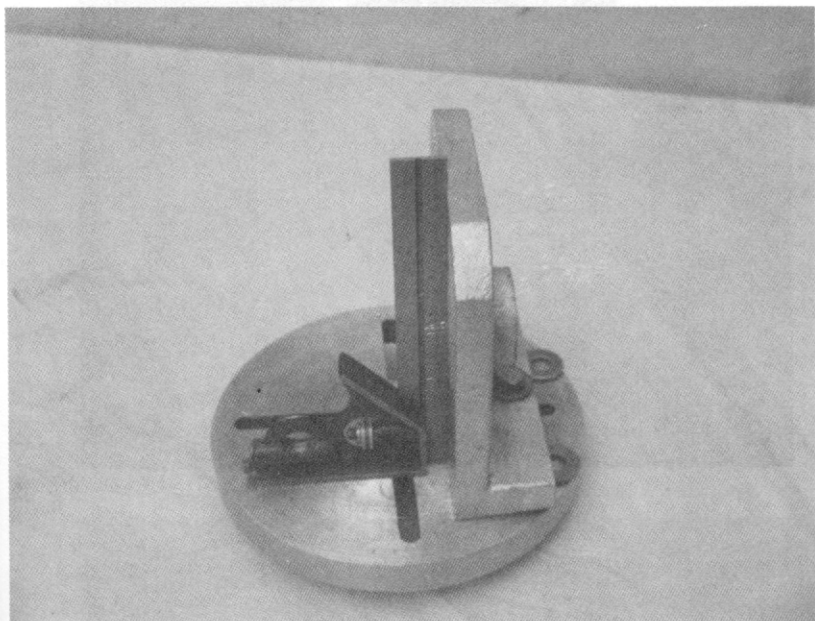
The face plate is used to align the two frame castings when they are joined, and they remain in the jig position to face off the top surface of the frame assembly.

Temporarily remove the foot casting from the back frame and bolt its base flange to the face plate. Use flat washers or other thin stock to shim the base flange as you adjust it to exact right angles to the face plate. Use an accurate try square to test as you adjust the shims. Snug down the mounting bolt and re-check the alignment.

When the back frame is well squared the front frame is mounted against it and shims are used in the same manner so that its base flange can be bolted to the face plate with the pair in perfect alignment. Snug down the second mounting bolt and re-check the alignment.

Drill three 13/64" holes through the back frame, using the holes through the spreaders to guide the drill. Enlarge the holes in the back frame to 1/4", and tap the spreaders

1/4"-20. Install three 1/4"-20 X 1 1/4" cap screws to join the frame halves.



ALIGN THE BACK FRAME AT RIGHT ANGLES TO THE FACE PLATE

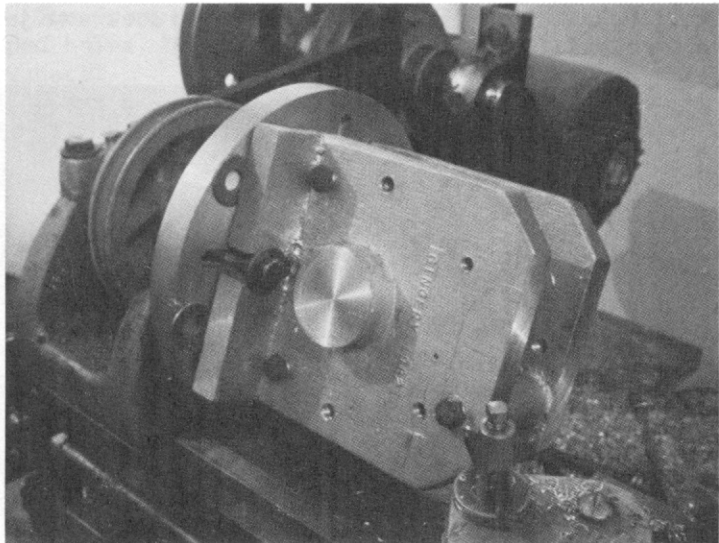
MACHINE THE FRAME ASSEMBLY

If the joining of the frames is done with care the frame assembly will be in the proper position for facing off the top surface, so mount the face plate on the spindle nose and make as many passes as needed to clean up.

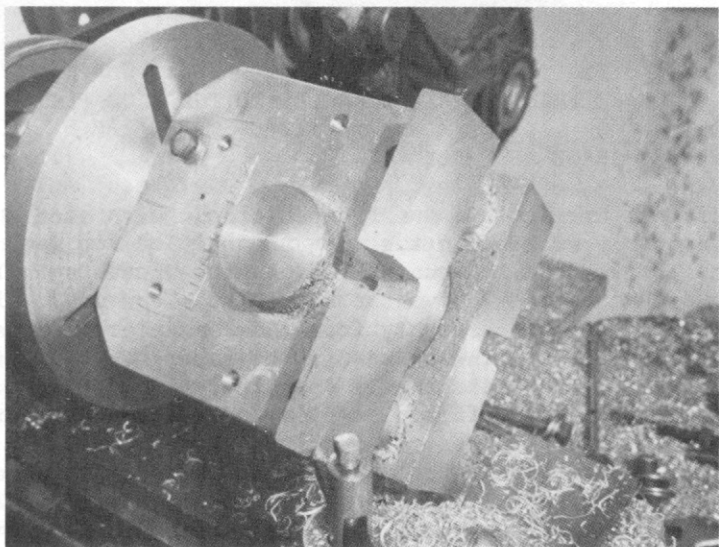
Then remove the assembly from the face plate and tap two 1/4"-20 holes in the faced off top surface. One in each frame half, and diagonally opposite.

Mount the faced off top surface to the face plate to face off the base flanges.

These operations establish the top and bottom surfaces parallel, and the inside surface of the back frame is at exact right angles to the base mounting surface. The edges of the base flanges were established parallel when they were faced off in the earlier operations, so there are four surfaces that provide an accurate reference for remaining work and for set up when the dividing head is complete.



FACE OFF THE TOP SURFACE



FACE OFF THE BASE SURFACE

BORING THE FRAME ASSEMBLY

Carefully punch the center of the hub $2\frac{1}{4}$ " from the base surface and on the vertical center line of the frame.

Install the foot on the back frame and mount the assembly on the face plate through the slotted holes in the foot and the back frame.

Use the tail center to align the assembly so that the punched center mark is on the turning axis of the lathe.

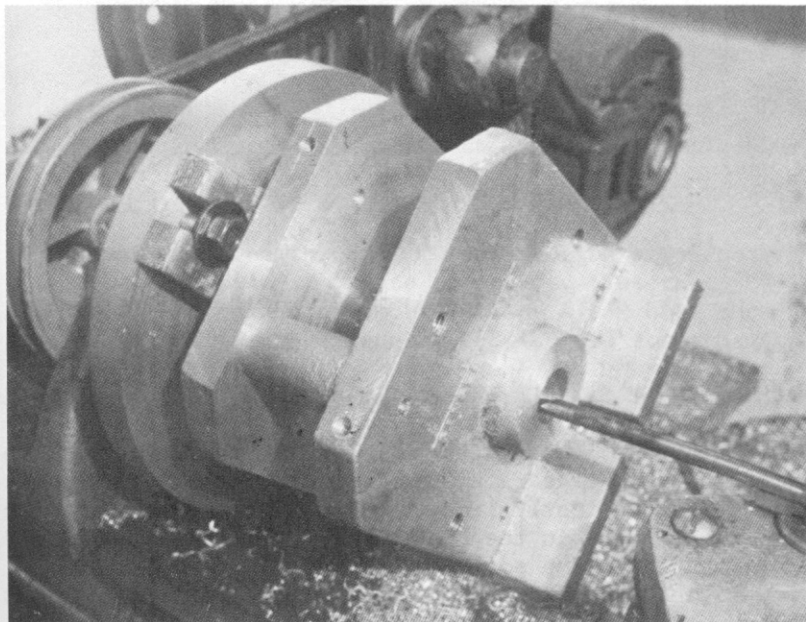
Drill the starting hole with the tail stock drill, and bore to $\frac{3}{4}$ " for a snug fit on a $\frac{3}{4}$ " X $\frac{5}{8}$ " bronze bushing.

Without disturbing the position on the faceplate, remove the three $\frac{1}{4}$ " bolts and set the front frame aside.

Now bore the back frame to $\frac{3}{4}$ " for its $\frac{3}{4}$ " X $\frac{5}{8}$ " bushing.

These operations establish the spindle bore at exact right angles to the back frame, and parallel to the base.

It will likely be necessary to ream the bushings after they have been pushed in, and a $\frac{5}{8}$ " shaft will align the frame halves for later re-assembly.



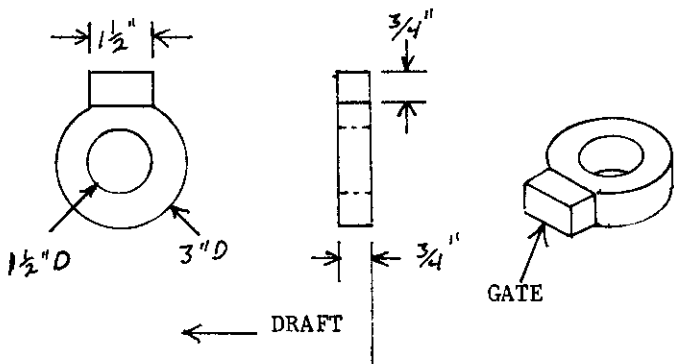
THE SPINDLE BRAKE PATTERN

The spindle of the dividing head must be locked before each cut so that strain won't be put on the latch pin or other parts in the train. A clamp brake is the best method because it won't damage the spindle as a set screw would.

The hub of the stock worm gear is accurately machined and it provides a convenient brake drum. It should not be necessary to do more than mount the worm gear on an arbor between centers and lightly file it to remove any knicks or burrs.

The Browning # CWG 1240-1 gear has a hub diameter of $1\frac{3}{4}$ " and it's $\frac{3}{4}$ " wide. The face of the worm is $\frac{1}{2}$ " wide for a total width of $1\frac{1}{4}$ ".

There is little clearance between the brake and the spreaders, so it will be best to make the circular portion of the brake pattern on the lathe so it will be true round and concentrically bored. Then cut a flat on the rim and fasten a $\frac{3}{4}$ " X $\frac{3}{4}$ " X $1\frac{1}{2}$ " block to it with brads and glue. Feed with a $1\frac{1}{4}$ " sprue and a very short runner.



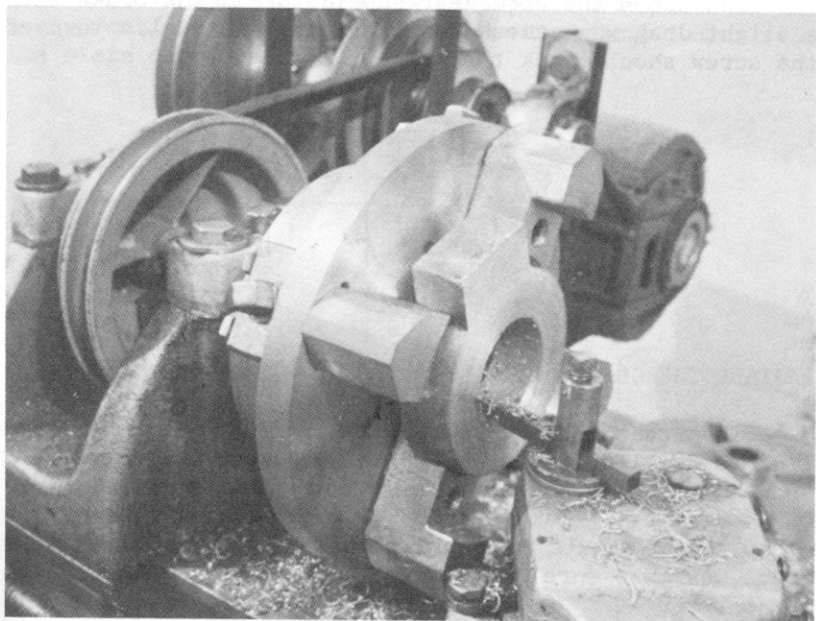
MACHINING THE SPINDLE BRAKE

The brake is bored to an exact fit on the hub of the worm gear, and it's faced off on both sides to reduce its thickness to slightly less than the width of the worm gear hub. Two blades in the hack saw will cut a slit about $\frac{1}{16}$ " wide, and the clamp screw is installed.

I used the new four jaw chuck to bore and face off, but there are other methods if you haven't yet built the chuck.

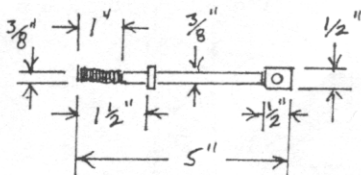
An extension can be cast on especially for machining, as is done for the plate carrier, and it is cut away after

machining operations are complete. You can also mount it to the face plate with spacing furniture and toe clamps to bore it. Then cut the slit and install a clamp screw to mount it on an arbor for facing off both sides.



THE CLAMP SCREW

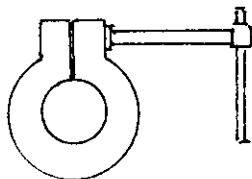
Mount a 5" length of $\frac{5}{8}$ " cold rolled stock between centers and machine it to size and shape. Cut the $\frac{3}{8}$ "-16 threads with a guided stock. Drill a $\frac{3}{16}$ " hole through the head and install a 3" length of $\frac{3}{16}$ " rod for a handle.



The shoulder near the threaded end is about $\frac{1}{8}$ " wide and $\frac{1}{2}$ " diameter. The handle can be a press fit or you canpeen the ends so it won't slip out.

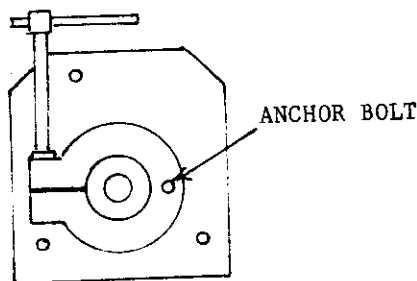
Cut the slit through the bored and faced off brake, and mount it on an angle plate to drill a $5/16$ " hole through the clamp. Enlarge the top half of the hole to $3/8$ " and tap the lower half $3/8$ "-16. Install the clamp screw.

The hub of the worm gear should turn in the brake with a slight drag when the screw is loose. About $1/4$ turn of the screw should lock the brake.



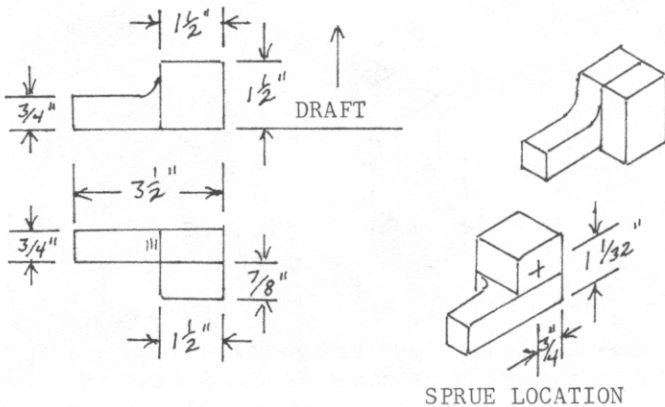
INSTALL THE CLAMP BRAKE

The brake is anchored to the back frame with a single $1/4$ "-20 X $1 1/4$ " cap screw. The worm gear is mounted on a short $5/8$ " shaft and it is used as a jig to center the brake on the frame. Take care to align the brake so that the clamp screw handle is parallel to the top surface of the frame, and make sure that there is clearance at the bottom for the spreader. Clamp securely and drill a $13/64$ " hole through the back frame and the brake. Enlarge the hole in the back frame to $1/4$ " and tap the hole in the brake. Install the cap screw with a lock washer.

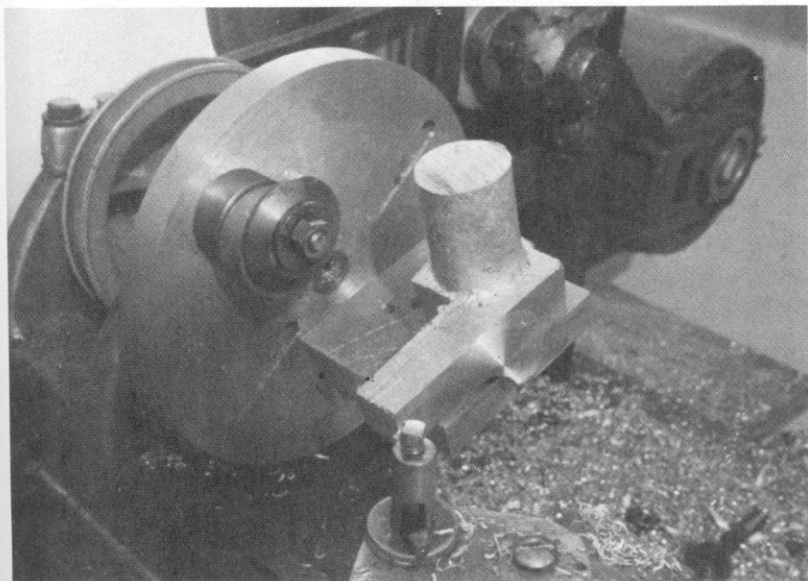


THE WORM CARRIER CASTING

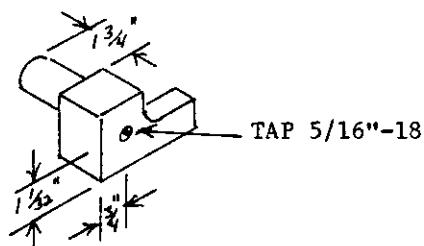
The pattern is most easily made in two parts and joined with brads and glue. The mold is fed with a 1 1/4" sprue that is located on its center with a pin. A portion of the sprue remains on the casting to form the round journal for the plate carrier.



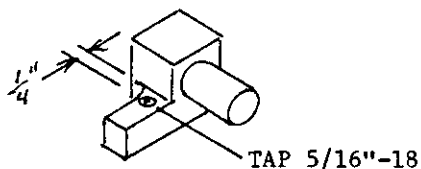
MACHINING THE WORM CARRIER



Cut off the sprue, leaving about 1 3/4" extending from the casting. Drill a 1/4" hole about 1" deep opposite the sprue and tap it 5/16"-18. It is on the same center as the sprue and will later be cut away when the casting is bored. Use the tapped hole to mount the casting on the angle plate, as seen in the photo on page 69, and face off the base.



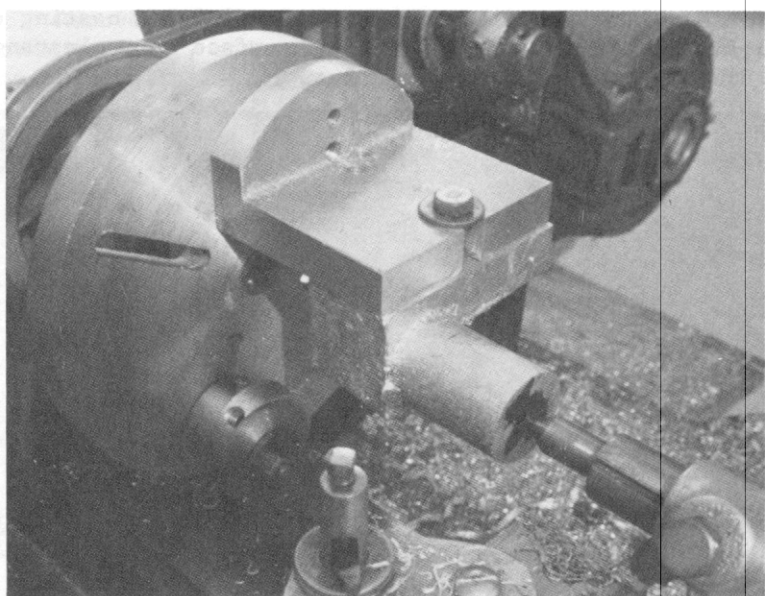
When the base is faced off remove the casting and drill a 1/4" hole in the shank as shown below, and tap it 5/16"-18. This will be the pivot hole, and it will also serve to mount the casting on the angle plate to bore it and turn the plate carrier journal.



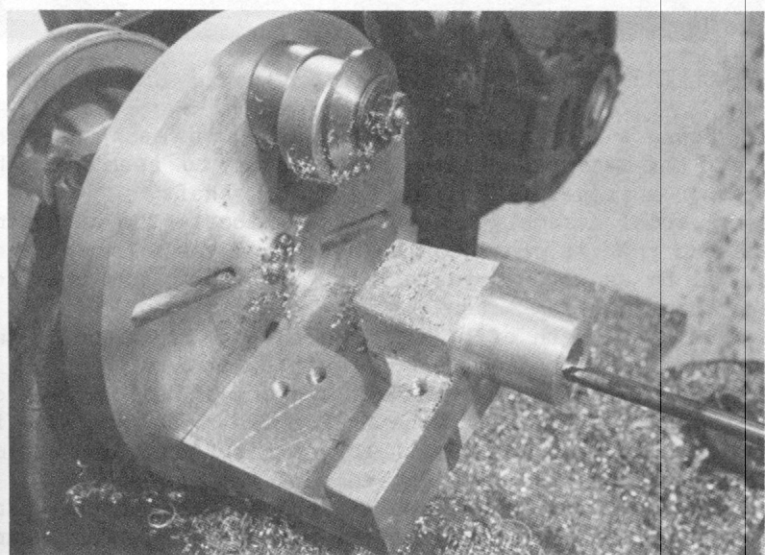
The boring and turning are done without changing the set up so that they will be concentric. Mark and punch the center of the sprue carefully, and use the tail center to position the work on the turning axis of the lathe. Note the counter weights on the face plate, which permit higher speed for a better finish.

Drill the starting hole with the tail stock drill and bore to 5/8" to accept a 5/8" X 1/2" bronze bushing.

Turn the outside diameter of the journal to 1 1/8", and face off the shank portion. Then face off the journal to a finished length of 1 1/2".

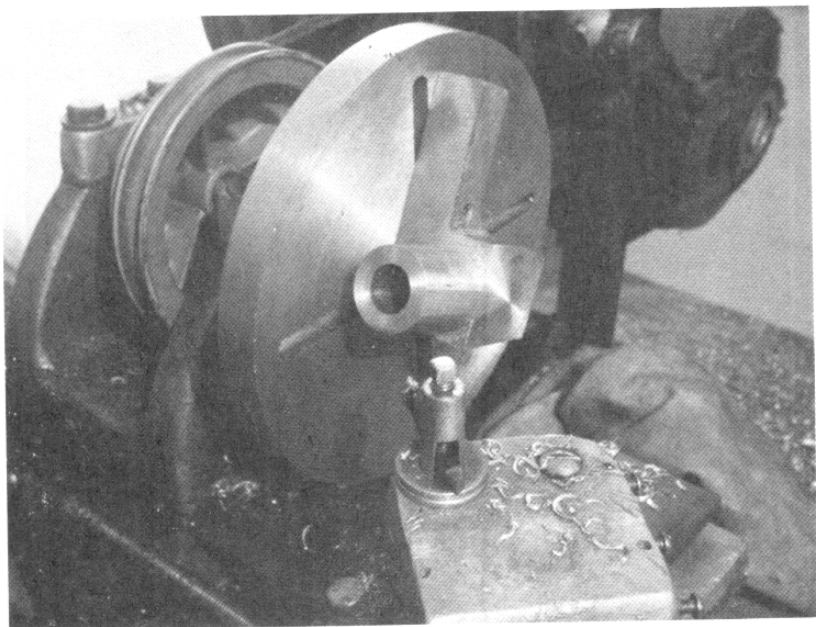


POSITION WITH THE TAIL CENTER



BORE, TURN AND FACE OFF

Use the pivot hole to mount the finished casting on the face plate to face off the top surface for clearance in the frame.



INSTALL THE WORM CARRIER

Press a $5/8$ " X $1/2$ " bronze bushing into each end of the bore of the carrier. It may be necessary to ream the bushings for a proper fit on the $1/2$ " worm shaft.

A trial assembly must be made to locate the adjusting screw so that it contacts the center of the clamp brake. It will be as well to install the pivot bolt and then locate the adjusting screw.

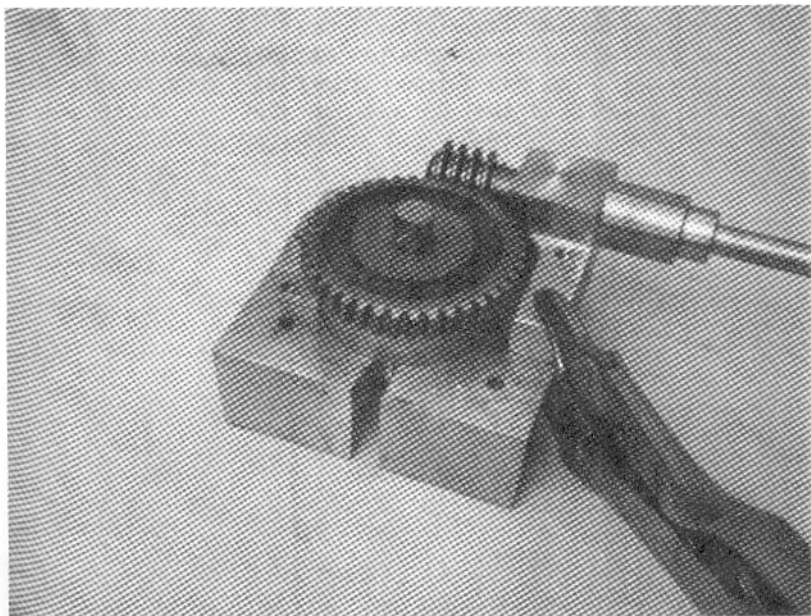
Slip a length of $1/2$ " shaft through the bore of the worm carrier and slip the worm gear on its end.

Install the worm gear with a short shaft in its bore, and clamp the carrier to the back frame with the worm in mesh with the gear, and with the carrier shank protruding about $1/32$ " beyond the right edge of the back frame.

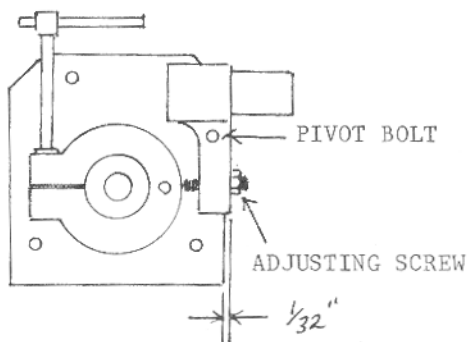
The worm meshes only on its end, and the greater part of it extends to the right of the center of the worm gear.

When all is well aligned you can drill a $1/4$ " hole in the back frame through the pivot hole in the carrier.

Remove the carrier and enlarge the hole in the back frame to $5/16$ " , and re-assemble with a $5/16$ "-18 X $1\ 1/4$ " cap screw with a flat washer and lock washer.



When the pivot bolt is installed you can locate the adjusting screw in the shank of the carrier so that it contacts the center of the brake casting.



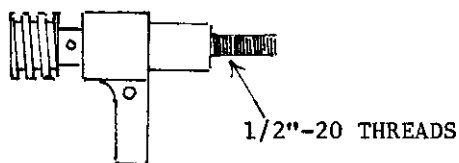
A $5/16$ "-18 X $1\ 1/4$ " square head set screw with a jamb nut provides the adjusting screw to adjust back lash between the worm and gear.

THE WORM SHAFT

A 6" length of 1/2" diameter cold rolled steel provides the stock. It should fit the bushings in the carrier to turn freely with no play.

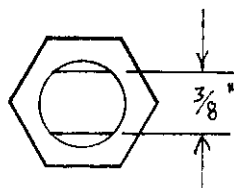
The Browning W 12-1 worm has a 1/2" bore and its hub is 3/8" long. The hub is too thin for a set screw, so a 1/8" hole is drilled through the hub and the shaft and it is locked with a 1/8" roll pin or rivet.

A trial assembly must be made to determine the length of threads on the other end of the shaft, so slip the assembled worm and shaft into the carrier to measure the exposed length. Use a guided stock to cut 1/2"-20 threads on all of the protruding end plus 1/8".



The final three or four threads are filed so that they won't damage the bushing.

Install the shaft again, and slip on a 1/2" S. A. E. washer followed by a 1/2"-20 nut. The portion of shaft that protrudes beyond the nut is filed on two sides equally to form a 3/8" thick flat.



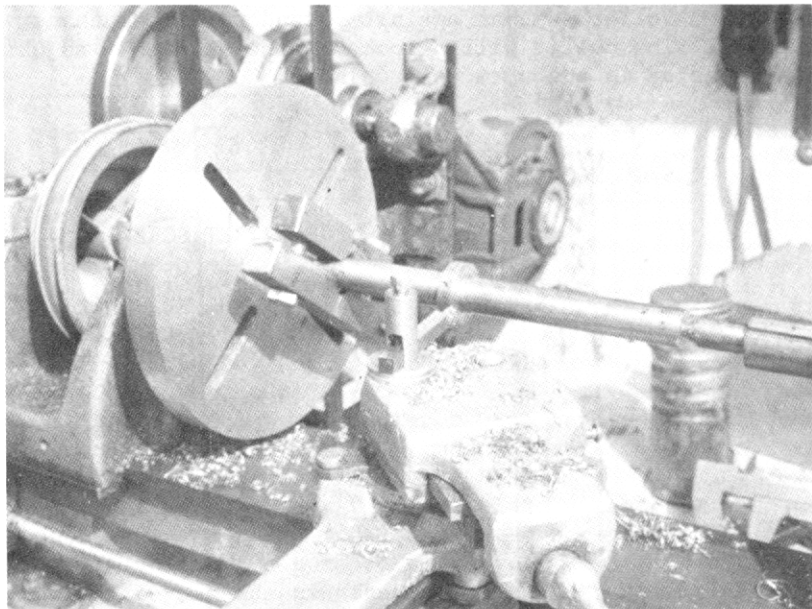
Now the worm and shaft can be installed permanently, with the thrust washer, the adjusting nut and a jamb nut. End play is taken up with the adjusting nut and it is locked with the jamb nut. When properly adjusted the shaft will turn freely with no end play.

The crank will later be installed on the flatted stem with a pair of washers and a nut.

THE WORM GEAR SPINDLE

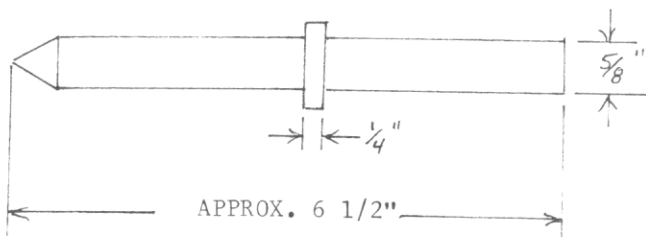
The finished spindle is about 6 1/2" long, but it will be best to begin with a blank about 7" long. 1" or 1 1/8" diameter cold rolled steel will provide suitable stock.

It's a simple matter to mount the stock between centers and machine both ends to the collar.



The collar bears against the front surface of the worm gear, and the blunt end of the spindle extends 9/16" beyond the back bearing to accept the adjusting collar.

The cone nose point extends 2 1/4" beyond the front bearing to accept the drive plate and other accessories.



When the collar and diameter are finished to size you can make a trial assembly to find the finished length for the cone nose. Then use the steady rest to machine a 60 degree cone nose as seen in the photo on page 45.

THE ADJUSTING COLLAR

Just install two #8-32 set screws in a standard 5/8" set screw collar to bear against a standard 5/8" machinery bushing. The collar will be locked to the spindle to adjust the end play in the worm gear spindle.

5/8" MACHINERY BUSHING



#8-32 SET SCREWS



5/8" SET SCREW COLLAR

FINAL ASSEMBLY

Install a 5/16"-18 set screw in the hub of the worm gear and grind or file a flat on the spindle for it to seat against. Also grind or file a flat for the set screw of the adjusting collar to seat against.

Install the spindle in the worm gear with its collar against the front of the gear and lock the set screw.

Slip the assembly into the rear frame bearing and install the machinery bushing and the adjusting collar. Adjust the two set screws until the spindle turns freely with no end play.

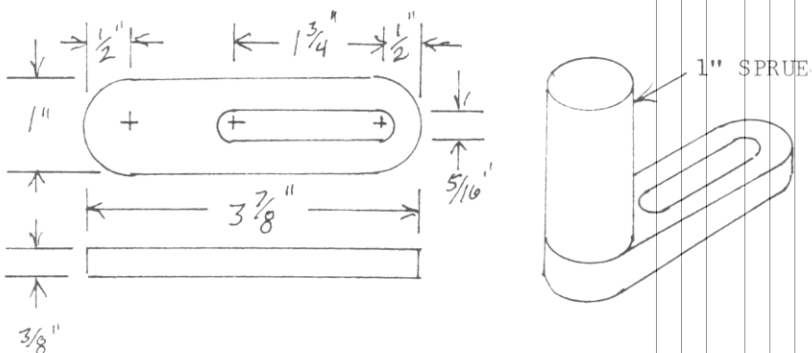
Install the whole assembled worm carrier, leaving the pivot bolt a bit loose. Adjust the carrier to eliminate all but the tiniest bit of back lash, and tighten up.

Slip the front frame over the spindle and rest the assembly on a true flat surface as you install the three cap screws that join the frame halves.

Oil all spindles and grease the worm and gear.

THE WORM CRANK CASTING

A very simple pattern, and again the sprue becomes part of the casting to form the handle.



MACHINING THE CRANK HANDLE

The finished length of the handle is 2", so saw off the sprue to leave about 2 1/8".

Mark and punch the center of the handle, and file or mill the slot until it fits the center of the flattened stem of the worm shaft closely.

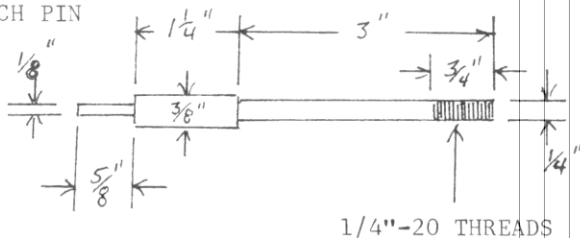
Mount the casting on the face plate with bolts through the slots and spacing furniture so the boring bar can pass through. Align the punched center of the handle with the tail center and tighten the mounting bolts securely.

Face off the end of the handle to 2" length, drill a 5/16" starting hole through the handle with the tail stock drill, and carefully bore to 3/8" all the way through.

Use the tail stock chuck to support a 7/16"-20 tap as you cut threads about 1/2" deep in the end of the handle.

Turn the outside diameter of the handle to 7/8".

THE LATCH PIN

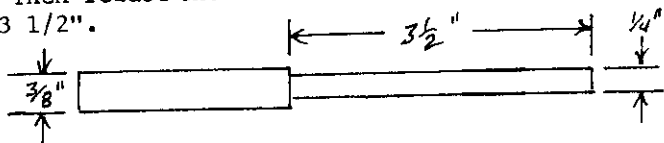


1/4"-20 THREADS

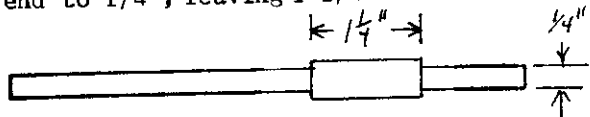
The latch pin is a rather delicate job, but it's easy to do between centers.

Begin by mounting a 6" length of 1/2" cold rolled steel between centers, and reduce its diameter to 3/8" for its entire length.

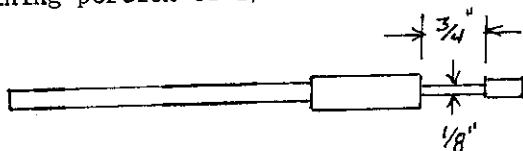
Then reduce the diameter of the tail stock end to 1/4" for 3 1/2".



Then invert it end for end in the lathe and reduce the opposite end to 1/4", leaving 1 1/4" of the 3/8" diameter.



Now you can reduce about 3/4" of the tail stock end to 1/8" diameter, while retaining tail stock center support on the remaining portion of 1/4" diameter.



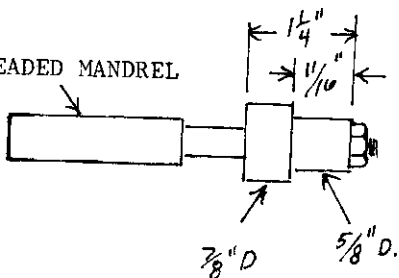
Only light cuts can be taken as you finish up, and all of the larger diameter portions should be file finished to exact size before you reduce the smaller diameter. The 3/8" portion fits the bore of the handle, and the 1/4" stem fits the bore of the retainer.

It's a simple matter to cut the 1/4"-20 threads with a guided stock and trim both ends to finished length. Be careful to avoid bending it when trimming to length.

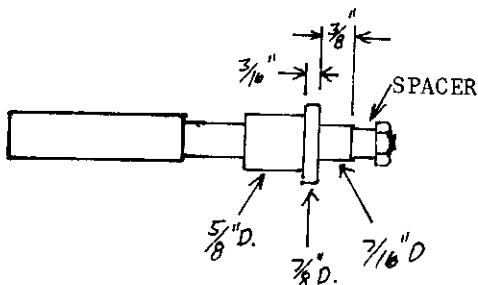
THE LATCH PIN RETAINER

Square up the ends of a scrap of 1" sprue 1 1/4" long. Drill an undersize hole through the center and ream it to 1/4". Mount it on the 3/8"-1/4" threaded mandrel that is described in chapter I. Reduce its diameter to 7/8" for the entire length. Then reduce the diameter of the tail stock end to 5/8" for 11/16" of its length.

1/4"-3/8" THREADED MANDREL

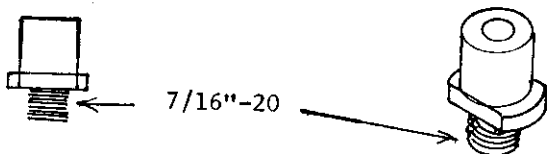
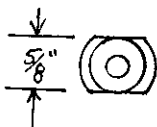


Invert the stock on the mandrel, using a short piece of 1/4" X 3/8" bushing as a spacer between the nut and the stock. Reduce the diameter of the tail stock end to 7/16" for 3/8" of the length to leave a 7/8" diameter collar of 3/16" width.

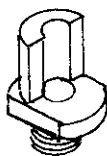


Two sides of the collar are filed flat to form a grip for a 5/8" open end wrench, and 7/16"-20 threads are cut right up to the collar.

Install a 1/4" die in the guided stock and run in a 1/4" bolt to adjust the guide. Then install a 7/16"-20 die in reversed position. Slip a 1/4" rod through the retainer and use it to guide the stock as you cut the threads. To finish cutting to the collar you can invert the die.

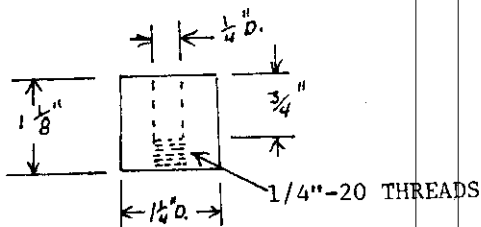


Carefully saw away 1/2 of the 5/8" diameter portion on the vertical center line.

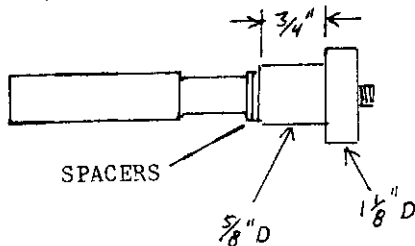


THE LATCH PIN PULL HANDLE

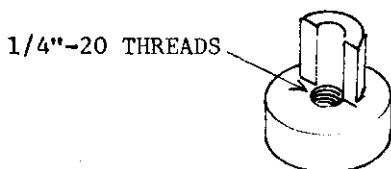
Square the ends of a 1 1/8" length of 1/4" sprue, and punch the center of either end. Drill a 13/64" hole through the center and follow with a 1/4" drill to a depth of 3/4". Tap the remainder of the 13/64" hole 1/4"-20, using the 1/4" hole to guide the tap.



Screw the prepared stock onto the 1/4"-3/8" threaded mandrel, using flat washers as spacers so that it seats firmly against the shoulder of the mandrel. Reduce the diameter to 1 1/8" for the entire length. Then reduce the diameter of the 1/4" drilled end to 5/8".

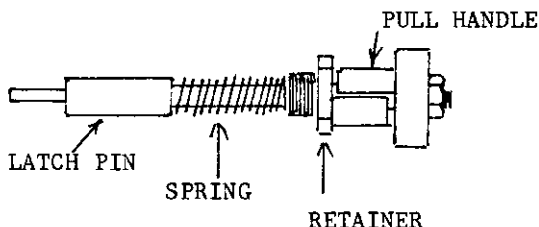


Carefully saw away 1/2 of the 5/8" diameter portion on the vertical center line.



ASSEMBLE THE LATCH PIN

A compression spring about 1 1/4" long is slipped over the stem of the latch pin. This is followed by the retainer, and the pull handle is screwed on. A 1/4" nut jams the pull handle to complete the assembly.



The assembly screws into the 7/16"-20 threads of the crank handle, but final assembly must wait until the plates are finished and installed.

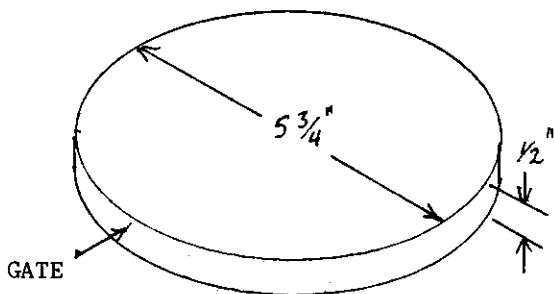
In use, when the latch pin is withdrawn from the plate hole the pull handle is given a partial turn so that it is held in the out position while the crank is turned. Then it is turned again when the pin comes near the last hole, so that it can fall in the hole without running past.

The overall length and the length of the pin end will have to be trimmed at final assembly. When locked in the out position the pin end must clear the sector arms. When in the engaged position the pin enters the plate hole about 3/16" to 1/4".

THE FRACTION PLATES

There are three plates in a basic set, but it is wise to make two or more extra blank plates at this time.

The plate pattern is a simple disc which you can make on the lathe. It is fed at the rim with a 1 1/4" sprue and a very short runner.



CAST THREE OR MORE

THE PLATE CARRIER

Very similar to the clamp brake, but it is cast with an extension that is used during the machining operations that follow. Feed at the heavy end with a 1 1/4" sprue and a very short runner.

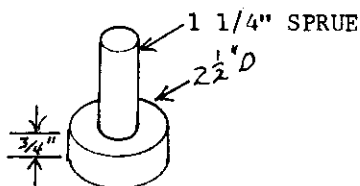
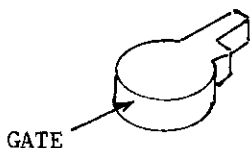
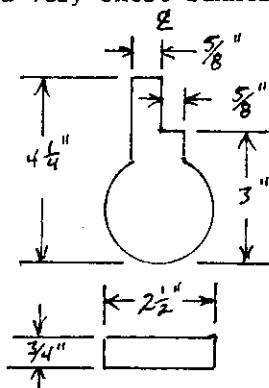


PLATE HUB

THE PLATE HUB

This hub will support the plates as their hole circles are drilled, and it can find use as a work holding fixture when the dividing head is complete.

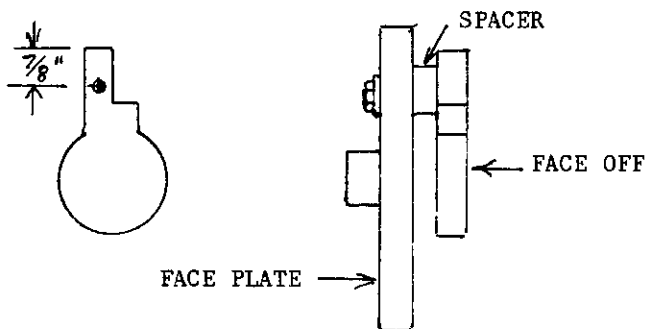
The pattern is a 2 1/2" diameter disc, and a portion of the 1 1/4" sprue becomes the hub.

MACHINING THE PLATE CARRIER

The extension on the plate carrier is used to mount it on the face plate. When it is properly prepared the carrier will be used as a fixture for machining the plates.

First locate the mounting hole in the extension, drill a 1/4" hole and tap it 5/16"-18.

Mount it on the face plate with a set screw collar for spacing furniture and face off one side clean. Then invert it to face off the second side clean. The finished thickness is not critical. From 5/8" to 11/16" is OK.



THE DRILLING TEMPLATE

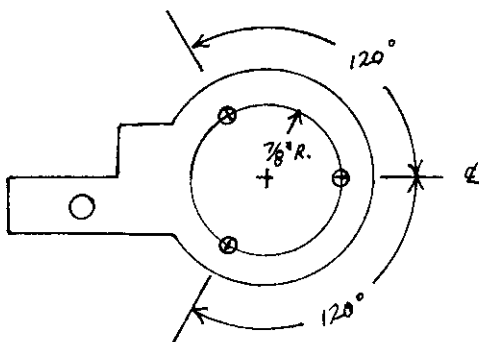
The fraction plates will be mounted with three flat head screws through countersunk holes. The hole pattern must be identical on all three plates, the plate carrier, and the plate hub. A template is prepared at the same time the plate carrier is drilled so that it can be used for the plates and the hub. It is nearly impossible to lay out and drill a perfect hole circle without exotic equipment, but the template will ensure that any error is duplicated in all pieces so that they will be interchangeable.

Paint either side of the faced off plate carrier with blue layout dye and carefully locate and punch the center of the circular area.

Set the dividers for a 7/8" radius and scribe a circle from the punched center. It's a good idea to scribe another circle on a piece of scrap at the same time.

If you step off the radius twice on the diameter, then the setting will be very close for pacing off three equally spaced hole centers on the circle. Try it on the scrap, and make any needed adjustment before you mark the hole centers

on the plate carrier. Carefully punch the centers and use the drill press to drill three $13/64$ " holes.



Use the drilled plate carrier as a guide to drill the same hole pattern in a scrap of $1/16$ " thick sheet metal, and drill a small sight hole in the center of the template so you can locate it on the center of the plates.

MACHINING THE PLATES

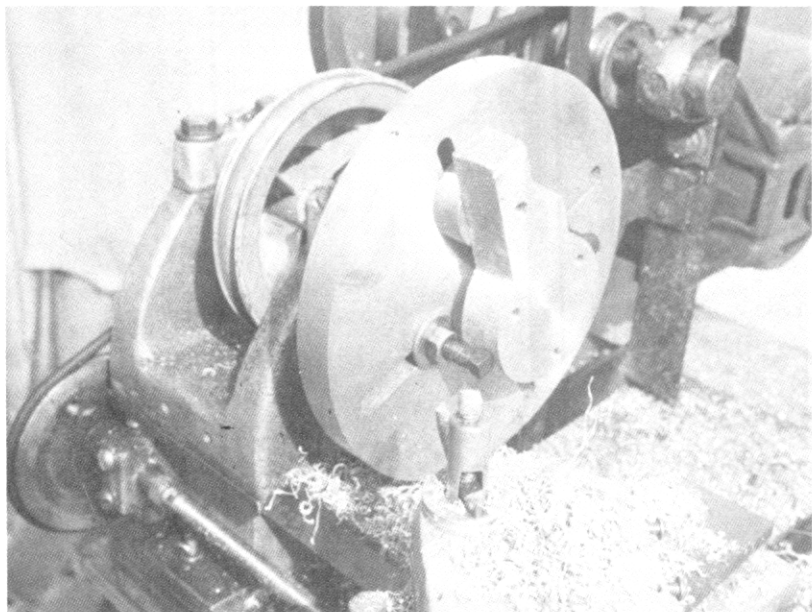
The holes in the plate carrier are tapped $1/4$ "-20, and it is mounted on the face plate with the spacer as before. Use the tail center to very carefully locate the punched center on the turning axis of the lathe, and install a stop bolt on each side of the carrier with double nuts.

This is the set up that will be used to face off and bore the plates, and the plate carrier will be bored at the same time. Center it very carefully, and make sure that the mounting is secure so that it won't be moved off position before you finish machining all of the plates.

The plates are drilled with the template and the holes are then enlarged to $1/4$ " and countersunk on both sides of the plate to receive the heads of the $1/4$ "-20 flat head machine screws that mount the plate to the carrier. They must be countersunk deeply enough so that the heads will be below the surface when the plate is faced off to a finished thickness of $3/8$ ".

Both sides of the first plate are faced off to reduce its thickness to $3/8$ ". Then a starting hole is drilled and both the plate and the carrier are bored to $1 1/8$ " for a close fit on the worm carrier journal. The remaining plates

are faced off on both sides and bored, but the bar is not permitted to enter the bore of the carrier more than 1/16" after the first plate has been bored.



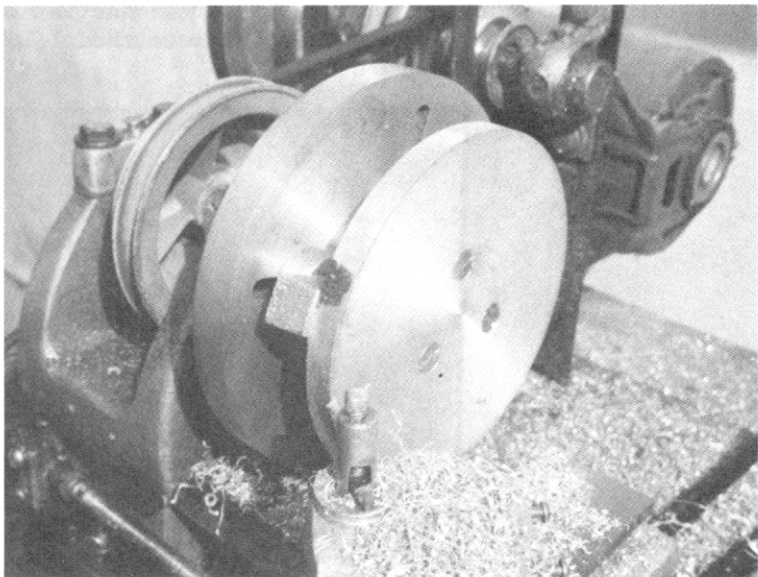
The rims of the plates are not machined at this time because of the danger of knocking the set up off center. They will be machined later by mounting them on the plate hub with an arbor between centers.

It's a good idea to mark the rim of the plates in relation to the carrier in case you have to remove one before it is completely machined. You may have to deepen a countersink if the plate surface doesn't clean up before the tool touches the screw heads.

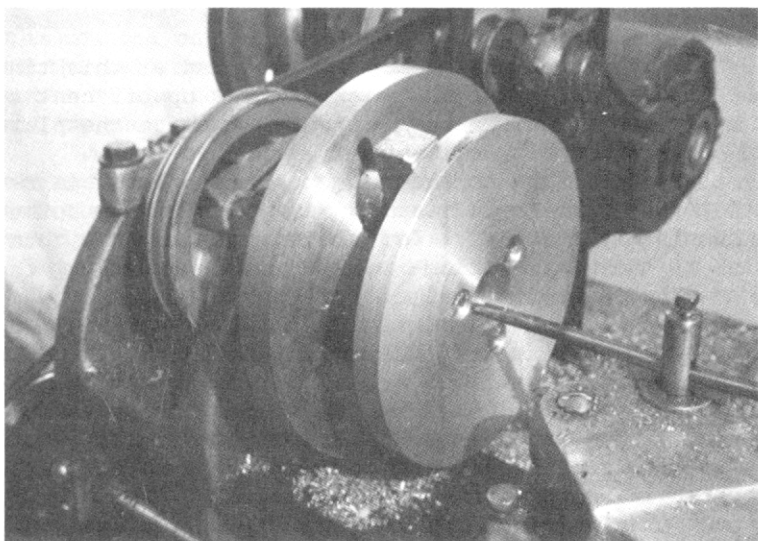
Finish all of the plates at this time, including any extra plates, so that all will be interchangeable. Take all the time it requires to be very careful.

When they are finished the holes must be countersunk deeply enough so that the heads of the screws are below the surface. The sector will rest on the surface of the plates and protruding screw heads would interfere.

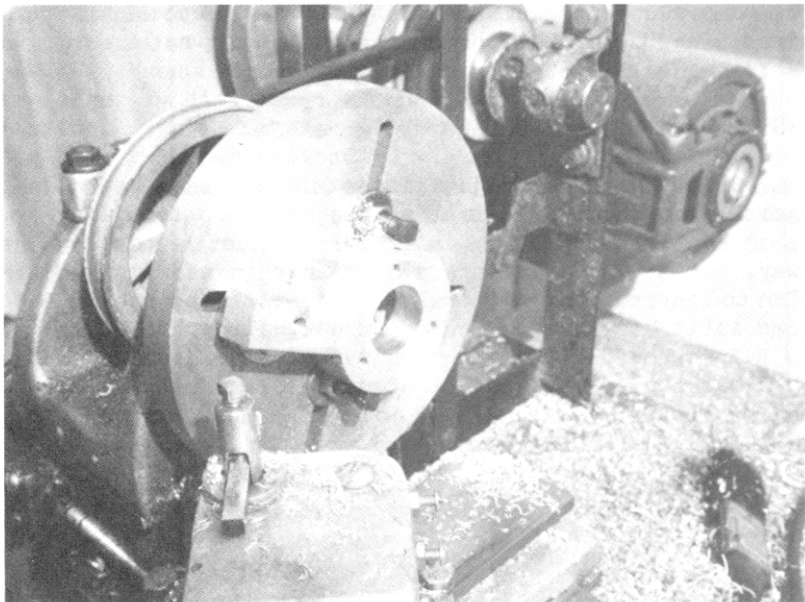
Keep the facing off tool very sharp. You can spray the surface of the plates with kerosene as you machine them for a smoother finish.



FACE OFF THE FIRST PLATE ON BOTH SIDES



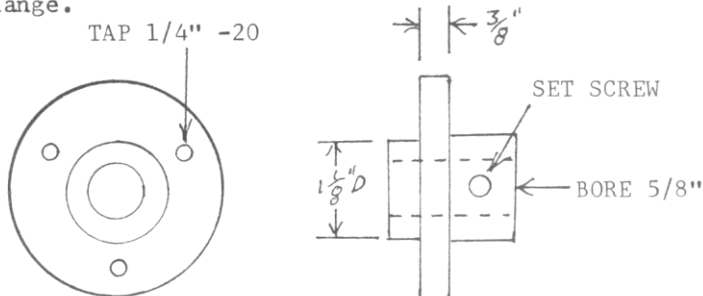
BORE THROUGH THE FIRST PLATE AND THE CARRIER



THE BORED PLATE CARRIER

MACHINING THE PLATE HUB

Cut off the sprue, leaving a hub $\frac{3}{4}$ " long. Bore to $\frac{5}{8}$ " for a close fit on the spindle of the dividing head. Install a $\frac{5}{16}$ " set screw in the hub and mount it on an arbor between centers. Machine the face to $\frac{3}{8}$ " thickness, leaving a $1\frac{1}{8}$ " diameter boss in the center to exactly match the bore of the plates. Use the plate carrier to guide the drill as you drill three $\frac{13}{64}$ " holes through the flange.



Now you can mount the plates on the hub to machine the rims. The finished diameter is not critical, but should not be less than 5 5/8".

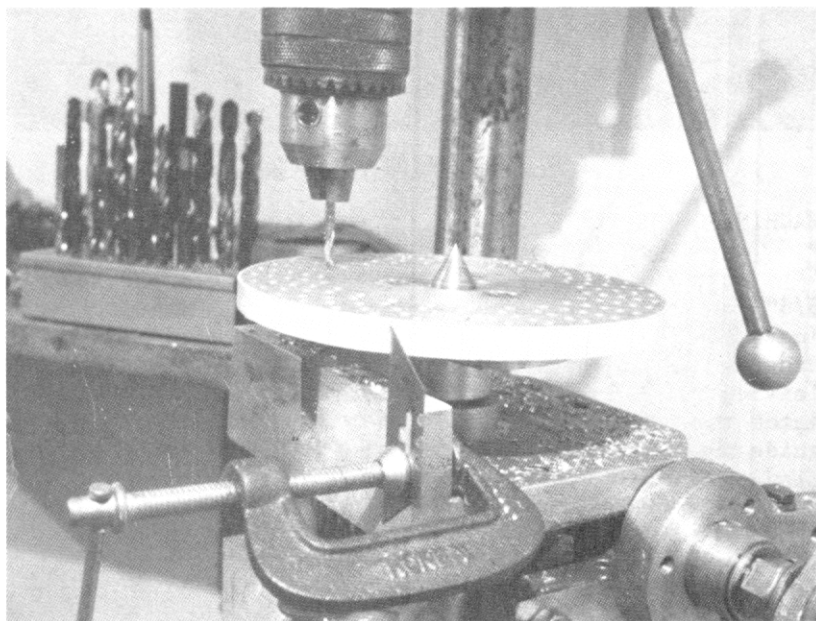
INSTALL THE PLATE CARRIER

Split the casting just as you did the clamp brake, and install the clamp bolt in the same manner.

The extension that was used for mounting can be cut away, but it won't interfere with anything so it might be wise to leave it on. It could be an aid if you need to do some split hole indexing for an unusual job.

Push the finished carrier up to the shoulder on the worm carrier journal and tighten the clamp bolt.

DRILLING THE PLATES



The plate hub is installed on the spindle of the dividing head to support the plates for drilling the hole circles.

The dividing head is mounted on the drill press as a rotary table, and the rim of the plates are fit with an accurately divided strip to index the drilling. This is a

very simple operation, though a bit tedious. It is quite accurate if you use reasonable care in preparing the rim strips. Even a poorly made plate will work fairly well as the error is diminished through the principles discussed earlier. Try to make them perfect, but be content with a bit less than perfection.

Each plate has six circles of holes of a different number to give eighteen different denominators. Many of them can be factored, so there are a broad range of possible fractions available.

The suggested set differs from a commercial set only in that I have replaced the 16 hole circle with a 24 hole circle. This was done so that a gear of 96 teeth could be made. The numbers 2, 4 and 8 are all factors of 16, and these factors can be found in the 24 hole circle so no important numbers are lost.

This set of plates will divide all numbers through 50, and all even numbers and multiples of 5 through 100. The dividing chart in the appendix will show you all of the numbers that are available through 360, and there are a great many available beyond. One hole in the 49 hole circle gives 1,960 divisions, so you can see how far beyond normal needs this simple device will serve.

There are limitation though, because there are many numbers that are not available. It is when this problem comes up that you will appreciate being able to make a special plate for the job.

THE BASIC PLATE SET

PLATE #1, 15 - 17 - 18 - 19 - 20 - 21

PLATE #2, 23 - 24 - 27 - 29 - 31 - 33

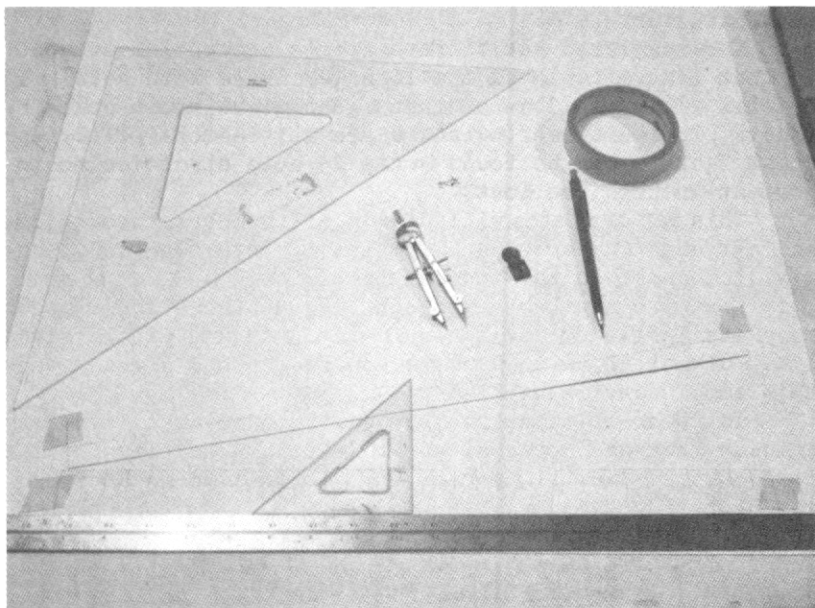
PLATE #3, 37 - 39 - 41 - 43 - 47 - 49

PREPARING THE RIM STRIPS

If you were to scribe a circle on the plate and try to step off equal divisions for each hole circle it would be a very frustrating experience, and accuracy would be poor. As all radial lines converge on the center of the circle, any divisions spaced off on the rim will be equal at any diameter of the circle even though they become smaller. It is not difficult to divide a straight line into equal

parts, and that's the secret to the success of this simple dividing method.

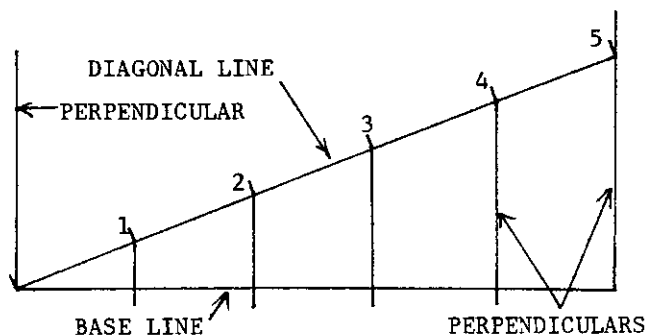
The required equipment and materials are seen in the photo below. A good 24" rule or straight edge, a small and large triangle, a good quality divider and a pencil that is kept very sharp throughout the job are the only tools. Two 24" X 36" sheets of poster card or 10 point bristol board and some masking tape are the materials.



One sheet of the poster card is used for the layout, and it is left whole. The rim strips and diagonal strips are cut from the other sheet. The rim strips are $\frac{3}{8}$ " wide and their length is exactly the circumference of the plate at the rim. The circumference of the plates will be something less than 18" when they are machined smooth, and it's a simple matter to cut the strips over length and wrap them around the rim to trim them to length. They must fit snugly and the joint butts together with no overlap and no gap. Six strips are required for each plate, and they are easiest to trim when the plate is mounted on the dividing head. It is likely that the plates will differ slightly, so make a set for each as you install them for drilling. The butt joint represents a division, so make it sharp and clean.

The diagonal strips are 1" wide and about 2" longer than the rim strips. Make them about 21" long to start, and we'll trim them later. Draw a very sharp clear pencil line down the center of each diagonal strip. You'll need one for each rim strip.

The method we're using is called "dropping perpendiculars". The diagonal line is marked off into equal spaces that are a bit longer than those required. The exact space doesn't matter, just so the total length of the diagonal is greater than the base line. A pair of perpendicular lines are raised from the base line and the diagonal line is set so that its total length exactly fits the perpendiculars. Then perpendicular lines are dropped from the diagonal to the base line. The spaces on the base line will be smaller than those on the diagonal line but they will be equal to each other.



To apply the method to our problem we just use the rim strip for the base line, tape it securely to the layout card, raise a perpendicular line at each end and fit the divided diagonal strip exactly between the perpendiculars. The straight edge is taped securely parallel to the base line, and the triangles are used to drop the perpendiculars from the diagonal line to the base line.

Keep in mind that the ends of the rim strip are joined to form a single division line. Consider the left end of the strip as the zero line and begin the count on the first mark. The opposite end of the strip is the last division.

No precise measurements are needed because the diagonal line can be any length that is from 1 1/2" to 2" longer than the base line. You just measure the base line and add 2" for the calculation and round it off for simplicity.

I began with the 49 hole circle because I knew that my patience would wear thin, and I wanted to have the worst part of the job done before my brain turned to pudding.

The center line of the diagonal strip is called the "walk line". We begin at one end, which is the zero mark, and "walk" the divider 49 steps along the line to leave 49 equal spaces. Each step leaves a tiny prick mark, and it is from these that we drop the perpendiculars. We need an approximate setting for the dividers.

My rim strips measured about $17 \frac{5}{8}$ " long, so adding 2" I get $19 \frac{5}{8}$ ". Round off to 20" for simplicity. Then divide 20 by 49 and the answer is .408. That's just .033" more than $\frac{3}{8}$ ", so set the dividers at a bit over $\frac{3}{8}$ " for a trial walk.

Begin near either end and step off 49 spaces. Press the dividers hard enough to leave a clear mark, but don't distort the setting. Remember that the first mark is the zero mark, so you will have 50 marks with 49 spaces between them. The total length over the spaces should be somewhere between $19 \frac{1}{2}$ " and 20". Each mark should be right on the walk line.

Cut the diagonal strip off at the first and last mark to leave some trace of the mark on the strip.

Tape the straight edge securely to the layout card, and tape the rim strip in place against its edge.

Raise a perpendicular line exactly at each end of the rim strip with a triangle. The space between the perpendiculars is the exact length of the rim strip.

Adjust the angle of the diagonal strip until the end marks fall exactly on the perpendicular lines and tape it securely in place.

Rest the base of the triangle against the straight edge and place a pin in the prick mark so that you can slide the triangle against it.

Hold the triangle firmly as you draw a sharp line from the diagonal through the rim strip for the first mark.

Repeat for each one of the marks until the rim strip is complete.

Keep the pencil very sharp at all times, and make sure that the triangle rests squarely on the straight edge when it is against the pin.

You can test the accuracy of your work by setting the divider to any space on the rim strip. It should then walk the length of the rim strip with none short and none left over. Just a little practice will make you a master.

The greatest potential for error is in the first and last space. Be very careful to align the diagonal strip so that the first and last prick mark fall exactly on the perpendiculars. If your rim strip doesn't test well, check your technique. The mere width of a pencil line, or even the tiny prick mark will add up to a substantial error when multiplied 49 times. Make sure that neither strip moves as you work.

Each strip becomes easier because they have less spaces and you grow in skill and speed with practice.

DRILLING THE PLATES

The circle with the largest number of holes is at the outside of the plate, and its center is $3/16$ " from the rim.

Each succeeding circle has fewer holes, and their centers are spaced $3/16$ ".

The holes are $1/8$ " to match the diameter of the latch pin.

Each circle is independent of the others, and no attempt is made to align any hole of one circle with those of the adjacent circle.

A standard jobbers length drill bit is likely to break easily. Special drill bits are made for work in sheet metal that have short flutes and split points for more accurate drilling without center punching. You can get them from a house that supplies to the heating and air conditioning trade if the industrial supply doesn't have them. It's a good idea to have at least one spare on hand in case you break one.

Aluminum tends to clog up the flutes of the drill. I just spray on a bit of WD-40 from time to time, and pick out stubborn chips with a sharp scribe. If the flutes clog up the drill will run off to one side.

The dividing head is bolted to the table of the drill press as seen in the photo on page 88. The plate hub is locked to the spindle of the head and the plate is mounted on the hub with flat head screws.

The center of the dividing head is aligned with the spindle center of the drill press and the entire table is swung at the column for each new hole circle. Bolt the head securely to the table and don't change its position on the table throughout the drilling operation.

The rim strip is drawn snugly around the rim of the plate with the ends butted together and fastened with clear tape. Add three or four pieces of tape around the rim to

make sure the strip doesn't slip during the drilling operation. The butt joint counts for one division, and the zero mark can be any mark on the rim strip.

An ordinary utility knife blade has a very sharp edge and its size and shape are ideal to serve as a cursor. I clamped it to the base flange with a C clamp. Align the cursor so that its edge is exactly parallel to the marks on the rim strip, and very close to the rim without touching. It will be best to rotate the worm crank counter clockwise so that the knife edge won't dig in to the rim strip in case there is a tiny bulge at the joint. It will spoil the job if the rim strip should be caught and moved during the drilling of any circle.

Raise the table of the drill press until there is just about 1/2" between the drill point and the plate, and swing the table to align the center of the drill point 3/16" from the edge of the plate. Lock the table securely.

Release the clamp brake of the dividing head and rotate the worm crank to bring any mark exactly in line with the knife edge of the cursor.

Lock the clamp brake and drill the first hole through the plate.

Release the clamp brake and rotate the worm crank to bring the next mark to the cursor in exactly the same position as the first mark. Make sure that you view the mark and the cursor from exactly the same perspective each time you advance to a new mark.

Lock the clamp brake and drill the second hole through the plate.

Repeat each step 49 times to complete the circle, and advance to the starting hole when the last hole in the circle is drilled. Try the drill through the starting hole to make sure that the rim strip hasn't moved during drilling.

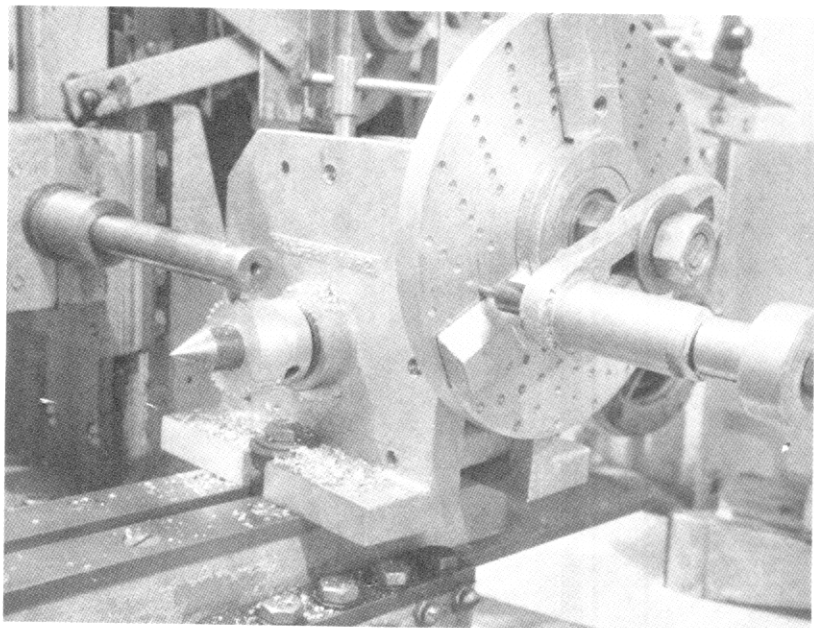
Swing the table to align the drill point 3/16" inside the hole center of the finished circle. This will be the hole center for the next circle.

The next circle has 47 holes, so prepare the rim strip as before and fasten it to the rim of the plate. Align any mark on the strip with the cursor before you fix its position on the plate, then add the three or four strips of clear tape to fix its position.

Repeat all steps for each hole circle until the plate is finished. Swing the drill press table to remove the first plate, and install the next plate without changing position of the dividing head on the work table.

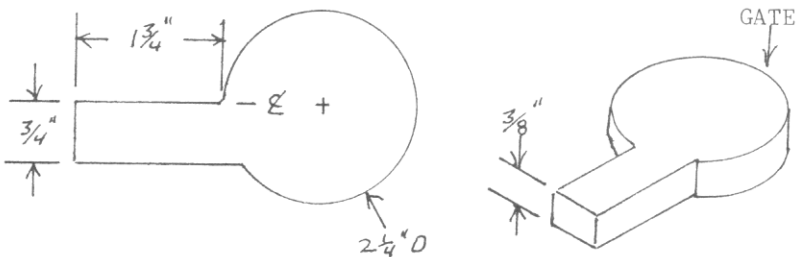
THE SECTOR ARMS

It would be very tedious to count holes each time the worm crank is advanced to a new position, and errors would surely result. The sector arms are adjusted to expose only the required number of holes, so the count need only be made one time for each set up.



THE SECTOR ARM PATTERN

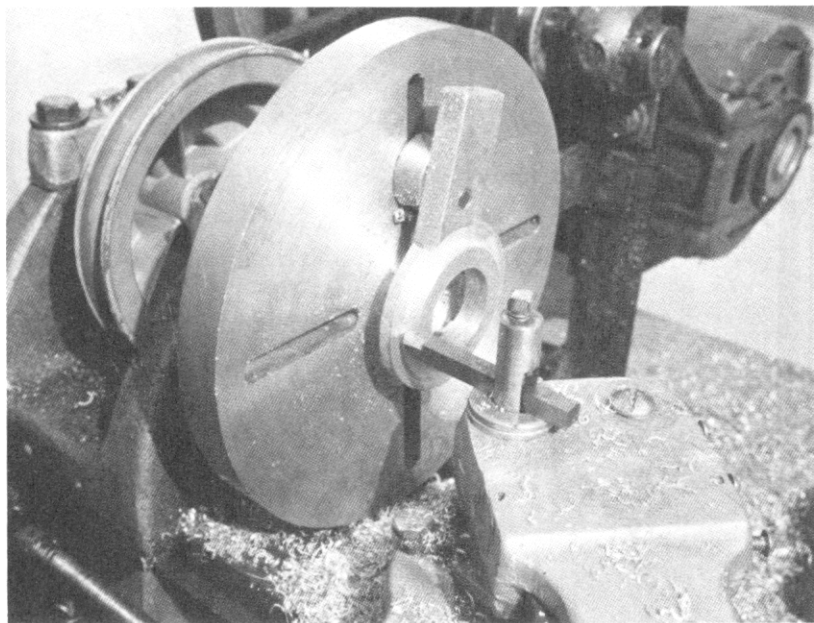
Just one pattern is used to mold both arms. Feed at the heavy end with a 1 1/4" sprue and a short runner.



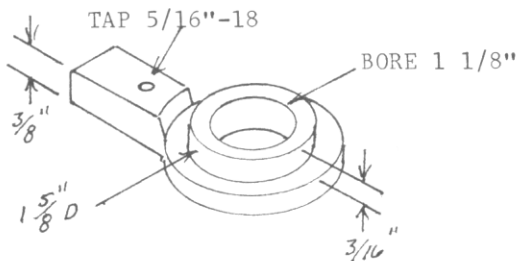
MACHINING THE SECTOR ARMS

The castings are the same for both arms, but they are machined differently to form a scissors joint. Drill and tap both castings $5/16''-18$ about 1" from the end of the arm.

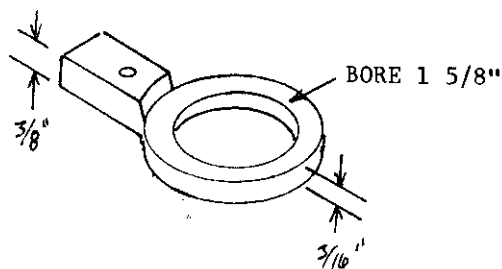
They are mounted to the face plate with spacing furniture so that the boring bar can pass through.



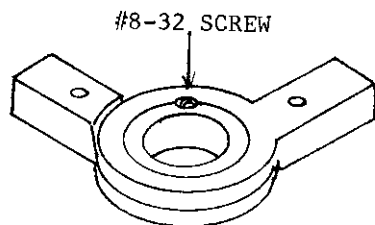
Mount the first arm as shown above and center it with the tail center. Bore it to $1\ 1/8''$ for a close fit on the worm carrier journal. Then machine the circular portion to leave a ring $1\ 5/8''$ in diameter and $3/16''$ deep.



The second arm is mounted on the face plate in the same way, but it is bored to 1 5/8" for a close fit on the ring of the first arm, and the circular portion is machined to 3/16" thickness.



A #8-32 tapped hole very close to the rim of the ring accepts a machine screw to lock the adjustment as the head of the screw clamps the second arm.



The facing edges of the arms are filed to a 45 degree bevel as seen in the photo on page 95.

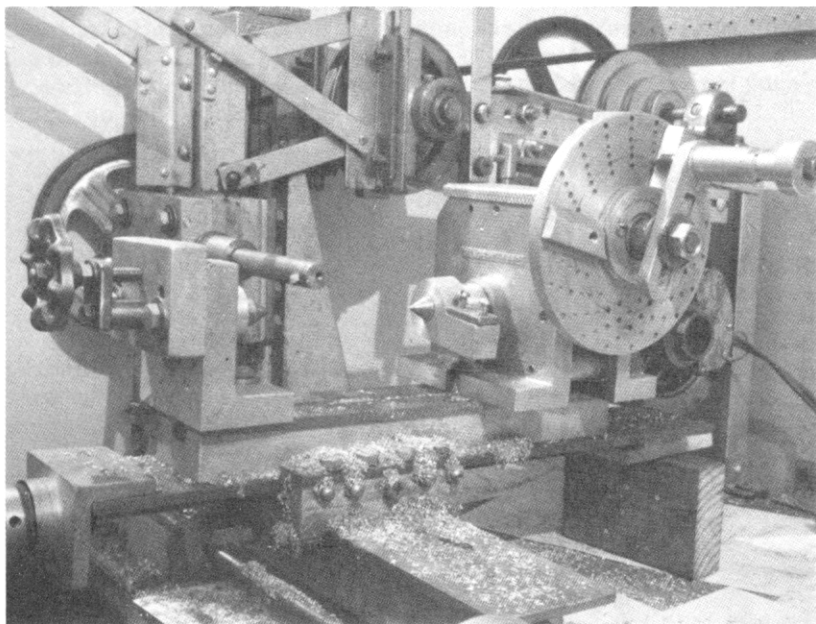
The assembled sector fits on the worm carrier journal and rests against the plate. Its spread is adjusted to expose the required number of open holes for a given job, which we'll discuss in a bit more detail later.

THE TAIL STOCK

Some work can be done on the spindle of the dividing head, such as the spindle gear as seen in the photo on page 95, but most jobs will require a tail stock to support a mandrel or arbor.

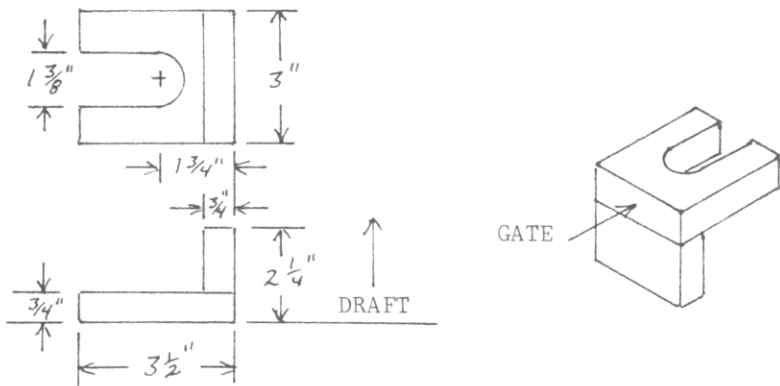
The center height of the tail stock is made adjustable so that taper work can be done, and so that it can be raised in the event that raising blocks are used to increase the

swing capacity of the dividing head. It's a very simple casting and machining job that turns out a sturdy tailstock.



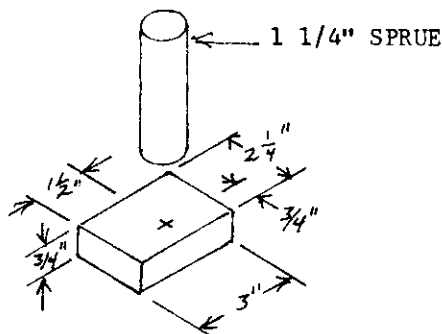
THE TAIL STAND PATTERN

A simple right angle shape. Feed at the center of the outside corner with a $1\frac{1}{4}$ " sprue and a very short runner.



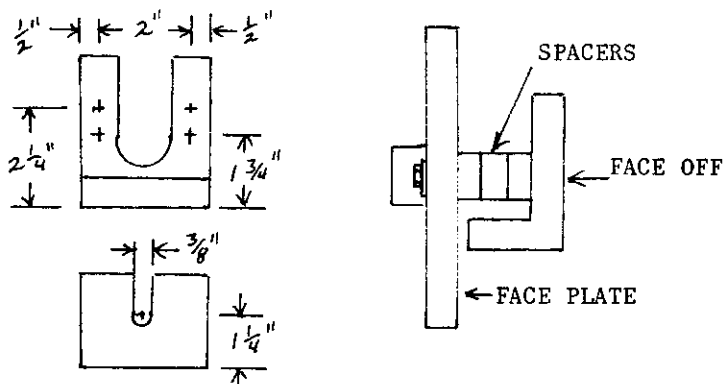
THE QUILL CARRIER CASTING

A simple rectangle fed with a 1 1/4" sprue which becomes part of the casting.



MACHINING THE TAIL STAND

Drill two 1/4" holes in each leg as shown below, and tap them 5/16"-18. Mount the casting on the face plate with spacing furniture to face off the vertical surface.



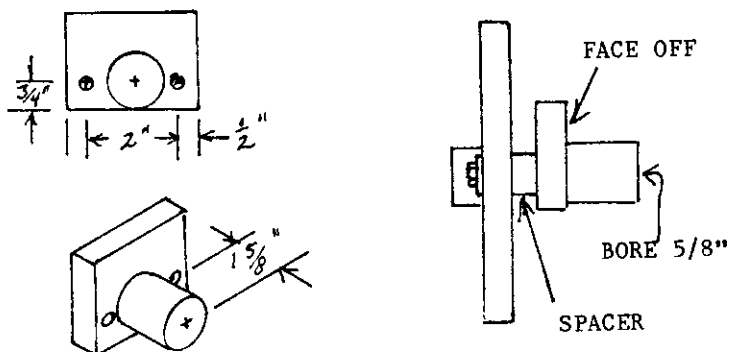
Clamp the faced off surface of the vertical legs to the angle plate and face off the base. The finished thickness is not critical for either the legs or the base. Just remove enough material to clean up the surface. The object is to establish the legs and base at exact right angles.

Drill a 3/8" hole through the base and cut a slot with the hack saw. This will be used for mounting the stand on the work table of the miller when in use.

MACHINING THE QUILL CARRIER

Cut off the sprue to leave 1 5/8" extending from the casting. Carefully locate the center of the sprue and punch it.

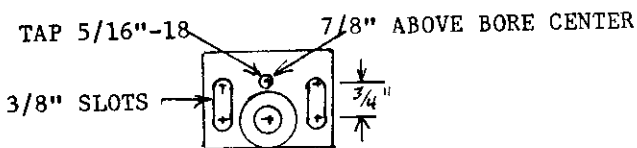
Drill two 1/4" holes to match the center distance of the holes in the stand and tap them 5/16"-18.



Mount the casting on the face plate with spacers as seen above. Center the extension carefully and bore through to 5/8" for a close fit on the 5/8" diameter quill. Face off the rectangular portion and machine the outside diameter of the extension just enough to clean it up.

Enlarge the two tapped holes to 3/8" and drill two more 3/8" holes centered 3/4" above them. Use a coping saw to cut away the material between the holes to form 3/8" slots.

Drill a 1/4" hole 7/8" above the center of the bore and tap it 5/16"-18.



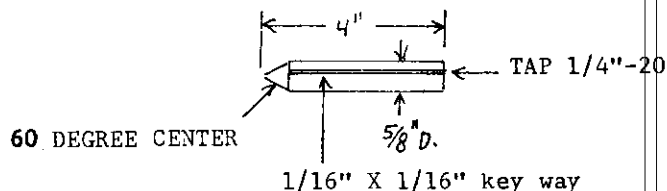
MACHINING THE QUILL

Prepare centers in a 4 1/2" length of 3/4" cold rolled steel and mount it between centers. Reduce its diameter to 5/8" for a close fit in the carrier bore.

Use the steady rest to machine a 60 degree cone nose on either end. The finished length will be about 4".

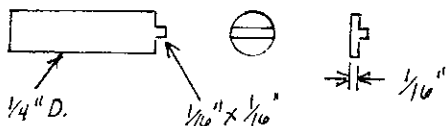
Drill a $13/64$ " hole about 1" deep in the blunt end, and tap it $1/4$ "-20

Use two blades in the hack saw to cut a $1/16$ " key way for the full length of the quill. $1/16$ " is deep enough.

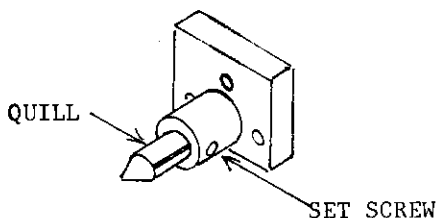


THE QUILL KEY

File a $1/16$ " X $1/16$ " key on the end of a scrap of $1/4$ " rod, and then cut it from the rod with a hack saw to leave a $1/16$ " thick disc attached to the key.



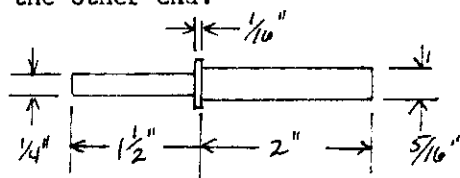
Drill a $1/4$ " hole through the quill support about $1/4$ " from the end. Tap it $5/16$ "-18. Slip the quill through the bore and install the key to engage the key way. Install a socket head set screw to lock the quill.



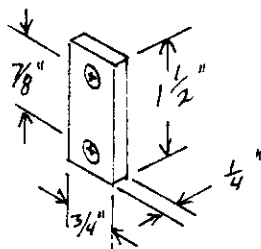
THE QUILL SCREW

Prepare a 3 1/2" length of 3/8" or 1/2" cold rolled steel with centers and mount it on the lathe to machine the screw blank as shown below.

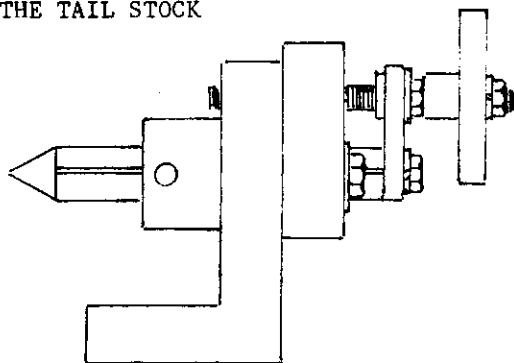
Use the guided stock to cut 5/16"-18 threads right to the shoulder on one end, and cut 1/4"-20 threads close to the shoulder on the other end.



The screw plate is a 1 1/2" length of 1/4" X 3/4" cold rolled steel. Drill two 1/4" holes on 7/8" centers.



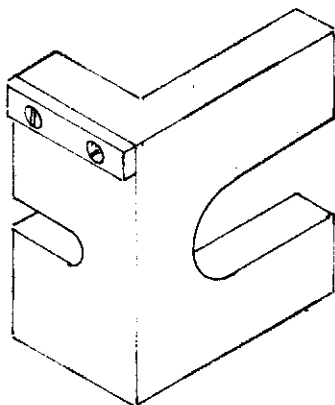
ASSEMBLE THE TAIL STOCK



You'll see in the photo on page 98 that I used a faucet handle for the screw handle. The screw is slipped in the screw plate and an S. A. E. washer is followed by a nut to adjust the end play. Then slip on the handle and follow with a nut to jamb the handle and lock the end play adjustment. Run the screw into its tapped hole in the quill carrier and fasten the other end of the plate to the quill with a 1/4"-20 X 3/4" cap screw with a lock washer.

Two 5/16"-18 X 1 1/2" cap screws with flat washers are used through the slotted holes in the carrier to mount it on the tail stand.

A 1/8" X 1/4" key is fastened to the base with #8-32 machine screws. If aligned carefully at exact right angles to the faced off surface, it will align the tail stock on the work table of the miller.



As the key is at exact right angles to the machined surface of the tail stock it will align it with the quill parallel to the work table of the miller when the key is resting against the left side of the table. The dividing head has no key, but it is aligned by squaring either the front or back base flange with the work table. The tail stand is first aligned and clamped. Then the dividing head is squared with its spindle nose aligned with the tail center. Then the tail stock can be moved any place on the table and the key will align it with the head.

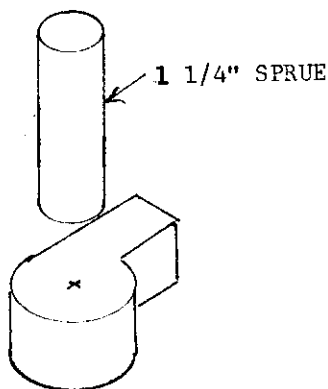
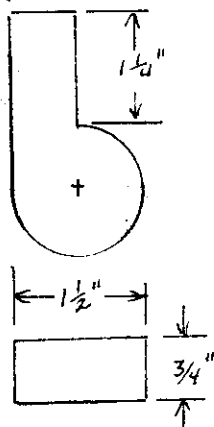
Of course a key can be added to the base of the head, but that may prove a problem when raising blocks are used or when the head is mounted in angular positions.

THE DRIVE PLATE PATTERN

A slotted drive plate, such as used on the lathe, will not be adequate for the dividing head because of the play between the dog pin and the slot. A clamp type plate is the answer, and it's not difficult to make.

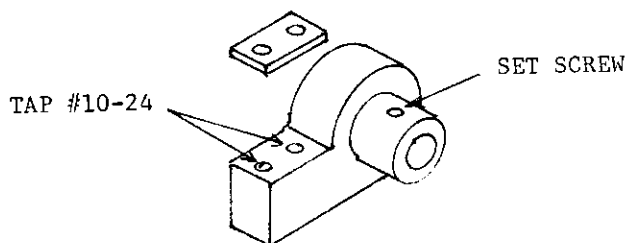
It's a simple pattern, and again the sprue becomes the hub, so a guide hole is made in the pattern to center the sprue pin when molding.

→ 3/4" ←



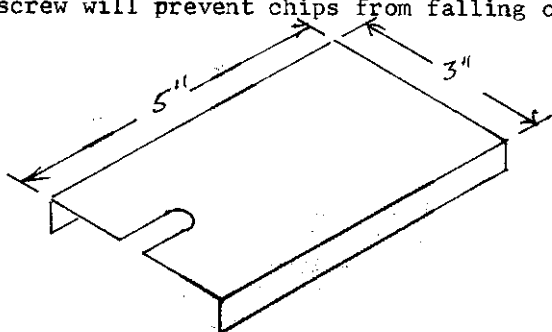
MACHINING THE DRIVE PLATE

Cut off the sprue to leave a hub 3/4" long. Bore to 5/8" and install a 5/16"-18 set screw in the hub. Make a clamp plate of 1/8" X 3/4" steel and install it with two #10-24 machine screws tapped into the arm.



THE CHIP COVER

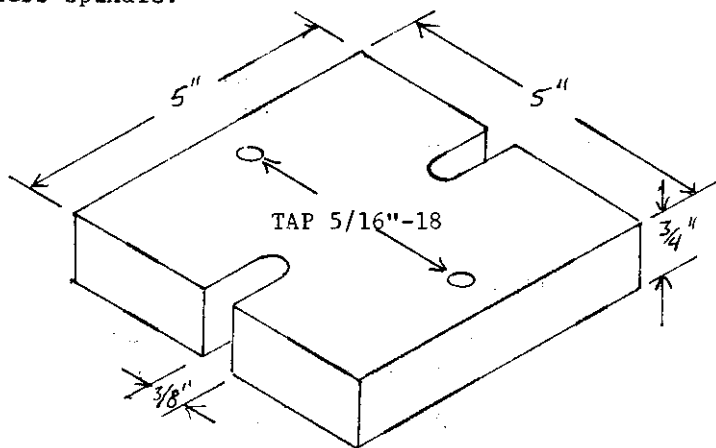
A simple sheet metal cover with a notch cut for the clamp screw will prevent chips from falling onto the worm.



RAISING BLOCKS

As detailed the dividing head will swing work $4 \frac{1}{4}$ " in diameter, which should cover most of the needs in the home shop. It's a simple matter to cast raising blocks if you find a need for a greater swing capacity.

Cast one or more as shown below, and face them off on both sides. The alternate slots and tapped holes also will permit mounting the head with its spindle parallel to the millers spindle.



GEAR CUTTING

Modern gear technology has developed to such a level that gears of amazing precision can be made in great quantities at relatively low cost. If you have need for gears that can be found in the standard stock catalogs it is most likely that it will be cheaper and easier to buy them than to make them. These stock gears are so precisely made that you can build your equipment to fixed standards and any of the gears of standard manufacture will fit the application. This is the miracle of modern mass production technique, but if you happen to need one or a few gears that differ in any way from industry standards you are in trouble. The same equipment that turns out those ten thousands of stock gears is not adaptable to one of a kind production, so costs run high for a gear that is special in any way. While we can't make gears to such precise standards or in such quantity in the home shop, we can make them remarkably true to form and at very low cost when only a few are needed.

TOOTH FORM

It would require an entire volume to discuss tooth form and the technical aspects of gear design and application. Others, who are far better qualified than I, have already written thoroughly on the subject, so we'll just discuss it at the basic level. We are interested in producing gears that will mesh nicely with each other in order to transfer motion from one shaft to another at a fixed ratio. The standard involute tooth form is what we want, so a standard gear of the right pitch or a standard gear tooth gauge will give us the form.

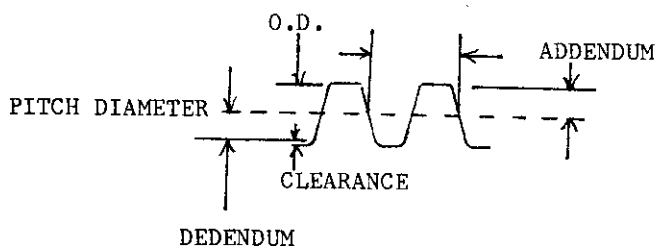
Involute tooth form means that the teeth of gears in mesh make a rolling contact with each other, and this reduces friction and noise. The curvature of the form is such that each pair of teeth are in full contact before the preceding teeth have separated as the gears turn. This results in a quiet transfer of motion from one shaft to the other. The transmission and differential gears of your car are a good example. They are virtually silent, even though delivering 100 horse power or more to the wheels. We could not produce such gears without spending much time and labor.

GEAR CALCULATIONS

It will be best to keep in mind that we are not cutting gear teeth, we are cutting spaces between the teeth.

The simplest way to grind a cutter to proper form is to use a standard gear tooth gauge. I got mine for about \$10.00 from Campbell Tool Co, and it covers all the standard pitches. It's a simple matter to grind a tool bit to fit the form of the gauge. You can also use an existing gear of commercial manufacture for the same purpose.

Having decided upon the pitch to be used, we need only be concerned with finding the correct outside diameter of the blank and the proper depth to set the cutter. Given a cutter of the correct form, set at the proper depth, the blank of the correct diameter and accurately indexed, and the result is a gear that is very close to commercial standards. Only a few simple factors must be understood, and these are clearly named in the diagram below.



PITCH

The pitch of a gear is determined at its pitch diameter. One half of the tooth depth is outside the pitch diameter and one half is inside. An additional amount of the depth is the clearance, which is calculated inside the pitch diameter.

The pitch is expressed in terms of teeth per inch, and for these calculations we are concerned with the number of teeth per inch of diameter. A 24 pitch gear with 24 teeth will have a pitch diameter of one inch. A 12 pitch gear with 24 teeth will have a pitch diameter of two inches. It's plain that the fine pitch gear contains more teeth for a given diameter than does the coarse one, and this is the

factor that determines our selection of pitch. Fine pitch gears require less room than coarse pitch gears of the same tooth count.

We need to know the pitch diameter in order to find the outside diameter for the gear blank, and this leads us to the first formula:

$$\frac{\text{NUMBER OF TEETH}}{\text{DIAMETRAL PITCH}} = \text{PITCH DIAMETER}$$

This means that the pitch diameter is found by dividing the number of teeth by the diametral pitch. The pitch diameter of a 24 pitch gear with 32 teeth is 1.333":

$$32/24 = 1.333''$$

THE ADDENDUM

The amount of tooth outside the pitch diameter is the addendum. It is found by dividing one by the diametral pitch:

$$\frac{1}{\text{DIAMETRAL PITCH}} = \text{ADDENDUM}$$

The addendum for a 24 pitch gear is .04166".

$$1/24 = .04166''$$

THE OUTSIDE DIAMETER

The outside diameter is equal to the pitch diameter plus twice the addendum:

$$\begin{array}{r} \text{PITCH DIAMETER FOR 32 TOOTH GEAR} - 1.333'' \\ \text{TWICE ADDENDUM} \text{-----} \quad \quad \quad \underline{.083''} \\ \text{OUTSIDE DIAMETER OF GEAR BLANK} \text{----} \quad \underline{1.416''} \end{array}$$

TOOTH DEPTH

The full depth of the tooth is equal to the addendum plus the dedendum plus the clearance, and this is the full depth of cut that is used in milling the tooth spaces. The dedendum is exactly the same as the addendum, so we need only one more formula to find the clearance.

CLEARANCE

Clearance is needed to allow for imperfections in form and changes in size and form that result from temperature changes. The lubrication film also occupies some space.

The clearance is found by dividing the constant .157 by the diametral pitch:

$$\frac{.157}{\text{DIAMETRAL PITCH}} = \text{CLEARANCE}$$

The clearance for a 24 pitch gear is .0065"

$$.157/24 = .0065''$$

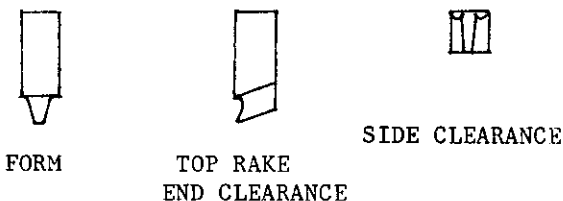
CUTTING DEPTH

ADDENDUM	-	.04166"
DEDENDUM	-	.04166"
CLEARANCE	-	<u>.0065"</u>
CUTTING DEPTH	-	.08982"

Round off to .090" for simplicity, and we have all the information we need. The correct outside diameter for a 24 pitch gear with 32 teeth is 1.416", and the correct cutting depth is .090".

THE GEAR TOOTH CUTTER

It's a simple matter to grind a tool bit to match the form of the gear tooth pitch gauge or an existing gear. It must have top rake, side clearance and end clearance just like a boring tool. You can use a magnifying glass as you compare the tool with the gauge if your vision is as poor as mine. Remember to keep the end squared, and the form must be symmetrical because you are cutting on the center of the tooth space. Each side of the cutter forms half of a tooth space and half of a tooth form.



The cutter bar is a 5" length of 5/8" cold rolled steel shaft with a square hole near the end for the cutter and a set screw in the end to lock the cutter. I made mine to accept a 3/16" square tool bit, but you may find it easier to file a 1/4" square hole. It will work as well. You can purchase such a bar already made up from Wholesale Tool Co. for about \$10.00.



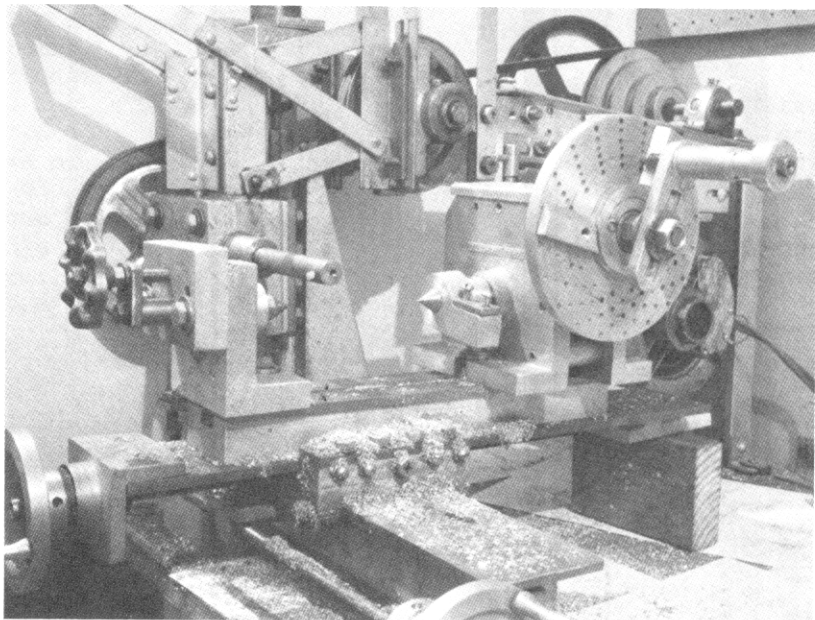
SETTING UP THE MILLER FOR GEAR CUTTING

With the exception of the spindle gear, all of the gears for the lathe will be mounted between centers of the dividing head on a threaded mandrel.

The spindle of the dividing head and the quill of the tail stock must be aligned parallel to the line of travel of the millers work table, and the cone noses of both the spindle and the quill must be aligned.

The tail stock has a key on its base which aligns the quill parallel to the work table, and it is used to center the dividing head. Mount the dividing head at the rear of the work table with T bolts through the slots. Slide the tail stock up close and adjust the height of its cone nose to match that of the head. Snug the T bolt of the tail

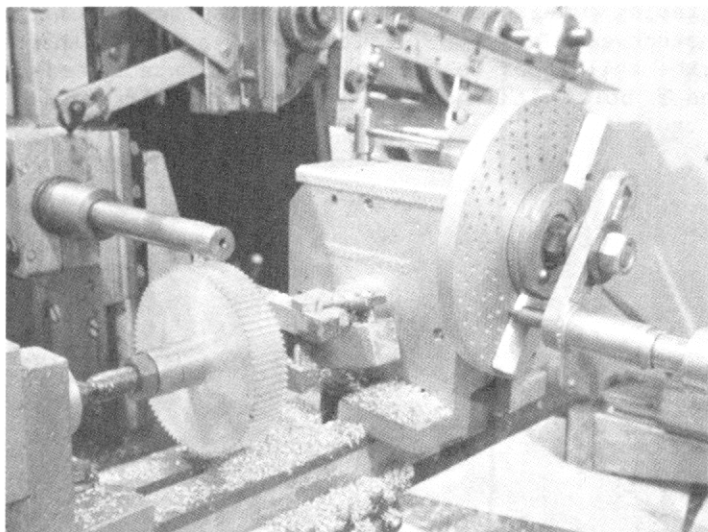
stock with the key against the left rail of the work table. Now use an accurate try square to align the front base flange of the head at exact right angles to the left rail of the work table, with its cone nose in exact alignment with the tail stock cone nose. Tighten the T bolts of the head. Move the tail stock to the front end of the table and tighten the T bolt with the key against the left rail of the work table.



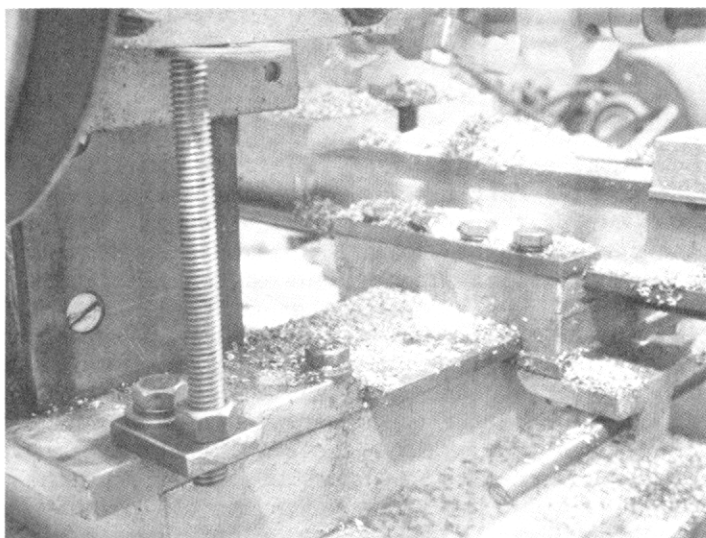
Lower the spindle head of the miller until the cutter is at the center height of the dividing centers, and move the carriage of the miller to align the dividing center with the center of the cutter. This sets the center of the cutter on the vertical center line of the gear blank, and it will remain there throughout the gear cutting. Lock the carriage gib of the miller and raise the millers spindle well above the dividing center.

The gear blanks are machined to the correct O. D. on the lathe, using the threaded mandrel with spacing collars and a nut to jamb them against the shoulder of the mandrel. They are transferred to the dividing centers on the same mandrel. The pin of the dog engages the clamp of the drive plate and the clamp is snugged to eliminate all play.

The outside diameter of the gear blank is now the reference point from which we establish the cutting depth.



SETTING THE CUTTING DEPTH

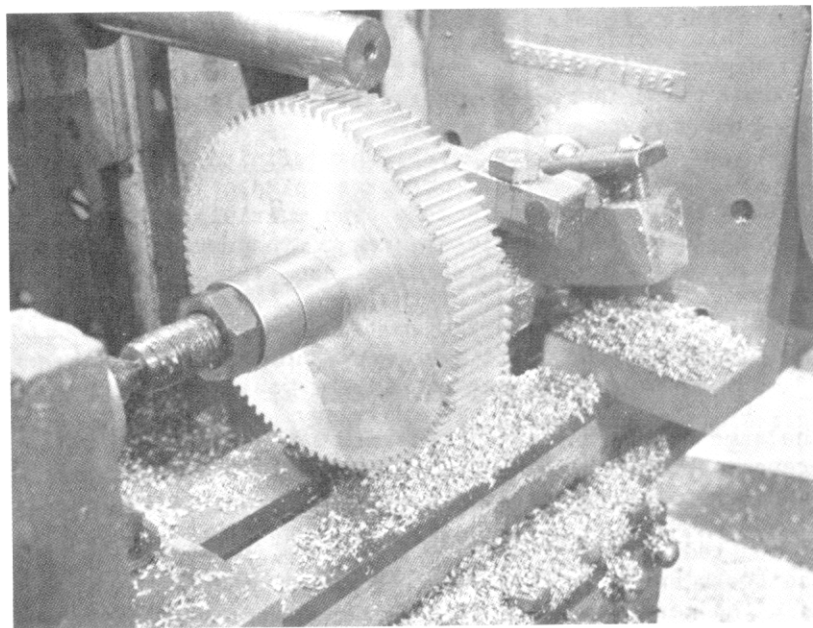


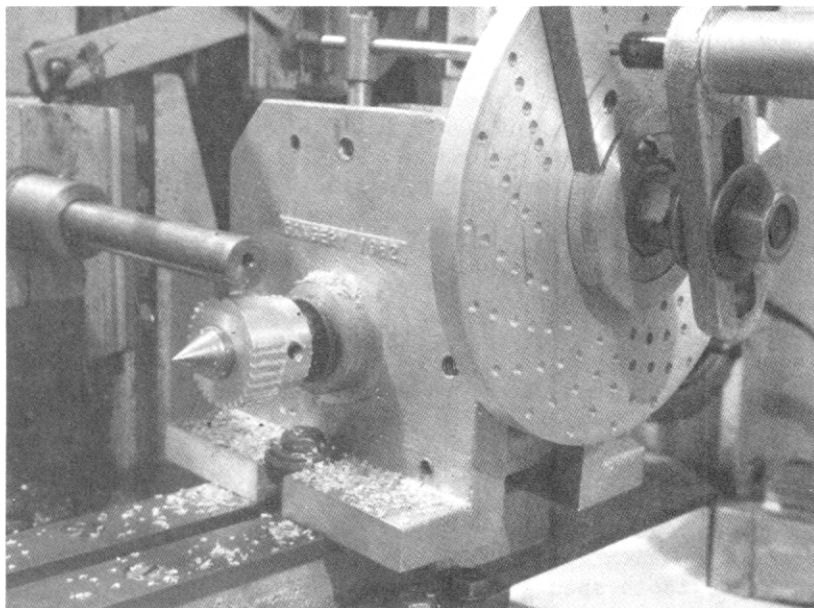
I added a depth stop to my home built miller as seen in the photo on page 112. It is a short length of steel bolted to the base of the head column. It's tapped for a 3/8"-16 threaded rod, and the rod is locked with a jamb nut.

It's a simple matter to set the cutting depth with the prepared blank mounted between the dividing centers. Just turn on the miller and slowly lower the head until the cutter barely makes contact with the outside diameter of the gear blank. Then carefully raise the head until the cutter no longer touches the blank. Move the table to the rear so that the cutter will clear the blank when it is lowered to the cutting depth.

Use a gauge that is the same thickness as the required tooth depth. I found a flat washer that is just .090" thick in my junk box, and that's just right for 24 pitch gears. Adjust the threaded stop rod until the gauge will slip in the space between the rod and the bearing cap of the spindle head and lock the jamb nut. The gauge must slip in and out easily with no play. Check with the gauge again when the jamb nut is tightened.

Now you can remove the gauge and lower the spindle head to contact the stop rod and lock its gib. The cutter will cut gear tooth spaces .090" deep.





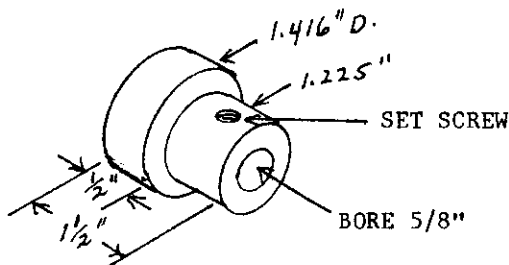
This exercise will serve to instruct you in the basic principles of dividing and cutting gear teeth, and it will produce the spindle gear that will be used on the lathe when the change gears are added.

As the change gears establish a definite ratio between the spindle and the lead screw, a spindle gear is chosen that has a tooth count in some even multiple of the pitch of the lead screw. The lead screw of the home built lathe has a 16 pitch, so we use a spindle gear with 32 teeth which is twice the pitch count of the screw. A 16 tooth gear would work, but its diameter would be too small. A 48 or 64 tooth spindle gear would also work, but the required gears to make up the change set and idlers would be too large.

Cutting the spindle gear is easy because its bore is the same size as the spindle of the dividing head. We can prepare the blank on an arbor and mount it directly on the spindle of the head to cut the teeth. The procedure will be the same for all other gears in the set, but they will be mounted on the threaded mandrel between centers to cut the tooth spaces.

The gear blank can be aluminum or pot metal, or even

brass if you happen to have an appropriate piece of stock on hand. The rough blank should be at least 1 1/2" in diameter and 1 1/2" long. Bore it to 5/8" for a very close fit on the spindle, install a 5/16"-18 set screw and mount it on an arbor between the lathe centers. Reduce the diameter to 1.416" for the entire length, and then reduce the diameter of the hub portion to 1.225" to leave a gear face width of 1/2".



The dividing head has been set up as discussed earlier, so mount the spindle gear blank on the spindle of the head as seen in the photo on page 114 and adjust the cutting depth to .090".

The dividing information is found in the table in the appendix, but you should calculate it as well to build your skill.

$$40/32 = 1 \frac{8}{32} = 1 \frac{1}{4} = 1 \frac{5}{20} = 1 \frac{6}{24}$$

Note that all of these fractions and mixed numbers are equal. There is no 32 hole plate in the set, nor is there a 4 hole plate. Both the 20 hole and the 24 hole plates are included though, and either will do the job. The table calls for a full turn of the crank plus 5 holes in the 20 hole circle, but if the 24 hole plate was on the head there would be no need to change it because 6 holes in the 24 hole plate does the job just as well. The plate in the photo has a 16 hole circle, and 1 4/16 is equal to 1 5/20. I did the job with one full turn plus 4 holes in the 16 hole circle, and the result is exactly the same.

Let's use the 20 hole plate for this first job. Mount it on the plate carrier and slip the sector on the journal. Install the worm crank and adjust it to engage the pin in the 20 hole circle. Tighten the crank nut securely with the pin disengaged, using a wrench on the handle and one on the

nut so there is no strain on the worm and gear. Try the pin in several holes around the circle to be sure the crank is properly aligned with the hole circle.

The zero hole can be any hole in the circle, and the crank can be turned in either direction. Once selected the direction of rotation remains the same throughout the operation. I always turn counter clockwise, but it will work as well in the opposite direction. Rotate the crank past several holes to take up back lash and engage the pin in any hole. This is the zero hole.

Rest one arm of the sector against the pin and adjust it so that the other arm exposes 5 holes in the 20 hole circle and lock the adjustment.

Lock the clamp brake of the dividing head and make a slow steady pass to cut the first tooth space. I used the highest speed in the low range which is 270 RPM and it did a nice job. When the cutter has passed all the way through the blank the tooth space is cut to full depth. Return to the starting position by moving the table to the rear with the power on, making sure you have traveled far enough so that the cutter will clear the blank when it is indexed to the next space.

The cutter of the miller turns counter clockwise and the work is fed from the rear forward to make the cut. If you attempt to feed a cut in the opposite direction the tool will take over the feed and do serious damage.

It will be best to turn off the power as you index until you are entirely sure of your skill.

Remember to release the clamp brake of the dividing head before you index to the next space.

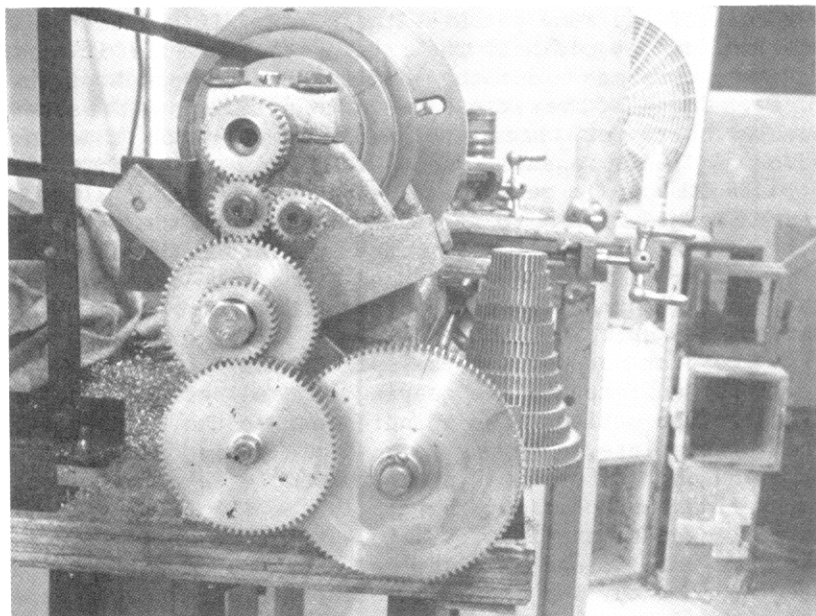
Hold the sector arm against the pin as you withdraw the latch pin. Turn the pull handle to hold the pin out as you rotate the crank one full turn plus the 5 open holes past the zero hole. Turn the pull handle to drop the pin as you approach the final hole so that the pin will ride the plate just before it drops into the hole. This prevents running past the hole.

Lock the clamp brake and cut the second tooth space. Repeat the procedure for each of the 32 spaces, and that's all there is to it.

The remaining gears will be cut in the same way, except that they will be mounted on the threaded arbor.

You have a capability now that is found in few home shops, and there is little that is beyond you in the way of metal working projects.

ADDING CHANGE GEARS TO THE LATHE



The home made lathe was first fit with a double reduction belt drive to connect the lead screw to the spindle. This provided automatic carriage feed for fine turning and boring operations, but thread cutting was not possible. It is not a difficult job to add the change gears, and the rewards are many. You will be able to cut all of the common screw threads from 8 threads per inch through 80 threads per inch, both right and left hand and internal or external. You will have a range of gear driven fine feeds that enable you to do a much better finishing job than the belt driven feed. Most important, you will have developed a level of skill that opens new horizons in your shop experience.

There are only three castings in addition to the gear blanks, and the remainder of the material is likely to be found in your scrap box. Both the castings and the machining operations are basic, and you have already acquired the necessary skill. The change gear mechanism is simple, and there will be no problem in fitting it to the lathe. This is certain to be your most satisfying shop experience.

THE CHANGE GEAR PRINCIPLE

If the lead screw is made to turn at the same rate as the spindle of the lathe it will move the carriage to cut a thread of the same pitch as the screw. If the screw is made to turn at one half the rate as the spindle it will move the carriage to cut threads of twice the pitch of the screw. Changing the ratio between the spindle and the screw enables us to cut threads of a different pitch than the screw, and this is easily done with a set of gears.

If the spindle gear has 32 teeth and another 32 tooth gear is meshed with it to drive the lead screw the ratio is 1:1 and the screw will turn at the same rate as the spindle. If the gear on the screw is changed to one with 64 teeth the ratio changes to 2:1 and the screw will turn at one half the rate of the spindle.

The distance between the spindle and the screw is not variable, so intermediate gearing is used between them to transfer the motion of the spindle gear to the screw gear. The intermediate gears may be in simple train or compound.

The photo on page 117 shows the complete train of gears in the fine feed mode. At the top is the spindle gear, and it is locked to the spindle with a set screw. It turns at the same rate of speed as the spindle. Below the spindle gear are the tumbler gears, and they serve to reverse the rotation of the screw for cutting left hand threads. The stud gear is below the tumbler gears, and it is a compound gear with a 2:1 ratio. The next gear in the train is the idler, and this one happens to be a 3:1 compound gear. It has a smaller gear pinned to it in back that is not visible in the photo. The smaller gear of the compound idler is meshed with the final gear in the train which is the screw gear. Both the screw gear and the idler gear are changeable so the ratio between the spindle and screw can be varied. These gears are installed in a compound train, and three reduction ratios are being used. The reduction at the stud gear is 2:1, at the compound idler it's 3:1 and the ratio between the spindle gear and the screw gear is 100:32. The product of all three reductions is the total reduction in the train. $2/1 \times 3/1 \times 100/32 = 18.75:1$. The spindle will turn 18.75 times while the screw turns once. This gives a fine feed of .003" per revolution of the spindle, because $1/16"$ divided by 18.75 is .003". To do the same job with a single train of gears would require a screw gear with 600 teeth, and of course it would be too large to fit.

If the compound idler in the same illustration is replaced with a simple idler of any size and meshed with the larger gear of the compound stud and with the screw gear, then all of the gears are considered in simple train. In a single train of gears only the first and last gear have any effect on the ratio. The intermediate gears effect the rotation of the final gear, but they do not effect the ratio. If the spindle gear is 32 teeth and the screw gear is 100 teeth the ratio will be 3.125:1 regardless of how many intermediate gears in the single train. The spindle will turn 3.125 times while the screw turns once. It will cut 50 threads per inch because 16 times 3.125 is 50.

CHANGE GEAR CALCULATIONS

Assuming that the stud gear turns at the same rate as the spindle, change gears are calculated by a simple formula expressed as a fraction.

$$\frac{\text{PITCH OF LEAD SCREW}}{\text{DESIRED PITCH}} = \text{GEAR RATIO}$$

It is a bit complex to calculate the ratio, and then apply it to the gears available, so the formula is simplified by multiplying both values by a common number. The product of those figures above the line represents the stud gear and that below the line represents the screw gear. As the home built lathe doesn't have a changeable stud gear, the product of the figures above the line is applied to the spindle gear. This simplifies the formula further because of the fixed ratio between the lead screw pitch and the tooth count of the spindle gear.

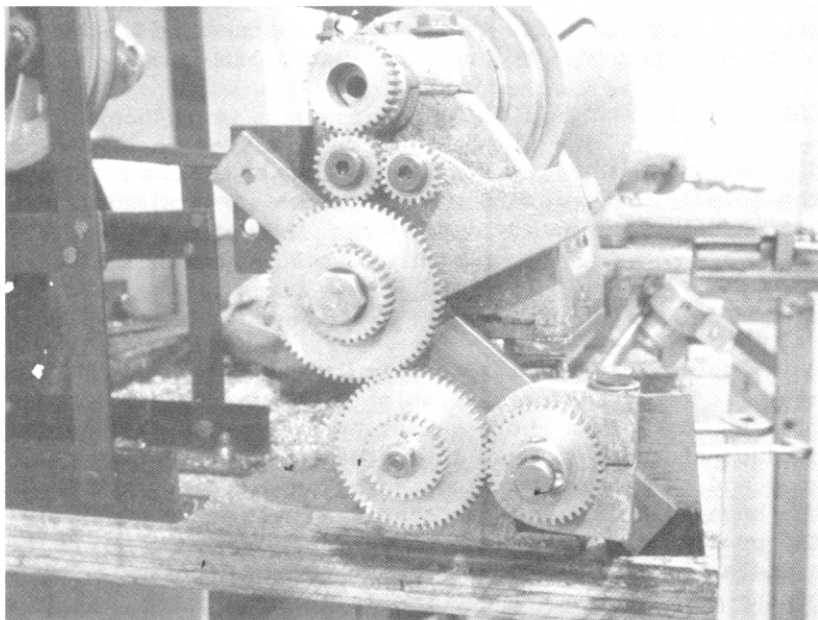
$$\frac{\text{TWICE THE PITCH OF THE SCREW} = 32 \text{ TEETH}}{\text{TWICE THE DESIRED PITCH} = \text{TEETH IN SCREW GEAR}}$$

Since the spindle gear always remains the same we need only multiply the desired pitch by the constant two to find the number of teeth in the change gear for a single train.

The compound stud gear has a 64 tooth gear in mesh with the spindle gear through the tumbler gears. When the screw gear is meshed with the 64 tooth gear of the compound stud through a simple idler all of the gears are in simple train. Fixed to the 64 tooth gear of the compound stud is a 32 tooth gear. If the screw gear is meshed with the 32 tooth

gear of the compound stud through a simple idler there is a 2:1 reduction through the compound stud. This has the same effect as a spindle gear with a number of teeth equal to the pitch of the screw. The constant now becomes one, so the lathe will cut a number of threads per inch that is equal to the number of teeth in the change gear.

The ratio can be further stepped up or stepped down with the use of a compound idler, so several thread pitches can be cut with the same change gear.

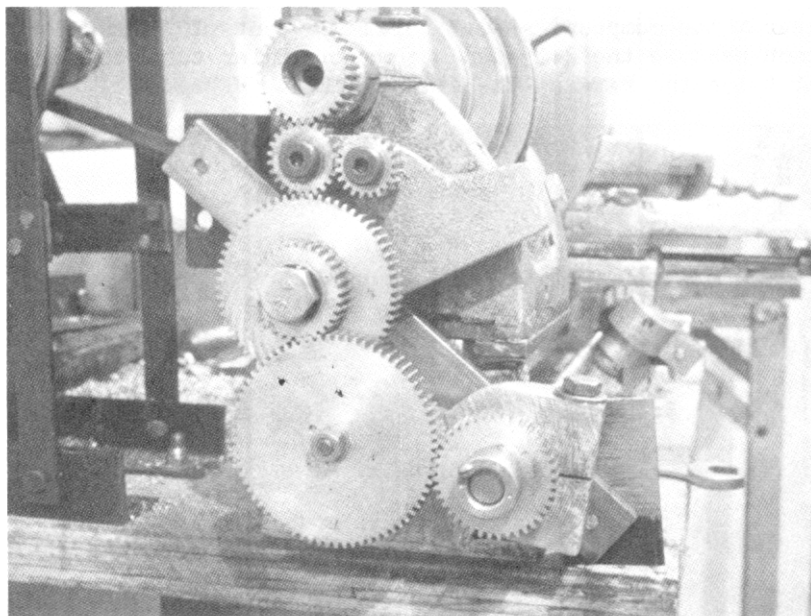


The photo above shows a 20 pitch set up. As the desired pitch is 20, then twice 20 is 40. A 40 tooth gear is installed on the screw, and it is meshed with the 64 tooth gear of the compound stud through a simple idler.

There is a smaller gear joined with the idler as a spacer only, and it does not enter the train. Neither does the 32 tooth gear of the compound stud.

As seen above the lathe will cut right hand threads. If the tumbler plate was raised to mesh the second tumbler gear the lathe would cut left hand threads. The tumbler gears are always in single train with the stud gear, and they never change the ratio. They serve only to reverse the rotation of the screw.

In the photo below the same 40 tooth screw gear is meshed with the 32 tooth gear of the compound stud through a simple idler to give a step down reduction of 2:1. The set up will cut 40 threads per inch.

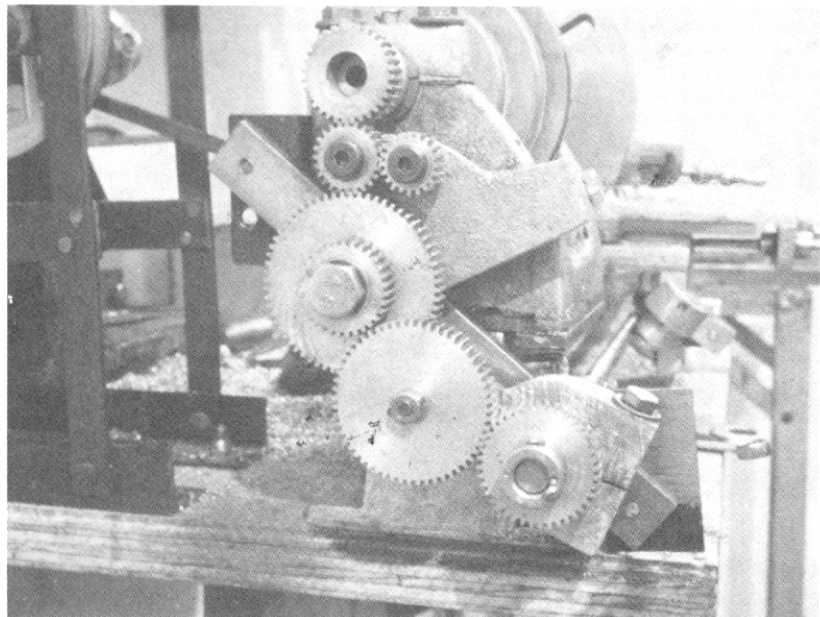


Each of the gears in the set will cut threads equal to their tooth count when meshed with the 32 tooth gear of the compound stud. They will cut threads equal to half the tooth count when meshed with the 64 tooth gear of the compound stud gear. Both of these applications are with a simple idler gear.

Any two gears in the set can be pinned together to make up a compound idler, and these further expand the range of the change gear set.

The 3:1 compound idler shown in the photo on page 117 is made up with the 72 tooth gear and the 24 tooth gear. Its use eliminates the need for a 600 tooth gear, which is not available anyway because it would be too large. Other gears would be too small to be practical, so compound idlers are used in the step up mode as well as the step down mode. A 2:1 step up compound idler can be made up with the 56 and 28 tooth gears or with the 48 and 24 tooth gears. It's not a bad idea to make extra gears to serve only as idlers.

In the photo below the 40 tooth gear is on the screw with a smaller gear behind it as a spacer only. The 56 and 28 tooth gears are joined in compound, with the 56 tooth gear meshed with the screw gear. The 28 tooth gear is pinned to the 56 tooth gear, and it meshes with the 64 tooth gear of the compound stud. This set up cuts 10 threads per inch because the 2:1 step up compound idler turns the screw at twice the rate as the simple idler.



Note that the teeth of the 56 tooth gear clear those of the 32 tooth gear of the compound stud by a small margin. The 48/24 combination can be used in the same combination.

This same set up is used to cut 8 threads per inch with the 32 tooth gear on the screw, 9 threads per inch with the 36 tooth gear, 11 threads per inch with the 44 tooth gear and 12 threads per inch with the 48 tooth gear.

Any of the larger gears in the set can serve as idlers in a single train, but the simple idler always needs a spacer, so the compound idlers do very nicely with the larger gear used as the idler and the smaller as the spacer.

A threading chart will be found in the appendix, and a copy should be on the wall near the lathe. A plastic cover will protect it from greasy hands.

THE GEAR BLANKS

This chart includes all of the information required to prepare the blanks to size and cut the teeth.

The cutting depth for 24 pitch gears is .090", and for the 48 pitch indicator gear it is .045".

CHANGE GEARS, 24 PITCH, 1/2" BORE

TEETH	O.D.	PLATE	TURNS	HOLES
24	1.083"	21	1	14
25	1.125"	20	1	12
28	1.250"	21	1	9
32	1.417"	20	1	5
36	1.583"	27	1	3
40	1.750"	ANY	1	
44	1.917"	33		30
48	2.083"	24		21
52	2.250"	39		30
56	2.417"	21		15
64	2.750"	24		15
72	3.083"	27		15
80	3.417"	20		10
84	3.583"	21		10
96	4.083"	24		10
100	4.250"	20		8

THUMBLER GEARS, 24 PITCH, 1/2" BORE

22	1.000"	33	1	27
24	1.083"	21	1	14

COMPOUND STUD GEARS, 24 PITCH, 5/8" BORE

32	1.417"	20	1	5
64	2.750"	24		15

INDICATOR GEAR, 48 PITCH, 1/4" BORE

32	.709"	20	1	5
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The face width of the change gears is 3/8".

Compound stud and tumbler gears also 3/8" width.

The indicator gear is special, blank dimensions in text.

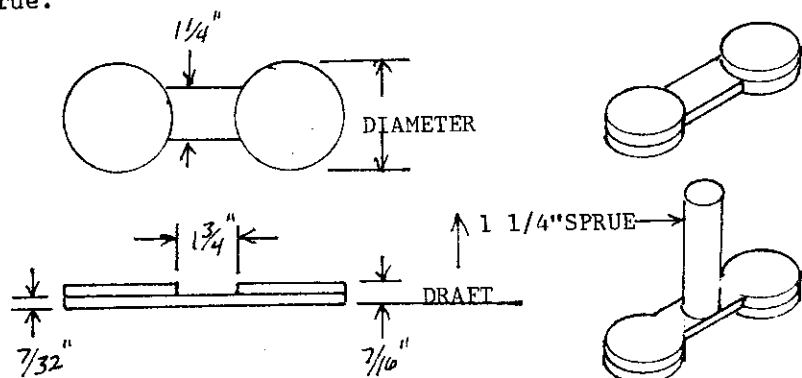
CASTING THE GEAR BLANKS

Only four patterns are needed to cast blanks for all 20 of the gears with $3/8$ " face width. The indicator gear can be made from a scrap of sprue or a piece of brass stock.

The patterns for the smaller blanks are made double to save time and labor, and the runner is attached to the pattern on all sizes to ensure a clean mold cavity. There can be no sand inclusions in these castings.

The finished width of the blanks will be $3/8$ ", so the pattern is made $7/16$ " thick to allow for machining. I was able to find some scraps of pre-finished wall panels that are $7/32$ " thick, so a sandwich of two pieces makes it just right.

Fill any flaws in the pattern and finish very smooth and well drafted for easy molding. Ram them up firmly and vent generously with the wire. Feed all with a $1\ 1/4$ " sprue.



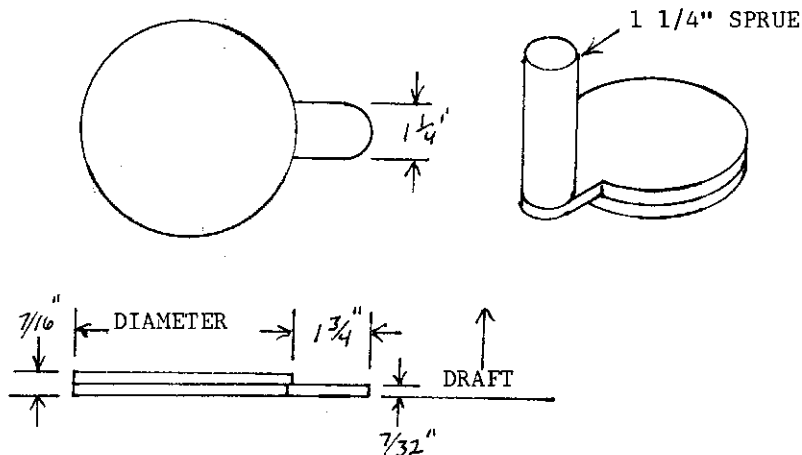
MAKE 1 PATTERN $1\ 1/2$ " DIA. - CAST 4
MAKE 1 PATTERN $2\ 1/2$ " DIA. - CAST 3

Each of these double patterns will cast two blanks. It's a good idea to cast at least one extra of each size.

The gear blanks can be cast in either aluminum or pot metal.

Zamac is an excellent low temperature alloy for this type of work. It's available from McKilligan Industrial and Supply in ingot form. Though it's a die casting alloy it works beautifully in sand castings. McKilligan also has aluminum ingot.

The larger gear blank patterns are also made with the runner attached, but the 1 1/4" sprue will not feed two of them properly in the same mold.



MAKE 1 PATTERN 3 5/8" DIA. - CAST 4
 MAKE 1 PATTERN 4 3/8" DIA. - CAST 2

MACHINING THE GEAR BLANKS

It's best to cast all of the gear blanks now, and one or more extras of each size is a good idea.

The runner is sawed off and the center of each blank is punched and drilled to 31/64". Carefully ream to 1/2", using a guide such as a pulley to make sure it is reamed at right angles to the flat surface.

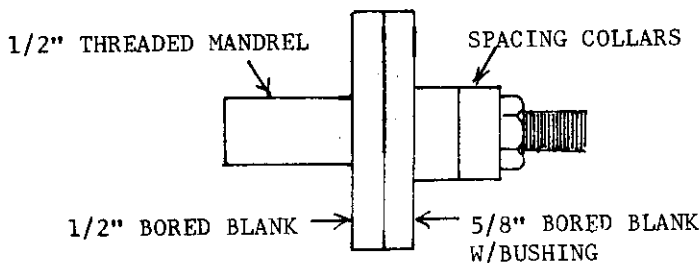
The reamed blanks are mounted on the expanding arbor described in chapter I to face them off on both sides. The complete directions for the operation are found on page 16. Finish all of the blanks to a thickness of 3/8", but don't make any attempt to machine the outside diameter with the expanding arbor.

All of the gears except the compound stud gears will retain the 1/2" bore. They will be mounted on the threaded mandrel between the lathe centers to machine them to the correct outside diameter, and then transferred to the dividing head centers to mill the tooth spaces. It will be best to mill the teeth as soon as the outside diameter is

machined, rather than to remove the blanks from the mandrel and later re-mount them. If you are making more than one gear of any size you can mount them on the threaded mandrel together to machine them to size and mill the teeth.

The blanks for the compound stud gear are bored to 5/8" before they are machined to size. You can do the job with the four jaw chuck, or you can mount the faced off blanks on the face plate with a spacer and toe clamps. They are later joined together on a 5/8" X 1/2" bronze bushing and keyed together with a pair of pins through both gears.

There is a 32 tooth and a 64 tooth gear in the change gear set, so you can mount the compound stud gears with them to machine them to size and mill the teeth.



Thus you can make two 32 tooth gears and two 64 tooth gears at the same time even though the bores are different. Both the 24 tooth change gear and the 24 tooth tumbler gear can be made together also, and their bores are the same. If you plan to make extra gears for the compound idlers it will be easy if you make them together.

CUTTING THE CHANGE GEAR TEETH

It will be best to begin with the largest gears in the set. In the event that you spoil a blank you can reduce it to a smaller size and try again.

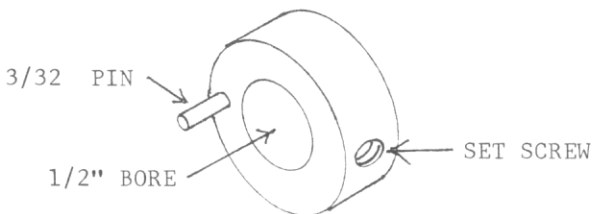
Make all of the gears whose hole circles are found on the same plate before you change plates. You might do the 52, 44 and 22 tooth gears first, because these are the only ones that use the 33 and 39 hole circles. Then do the 100 tooth gear followed by all those that use the 20 hole circle to avoid time lost in changing the plates and adjusting the worm crank.

The indicator gear is 48 pitch so you need to grind a different cutter for it. It is bored 1/4" and done on the 1/4" threaded mandrel. Make it last of all.

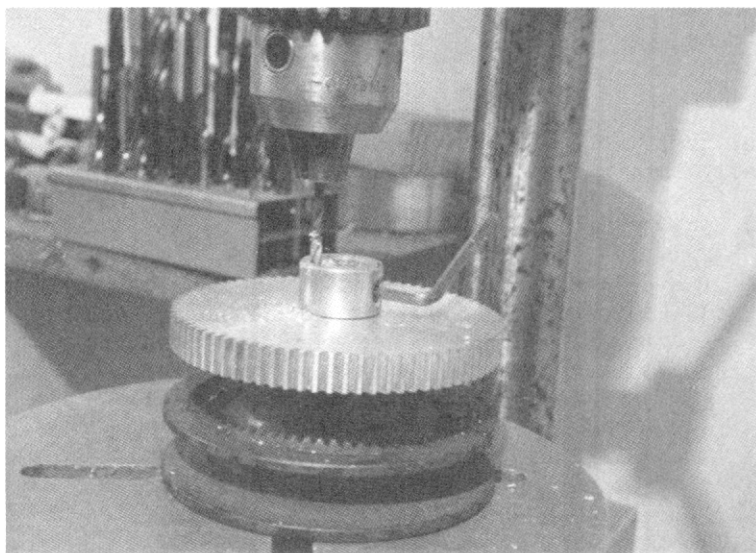
THE CHANGE GEAR DRIVE COLLAR

It would be very difficult and tedious to cut the conventional double keyway in the bores of all of the gears. It will take only a short time to drill a $3/32$ " hole near the bore of each gear, and a $3/32$ " round pin is used for a key in both the change gears and the compound idlers.

The drive collar is a standard $1/2$ " set screw collar with a $3/32$ " hole drilled through its rim. It is fit with a pin to engage the hole in the change gear, and its set screw locks it to the lead screw journal.



The collar is drilled carefully in the center of the rim, and it is then used as a guide to drill the key hole in each of the gears except the tumbler gears and the compound stud gears.

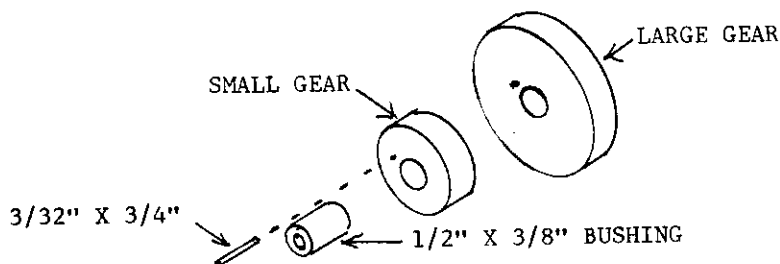


The simple drilling fixture seen in the photo on page 127 is a 1/2" bored pulley with a short length of 1/2" shaft locked in its bore. The collar is first locked to the shaft and drilled, and then each gear is slipped onto the shaft and the collar serves to locate all of the key holes in the proper position so that all are interchangeable.

When the drilling is finished a short length of 3/32" drill rod is fit in the hole. A row of about three punch marks on the collar will deform the hole to hold the pin.

COMPOUND GEAR SETS

Those pairs of gears that are used as compound idlers are slipped onto a 1/2" X 3/8" bronze bushing that is 3/4" long, and they are keyed together with a 3/32" X 3/4" pin.



The bushing can be mounted on the 3/8" threaded mandrel to lightly file its O. D. so that it will slip more easily into the bore of the gears.

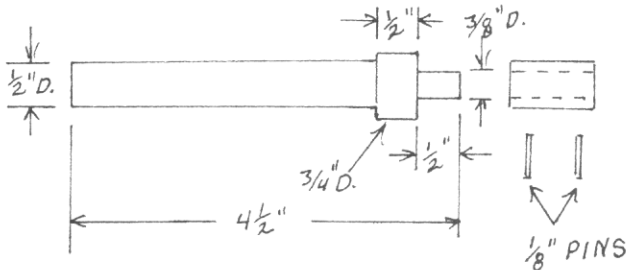
THE LEAD SCREW JOURNALS

The original lead screw of the home made lathe was fit with journals that are too short for the change gear installation. They are probably not exactly concentric either, but now you have a lathe to make better ones.

The journal for the left end is made solid, but the right hand end is hollow like the original.

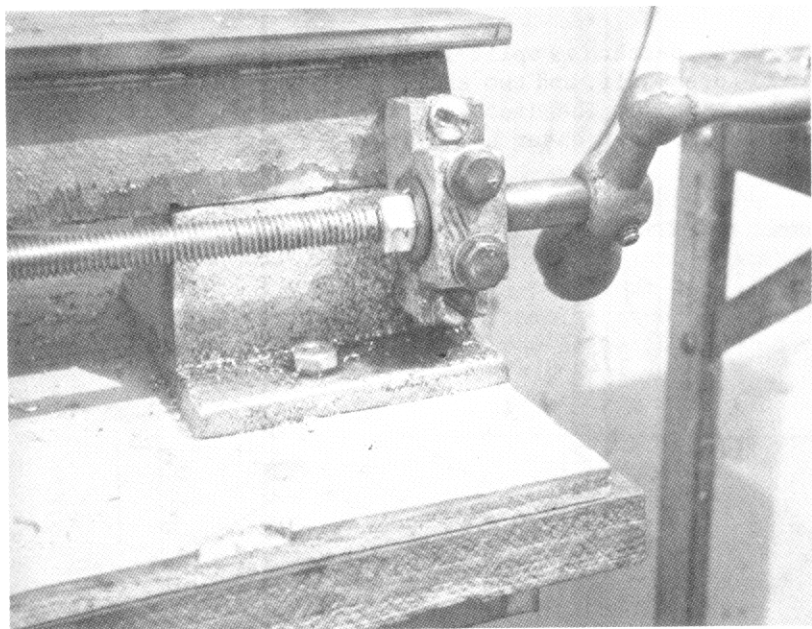
A coupling is made from a 1" length of 1/4" pipe to join the new journal to the left end of the screw. A pair of 1/8" roll pins or rivets are installed in holes drilled through the coupling and the screw and journal.

A 4 1/2" length of 3/4" cold rolled steel is mounted between centers to make the left hand journal.



A 4" length of 1/4" pipe can be mounted on the lathe centers by lightly chamfering the bore at each end. Turn its outside diameter to exactly 1/2" when filed smooth. Support one end in the steady rest as you cut 3/8"-16 threads with the tap held in the tail stock chuck.

The new journal is installed on the right hand end of the screw with a washer and jamb nut so that adjustment can be made to take up end play in the screw.



The lead screw must be very straight, so if the present one shows very much run out you must plan to either do a very careful job of straightening it or to replace it with a new screw.

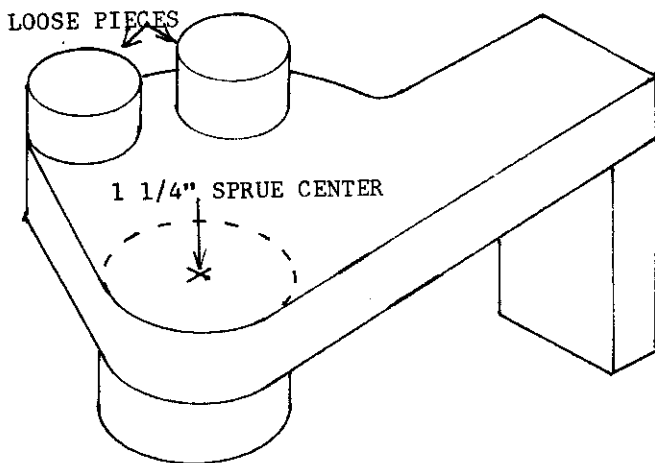
The new right hand journal is intended to move the ball handle a greater distance from the end of the bed. There will be no give to the gear driven feed as there was with the belt drive, and a serious injury could result if the hand was caught between the ball handle and the bed.

THE TUMBLER PLATE

The tumbler plate pivots on the same axle as does the compound stud gear. The 24 tooth forward tumbler gear is permanently in mesh with the 64 tooth gear of the compound stud gear in any position of the tumbler plate. The 22 tooth reverse tumbler gear is permanently in mesh with the forward tumbler gear, and it reverses the rotation of the lead screw when the tumbler plate is raised to mesh it with the spindle gear. A stop pin is installed to engage holes in the head stock casting for forward, neutral or reverse.

THE TUMBLER PLATE PATTERN

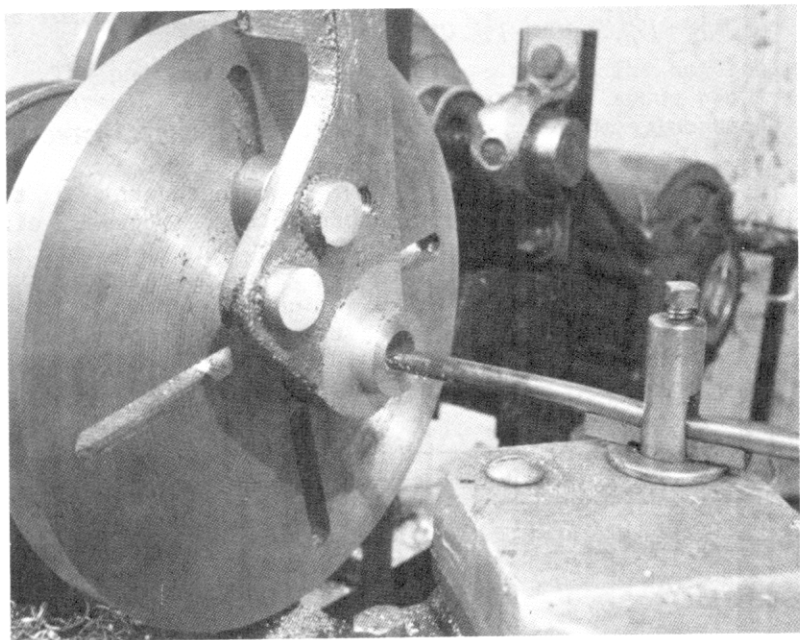
The pattern is split for easy molding. The main body is the drag half, and two small discs and the sprue pin are the cope half. The discs and the sprue pin are located by small pins that enter holes in the drag half.



The two small loose pieces are $3/4$ " diameter and $5/16$ " thick. Each has a small pin in the center that enters a locating hole in the pattern. The large circular area is the pivot center, and the $1\ 1/4$ " sprue pin is located in its center to align with the fixed hub on the under side. A portion of the sprue will be left as part of the casting. Both the hub and the stem angle are fastened to the pattern with brads and glue. The stem angle must be at exact right angles and well drafted.

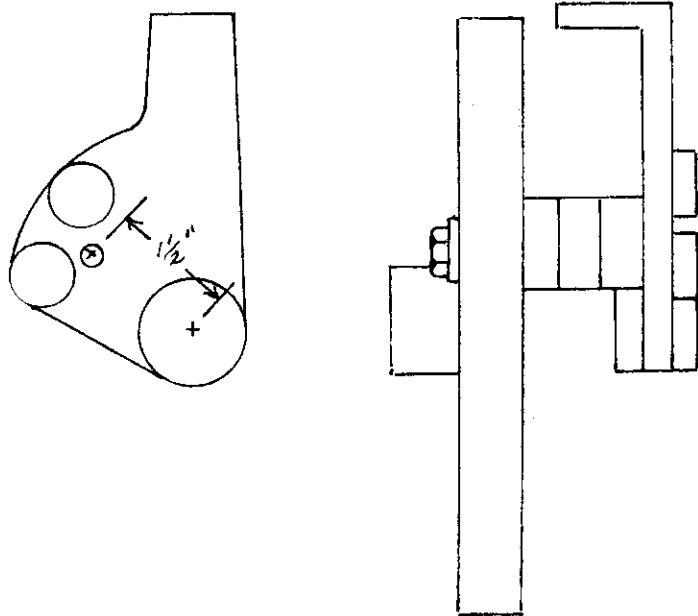
Lay the flat side of the pattern on the molding board and ram up and vent the drag. Roll over and set the loose pieces in place and set the guided sprue pin at the hub. Ram up the cope, prepare the sprue top and pull the pin. Rub in a bottom board and open the mold. The loose pieces should remain in the cope, so lay it on the bottom board to rap and draw the loose pieces. Swab the sprue opening to form a fillet at the junction. Swab, rap and draw the drag pattern. Clean up the cavity carefully and close up to pour.

MACHINING THE TUMBLER PLATE



Saw off the sprue to leave about $1/2''$ to form the hub. Drill a $1/4''$ hole located between the two tumbler bosses, and tap it $5/16''-18$. The photo on page 132 shows the tapped hole in the wrong location. I later drilled a second hole to finish the opposite side of the casting.

Bolt the casting to the face plate with sufficient spacing collars to clear the stem angle. Center the hub area carefully and bore the hub to $1/2''$ for a close fit on a $1/2''$ shoulder bolt. Face off the hub and the tumbler bosses until their surfaces are clean and parallel.

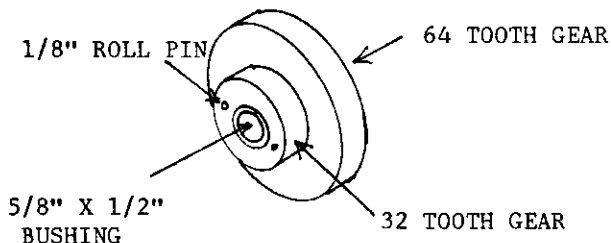


When the hub is bored and the surface is faced off you can invert the casting on the face plate without the collars and face off the back side of the hub to reduce the total thickness to $11/16''$.

ASSEMBLE THE COMPOUND STUD GEAR

Both of the compound stud gears are bored $5/8''$, and they are joined by pressing them onto a $5/8'' \times 1/2''$ bronze bushing. Drill two $1/8''$ holes through both gears and drive in two $1/8''$ roll pins to key them together.

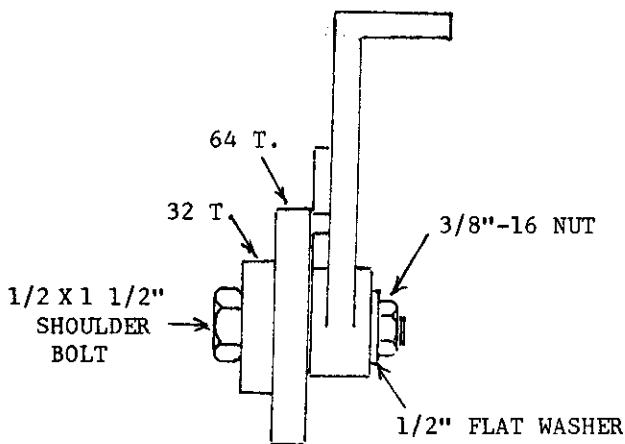
The roll pins can be replaced by flat head screws if you prefer.



INSTALL THE TUMBLER GEARS

The entire change gear mechanism is mounted on a bar of cold rolled steel that is fastened diagonally to the left end of the lathe. The tumbler plate pivots on a 1/2" shoulder bolt that threads into the mounting bar. I used our old friend the lawn mower wheel axle, but you can use a hex socket head shoulder bolt as well. Its shoulder diameter is 1/2" and it's 1 1/2" long. All but 1/4" of the 3/8"-16 threaded portion is cut off.

Mount the assembled compound stud gear on the tumbler plate with the shoulder bolt and a washer and nut for installing the tumbler gears.



The tumbler gears rotate on standard $3/8"$ X $3/8"$ shoulder bolts. These have a shoulder $3/8"$ in diameter and $3/8"$ long, and the threaded portion is $5/16"$ -18.

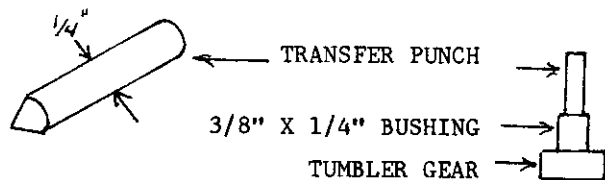
The photo on page 122 shows the tumbler gears engaged in the forward position. The 24 tooth tumbler is meshed with the spindle gear and the 64 tooth gear of the compound stud gear. The 22 tooth tumbler is meshed with the 24 tooth tumbler, but it is not in the train. If the plate is raised to engage the 22 tooth tumbler with the spindle gear the 24 tooth tumbler then becomes the second idler in the train to reverse the rotation of the screw. The plate can also be positioned so that neither tumbler meshes with the spindle gear and the screw drive is then in neutral.

Since both tumbler gears are in fixed locations, the tap holes for the shoulder bolts must be accurately drilled. It's easy to mark the drilling center with a transfer punch.

Both tumbler gears are bored $1/2"$ and fit with $3/8"$ X $1/2"$ bronze bushings. The transfer punch will be used with a $3/8"$ X $1/4"$ bushing to center it in the bore of the gear.

Mount a 2" length of $1/4"$ rod in the chuck on the lathe or the drill press and carefully file or grind the end to a point. The point must be truly centered.

When the tumbler gear is in position on its boss on the tumbler plate the $3/8"$ X $1/4"$ bushing is slipped into the bore, and the transfer punch is slipped into the bushing and given a rap to mark the center of the gear bore on the boss.



There must be clearance between the meshed teeth of the gears at the pitch circle, and this is easily provided by crushing a $3/8"$ wide strip of $.002"$ shim stock between the teeth as you locate the center of the tap hole.

Paint the tumbler bosses on the plate with lay out dye and mark their approximate centers. Hold the strip of $.002"$ shim stock on the teeth of the 64 tooth stud gear and crush it into the teeth with the 24 tooth tumbler gear as you

sight through the bore of the gear to locate it as near as practical to the center of the boss. Hold the tumbler very tightly in mesh with the stud gear as you slip in the bushing and the punch to mark the center of the tap hole.

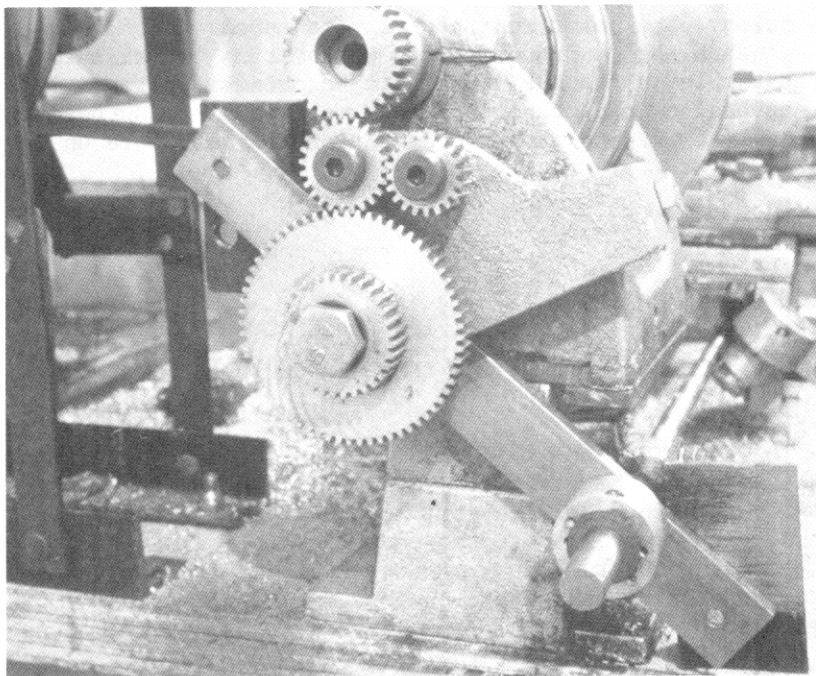
Set the tumbler gear aside and begin with a 1/8" bit to step drill the tap hole to 1/4". Hold the tap in the drill press chuck as you start 5/16"-18 threads, and tap all the way through the boss. Turn the tap by hand.

Install the forward tumbler gear with its shoulder bolt and it should mesh with the 64 tooth stud gear with a tiny bit of play.

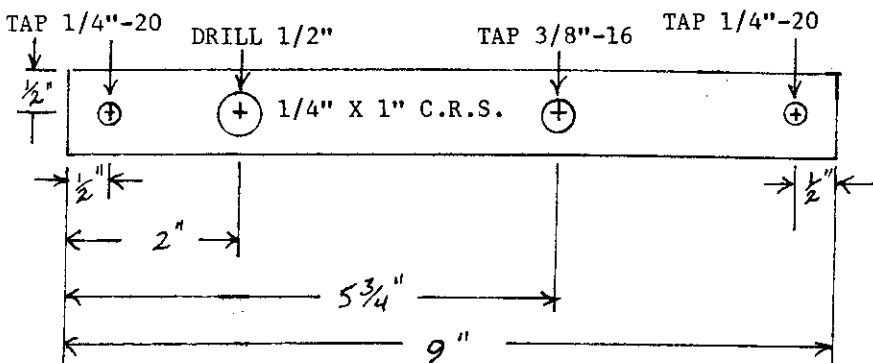
Repeat the entire procedure to install the 22 tooth reverse tumbler gear in mesh with the 24 tooth tumbler. The .002" shim stock is crushed between them to provide clearance.

THE MOUNTING BAR

A 1/4" X 1" X 9" bar of cold rolled steel mounts the entire change gear mechanism on the left end of the lathe.



The bar is drilled and tapped to receive the tumbler pivot bolt, and the lead screw hole and the mounting bolt holes are also drilled as seen below.

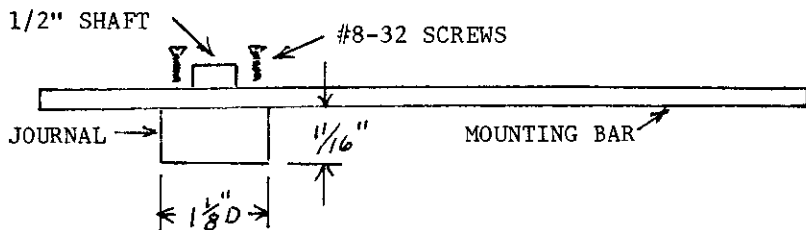


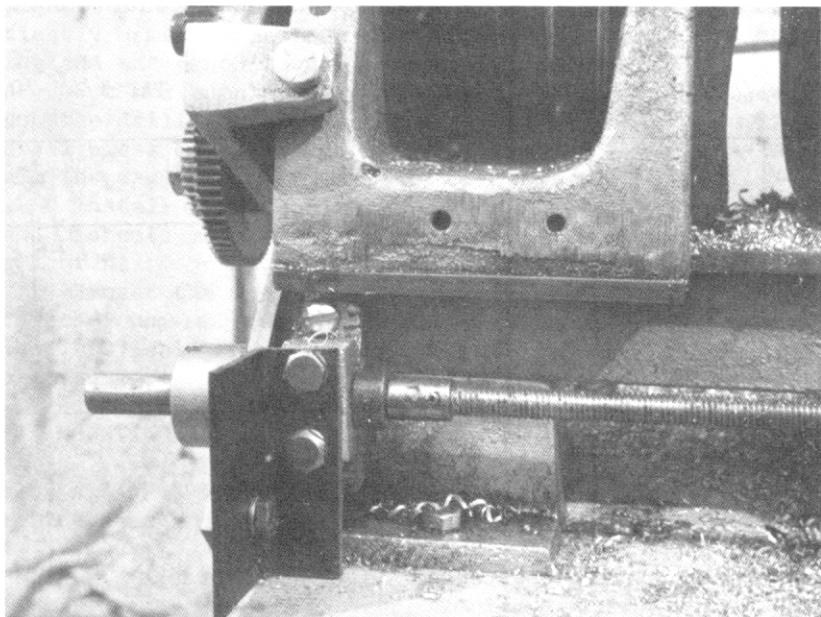
THE IDLER GEAR BRACKET JOURNAL

The journal supports the idler gear bracket so that the idler gear stud remains concentric with the screw gear as it is moved into mesh with the stud gear.

A 7/8" length of 1 1/2" sprue scrap or other round stock can be drilled and reamed to 1/2" for a close fit on the lead screw journal. Mount it on the expanding arbor to face off both ends and reduce its length to 11/16". Then mount it on the threaded mandrel to reduce its outside diameter to a very smooth 1 1/8".

Slip a short length of 1/2" shaft through the bore to align it with the 1/2" hole in the mounting bar and install two #8-32 flat head machine screws. Countersink the screw heads into the surface of the mounting bar.





These are made from 2 1/2" lengths of 1 1/2" X 1/8" angle iron. One is mounted to the left end lead screw bearing cap, and the other is mounted on the rear of the head stock casting. The actual hole locations must be taken from a trial assembly.

Note in the photo above that the mounting holes match the holes in the lead screw bearing cap. The bracket is bolted to the cap with longer bolts and lock washers. The mounting leg of the angle is cut to fit after the holes are located.

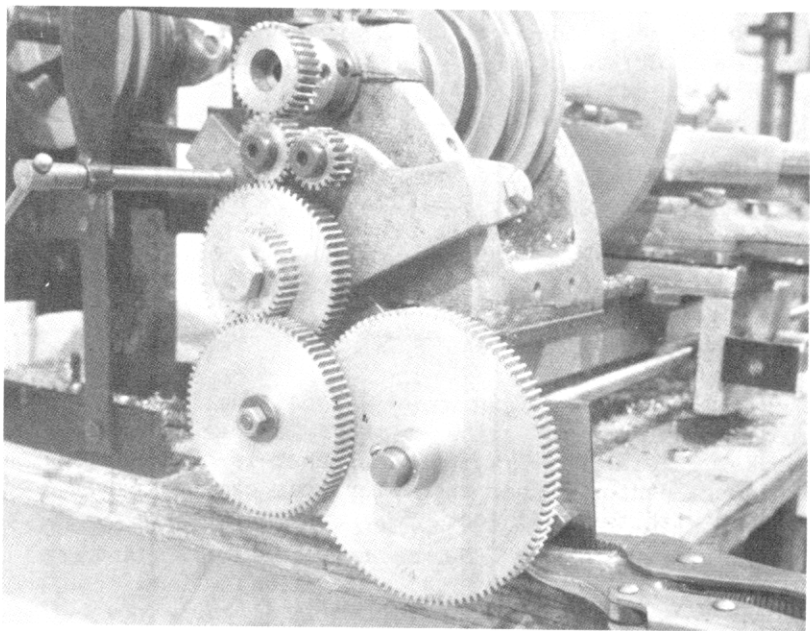
The new lead screw journals are installed at this time, and the mounting bar is slipped onto the screw journal to leave about 1/16" clearance between the bar and the left end of the head stock. Locate the holes in the bracket to mount the bar at this position. Drill two 5/16" holes so that there is a bit of play for alignment.

The brackets will not rest squarely on the mounting bar, and you must clamp them in the vise to bend them to the correct angle so that no strain will be put on the bar when the brackets are tightened up. Don't attempt to bend the angle bracket while it is bolted to the screw bearing

cap or you will damage the bearing or the screw. Make as many clamped up trial assemblies as necessary until the bracket fits perfectly.

The rear bracket is made in the same way, though its hole position will be slightly different. With the front bracket well fit, you can clamp the bar to it and adjust the angle of the bar until the forward tumbler gear meshes with the spindle gear with all three gear centers in line. Then position the bracket to suit and install it on the rear of the head stock casting with two 1/4"-20 cap screws. The rear bracket must be bent to the proper angle just as the front one.

The photo below shows the idler gear and the change gear in place, but these are left off while you are fitting the brackets.



When the brackets are properly fit and securely mounted in place you can adjust the position of the bar. The forward tumbler gear is meant to mesh with the spindle gear when the centers of the stud gear, the tumbler gear and the spindle gear are in a straight line. Use the .002" shim crushed between the teeth of the tumbler and the spindle gear to establish clearance and clamp the bar at both ends.

Drill 13/64" holes through the tapped holes in each end of the bar and through the brackets. Remove the bar and enlarge the holes in the brackets to 1/4". Install the bar with two 1/4"-20 X 1/2" cap screws with lock washers.

THE STOP PIN

The stem angle of the tumbler plate follows the curve of the head stock casting. Locate the position on the stem angle that aligns with the vertical center of the head stock casting and drill a 1/4" hole through the stem angle.

Clamp the tumbler plate in position with the forward tumbler gear in mesh with the spindle gear, and drill the 1/4" hole through the stem angle and about 1/2" into the head stock casting.

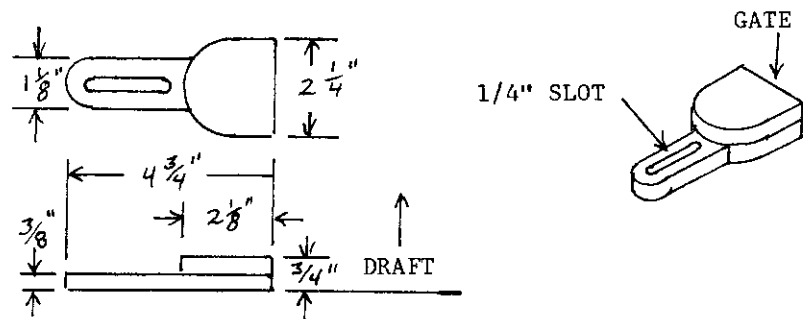
Raise the tumbler plate to mesh the reverse tumbler gear with the spindle gear, using the .002" shim for clearance, and drill the 1/4" hole through the stem angle and about 1/2" into the head stock casting.

Locate the tumbler plate so that neither tumbler gear meshes with the spindle gear and drill the third hole.

Tap the hole in the stem angle 5/16"-18. Grind the threads from the end of a 5/16"-18 X 1" cap screw to leave a 1/4" diameter pin to enter the drilled holes. Screw it into the tapped hole in the stem angle to engage the stop holes in the head stock casting.

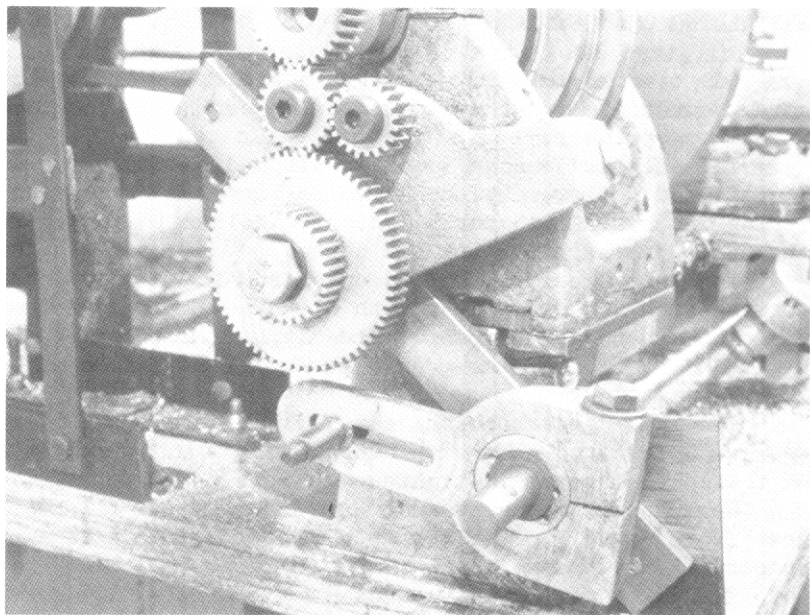
THE IDLER GEAR BRACKET CASTING

The idler gears rotate on a stud that can be moved along a slot so that various sized gears can be used. The bracket is clamped to the journal that is concentric with the screw center so that the idler gear can be moved to be in mesh with the stud gear.



It's a simple pattern. You can form the 1/4" slot in the pattern, or you can cast the bracket solid and form the slot in the casting by drilling two 1/4" holes and cutting away the material between with the coping saw. In either case the slot must be very straight to guide the squared shoulder of a carriage bolt. Feed the mold with a 1 1/4" sprue at the heavy end.

MACHINING THE IDLER GEAR BRACKET



File the slot to a uniform 1/4" width so that a 1/4" carriage bolt will fit nicely.

Locate the boring center 3 1/2" from the slotted end and drill a 1/4" hole to be tapped 5/16"-18. Use the tapped hole to mount the casting on the face plate to face off the flat side.

Then invert the casting on the face plate and mount it with spacing collars and bolts through the slot so that the boring bar can pass through.

Bore to 1 1/8" for a snug fit on the journal, and face off to a finished thickness of 11/16".

Saw the slot and install the clamp bolt as you did for the clamp brake on the dividing head.

THE IDLER GEAR STUD

A 13/16" length of 1/8" pipe is mounted on the 1/4" threaded mandrel and turned to 3/8" O. D.. Finish smooth with a file. A 1/4" X 1 1/2" carriage bolt is slipped in the slot and a close fitting flat washer and the sleeve are slipped onto the bolt. The idler gears are slipped on the sleeve and the sleeve is then locked with another flat washer and a nut. See the photo on page 141.

INSTALLING CHANGE GEARS AND IDLERS

One or more thin fiber washers are slipped onto the screw journal to provide clearance between the gear and the idler gear bracket.

The selected change gear is slipped onto the screw journal and followed by the drive collar with its pin entering the hole in the gear. The drive collar is locked to the screw journal with its set screw.

The idler gear is slipped onto its stud and adjusted to mesh with the screw gear with clearance. It's a common error to mesh change gears too closely, and this results in rapid destruction of the gears. The idler gear stud is locked by its nut.

The idler gear bracket is adjusted to mesh the idler gear with the stud gear with clearance, and the clamp bolt of the idler bracket is tightened.

When the change gear must be in line with the 32 tooth gear of the stud, a smaller gear is used behind it as a spacer.

The idler gear is always used with a spacing gear, even when used in a single train.

DANGER

These little gears may look harmless, but there is great power due to the geared reduction. Be even more careful of loose clothing and where you rest your hand while at work. Many a hand has been crushed because a man forgot about the gears for only a moment.

A gear cover made of sheet metal or a cast cover should be at the top of your present list of projects. Hinge it at the back or at the bottom, and make it fit well with a convenient latch so you won't be tempted to leave it open or to remove it.

THE THREADING INDICATOR

Screw threads are cut on the lathe by making multiple passes. The problem is to engage the split nut at the right moment to enter the same groove at the start of each pass.

You can stop the lathe at the end of each pass and reverse the lathe to return the carriage with the nut engaged, but this takes too much time.

The threading indicator enables you to release the nut and return the carriage without stopping the lathe, and you can close the nut at the right moment to start a new pass.

The indicator gear meshes with the lead screw threads, and when the carriage is stationary the screw acts as a worm to turn the gear. The gear turns the indicator dial so that you can close the nut at the moment when the mark on the dial is in line with the witness mark on the body. As soon as the carriage is in motion the rotation of the dial stops.

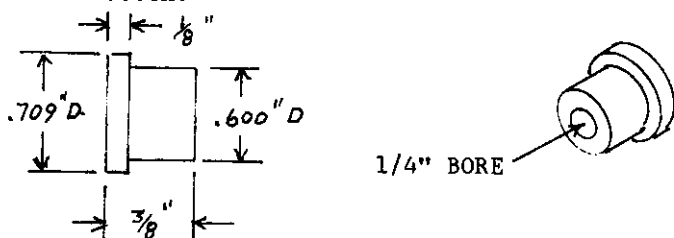
THE INDICATOR GEAR

The correct pitch for the indicator gear would actually be 50.2656 teeth per inch of diameter. There is no such standard gear pitch, so we'll forget about it right away.

A standard 48 pitch gear will mesh very nicely with the threads of the screw, and that will be much easier than trying to calculate the monster above. Even though the form is not quite correct, the teeth of the gear will soon wear to fit the screw threads nicely.

The gear would best be made of brass, but I made mine of aluminum just to try it and it performs very well. The tiny teeth are certainly delicate, whatever the material. It's not a bad idea to make two of them to provide a spare.

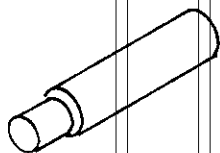
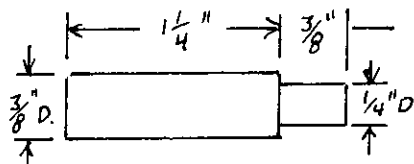
Drill and ream the blank to 1/4" bore and mount it on the 1/4"-3/8" threaded mandrel to machine it to size and mill the teeth.



The indicator gear is 48 pitch, so grind a new cutter. The cutting depth is .045". Use the 20 hole circle on the dividing head with one turn plus five holes to cut 32 teeth.

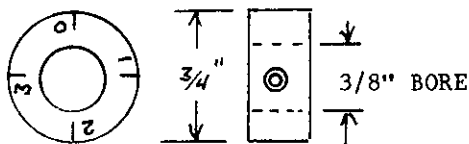
THE INDICATOR SPINDLE

An easy between centers job, turned from 1/2" stock.



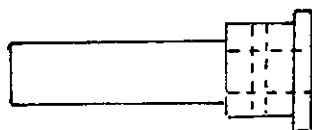
THE INDICATOR DIAL

A standard 3/8" set screw collar with its face carefully divided into quarters.



INSTALL THE INDICATOR GEAR

The finished gear is installed on the spindle and a 1/16" hole is drilled through to receive a roll pin.

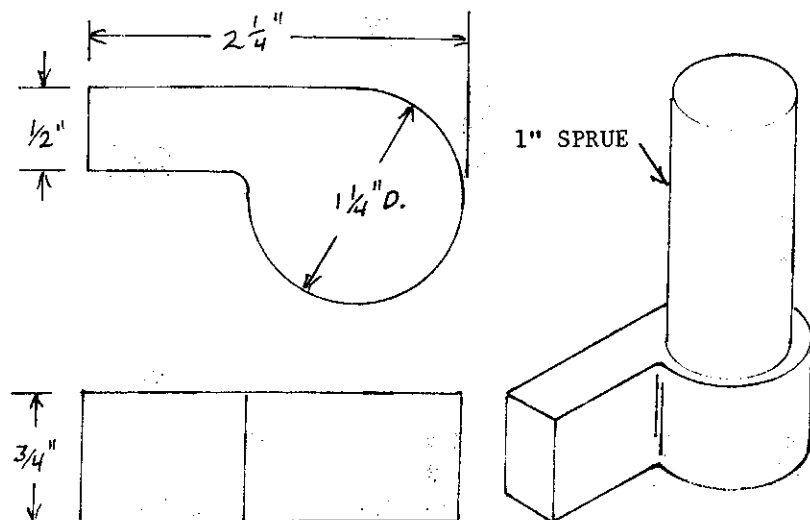


1/16" ROLL PIN



THE INDICATOR BODY CASTING

The pattern is very much like the drive plate for the dividing head, and it's fed with a 1" sprue pin.



MACHINING THE INDICATOR BODY

About $\frac{5}{8}$ " of the sprue is left on to form the hub, and a $\frac{1}{4}$ "-20 hole is tapped in the center of the stem.

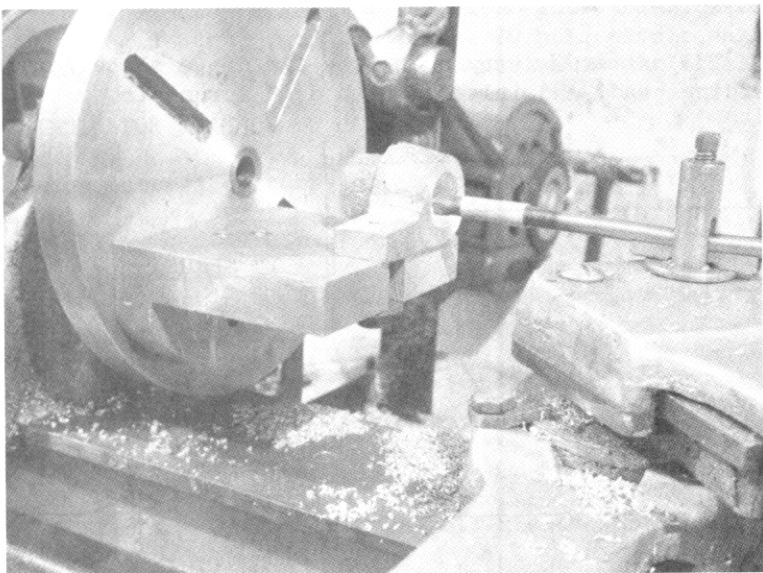
File the mounting surface flat and true square with the top surface and mount it on the angle plate with the circular area centered on the lathe's turning axis.

Face off the top surface and bore through to $\frac{1}{2}$ " to accept a $\frac{1}{2}$ " X $\frac{3}{8}$ " bronze bushing. Then counterbore to .775" diameter to a depth of $\frac{3}{8}$ " to receive the indicator dial. Reverse the mounting on the angle plate to face off the opposite end. Reduce the total length to $1\frac{1}{4}$ ".

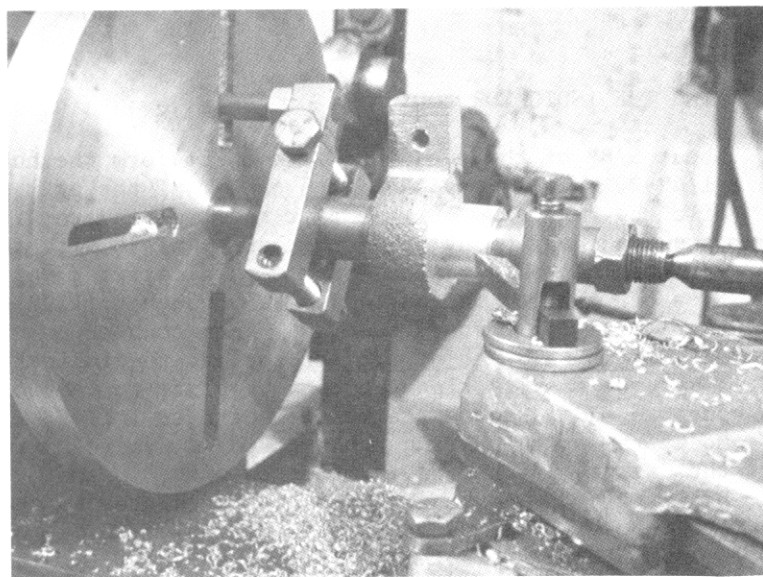
Mount the bored casting on the threaded mandrel to reduce the diameter of the hub portion to $\frac{3}{4}$ ".

Drill a $\frac{1}{4}$ " hole through the counterbored area so that you have access to the set screw of the dial.

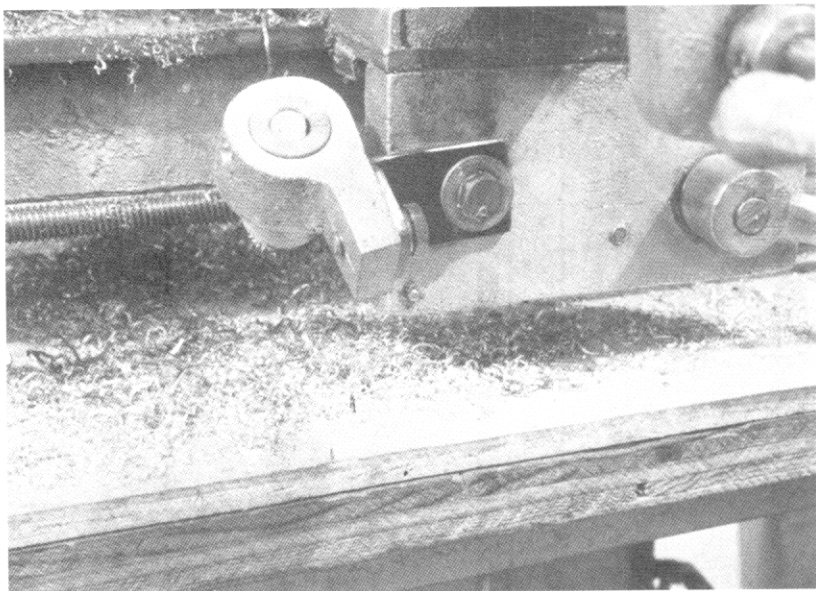
Grind a flat on the spindle for the set screw, slip the spindle into the bushed bore of the body and install the dial.



FACE OFF, BORE AND COUNTER BORE



REDUCE HUB DIAMETER TO 3/4"



As the teeth of the indicator gear are cut straight, and the threads of the screw lean to the left, the indicator is mounted at an angle to align the gear teeth with the threads of the lead screw.

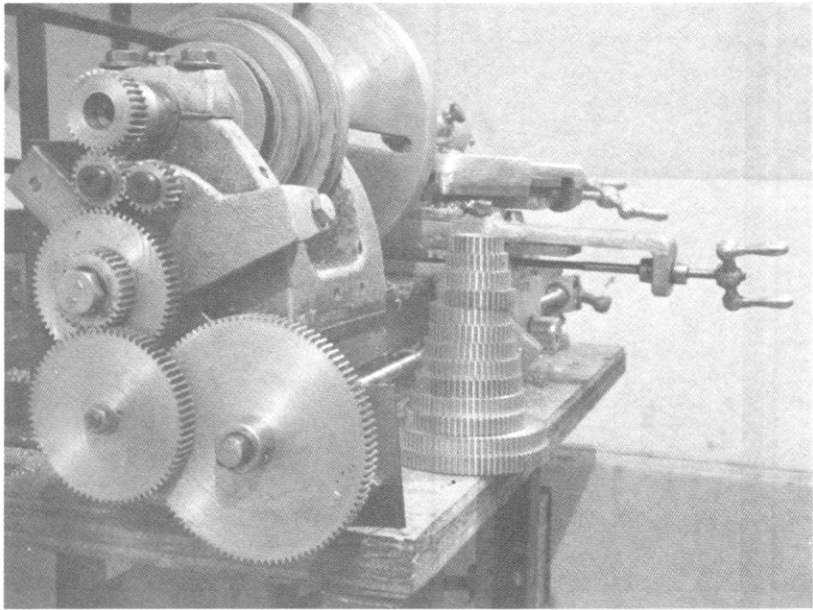
A 3/4" length of 1/8" X 1 1/2" angle iron provides the bracket, and a trial assembly locates the holes for mounting to the carriage apron and the indicator. Be careful to avoid drilling into any existing parts when you drill the apron.

The witness mark on the body is scribed when the nut has been engaged to run the carriage far enough to take up any back lash in the screw and gear train. Stop the lathe when the number one mark is at top and scribe a line on the body to align with it.

Use any mark on the dial for cutting even numbered threads, and use only the one and three mark for odd numbered threads. Half threads can be cut only with the number one mark.

If you later install metric transposing gears to cut metric threads the indicator dial will not work.

The transposing ratio for cutting metric threads with an inch lead screw is 127:100.



The big job is done now, but the fun has only begun. You have a fully equipped machine shop that you have built yourself, and I bet your scrap pile is even bigger than it was when you began.

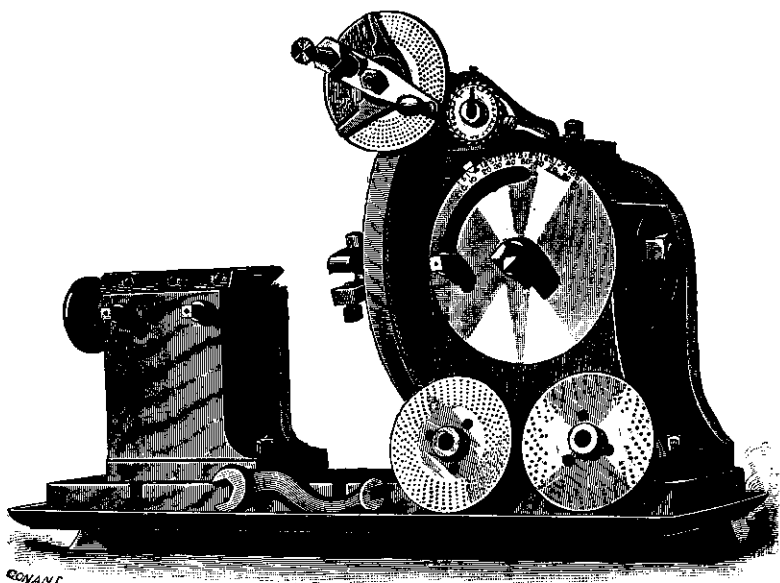
Your lathe will look like the one in the photo above, and it is ready to do just about any job you might want to tackle.

Most important, you have developed a level of skill that is even more valuable than the machines you have built. You can design your own projects, produce the castings in your own foundry, machine them and assemble them into the finished products that you would like to own.

If you have followed the series and built all of the projects you have roughly traced the development of machine tools in English history, but you have only reached a level of technology that was achieved over 100 years ago. There is much room for growth, and I hope you won't stop here.

Most of the information in these manuals was common knowledge to nearly every mechanic and machinist of a century ago. It was the foundation of the industrial revolution, and on it you can build a dream that few men realize.

You'll recognize some of the design elements of the dividing head in Brainard's gear cutting device below. The engraving is from my 1888 Hill & Clarke catalog.



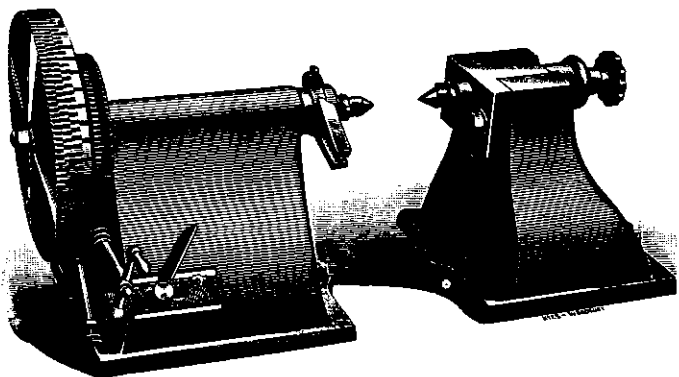
There is much about the device that is not apparent in the engraving. Here's some of the catalog copy:

" The worm wheel is nearly 12 inches in diameter, and it is mechanically perfect. This tool has cut the finest lines upon the edges of two cast iron discs, placed in contact, that the metal would bear; and these lines, under a microscope, were found to coincide exactly, in any position of the discs, a test, it is believed, that few, if any, of the largest and most expensive gear cutters could bear. "

Strong sales talk, no doubt, but it is an example of a level of skill and craftsmanship that was typical of the era. Note that it even has a self registering dial which automatically registers each turn of the worm. A touch on the little lever returns it to zero for the next division.

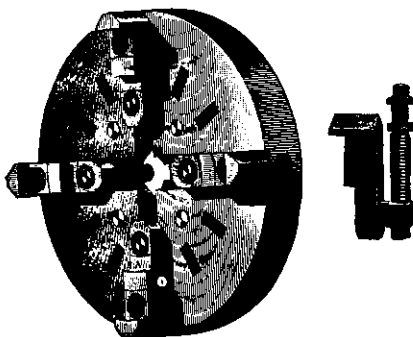
It sold for \$250.00 in 1888.

The Fay & Scott planer centers below are another example of the 1888 era.



20-inch Swing Planer Centers.

The index plate looks impossible to make, but it is really a set of four plates, each made separately, and then joined together. The notches are cut like gear tooth spaces, and of course the latch pin is much stronger than a drilled plate. On this model each disc was $7/16$ " thick and 12" in diameter. The divisions are 48, 110, 126 and 140, but other combinations were offered as well. It swings 20 inches and weighs 210 pounds. The 1888 price was \$55.00.



The Wescott independent four jaw chuck is a marvel of simplicity. The body is split, though it doesn't show in the engraving. Grooves in the face guide the jaws.

The foregoing illustrations of these turn of the century shop tools are presented to give you an idea of how the projects in this series were conceived. I hope that it will inspire you to develop your own projects to build an even bigger and better shop.

In those early years a skilled mechanic could carry the tools of his trade in one hand, and he could do just about any job that was assigned to him. He might earn as much as \$1.00 per day, if he was very good, but average men made from \$3.50 to \$5.00 per week. The work day was 12 hours, and there was no time and one half for over time.

Knowledge was hard to gain because older skilled men withheld it to protect their own job. An apprentice could learn only if he was very patient and made himself likeable. He had to sift through every kind of mis-information and be very alert to tricks. He would often be sent on a fool's errand, and sometimes lose his job because he was a fool.

Shops were dirty, noisy and poorly lighted. There was little done to protect the work men from danger, and many who survived ended their days as cripples. We live in a better time and have much advantage.

It was planned to include back gearing and a follower rest in this manual, but the main theme has consumed all of the available space. These are simple matters though, and can easily enough be worked out after you have come this far.

It has been a great adventure to trace the steps of early pioneers in machine tool history, and the response from so many readers has been gratifying. I really had no idea, when I began, just how much was possible with these simple methods. Before I was very far along I began to look for the end, but when I moved along a bit more I saw that there was no end. Each step builds on the last, and new horizons open up as the shop grows, and the project list just gets bigger and bigger.

The most important thing I've learned from the entire experience is, that it's a whole lot tougher to write a book than it is to build a machine.

The change gear chart and the dividing chart are put in these final pages in case you would like to remove them from the book for use in your shop. If you slip them into a plastic cover they will be protected from greasy fingers to give long service.

ANGULAR INDEXING

As the worm gear of the dividing head has 40 teeth, then $1/9$ turn of the worm will rotate the gear spindle $1/360$ turn, or one degree. This can be done by moving the crank 3 holes in the 27 hole circle or 2 holes in the 18 hole circle.

One third degree, or 20 minutes, is had by moving the crank one hole in the 27 hole circle.

One half degree, or 30 minutes, is had by moving the crank one hole in the 18 hole circle.

One full turn of the crank gives 9 degrees on the worm gear spindle.

Such commonly desired angular divisions as 5 or 10 degrees are easily done. 10 holes in the 18 hole circle or 15 holes in the 27 hole circle gives 5 degrees. 20 holes in the 18 hole circle or 30 holes in the 27 hole circle is equal to 10 degrees.

Remember that the zero hole is never counted as the first hole, but it is the last hole in a full turn count. If you are to move the crank 30 holes in the 27 hole circle, the count begins with the first hole adjacent to the zero hole and continues around the circle with the zero hole to be counted as number 27. 3 holes beyond the zero hole is 30 holes in the 27 hole circle.

BLOCK INDEXING

If any number of divisions can be factored by 2, 3 or 4 you can do them in blocks by repositioning the work after cutting a factored circle. As 81 can be factored by 27, cut 27 divisions and reposition the work $1/3$ space. Cut 27 more divisions and reposition again for the final 27 spaces for a total of 81 divisions. Repositioning can be done either on the work arbor or by moving the plate carrier. If done very carefully you can manage divisions not normally in the range of the standard plates.

GEAR CALCULATIONS

This information is condensed for easy review and for quick reference.

In order to make a gear you must prepare the blank to the correct outside diameter and face width, index accurately and cut the tooth spaces to the proper depth and form. These formulas and the dividing chart will give you all of the required information.

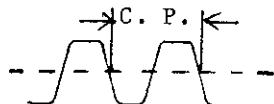
DIAMETRAL PITCH = D. P.

The number of teeth per inch of pitch diameter. A 24 pitch gear of 1" pitch diameter has 24 teeth.

CIRCULAR PITCH = C. P.

The distance from one tooth face to the next, measured at the pitch circle.

$$\frac{3.1416}{D. P.} = C. P.$$



The circular pitch of a 24 pitch gear is .131" +.

$$\frac{3.1416}{24} = .131" +$$

Circular pitch is converted to diametral pitch by inverting the formula:

$$\frac{3.1416}{C.P.} = D. P.$$

A gear whose pitch measures .131" + at the pitch circle is a 24 pitch gear.

$$\frac{3.1416}{.131} = 24 -$$

Circular pitch calculations are used to determine non-standard gear dimensions and for worm gear calculations. A gear to mesh with the 16 pitch lead screw is an example:

As the distance from one thread face to the next is .0625", then a gear with a circular pitch of .0625" is to

be meshed with it. By converting the .0625" circular pitch to diametral pitch, a 50 pitch gear is required.

$$\frac{\text{Circular Pitch}}{\text{Diametral Pitch}} = \frac{3.1416}{.0625} = 50 +$$

The indicator gear application doesn't require a precise mesh so we chose the 48 pitch standard pitch gear for simplicity. An accurate worm gear drive would require a precise mesh, and the full set of dimensions can be worked up to make a custom gear of any pitch by these formulas:

N = NUMBER OF TEETH IN THE GEAR

$$P = \text{PITCH DIAMETER} = \frac{N}{D. P.}$$

$$O. D. = \text{OUTSIDE DIAMETER} = \frac{N + 2}{D. P.}$$

$$\text{ADDENDUM} = .3183 \times C. P., \text{ OR } \frac{1}{D. P.}$$

$$\text{DEDENDUM} = .3183 \times C. P., \text{ OR } \frac{1}{D. P.}$$

$$\text{CLEARANCE} = .05 \times C. P., \text{ OR } \frac{.157}{D. P.}$$

$$\text{WORKING DEPTH} = .6366 \times C. P., \text{ OR } \frac{2}{D. P.}$$

$$\text{WHOLE DEPTH} = .6866 \times C. P., \text{ OR } \frac{2.157}{D. P.}$$

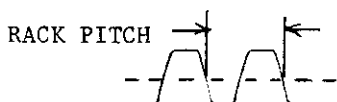
Note that the outside diameter of the blank can be found by simply adding two teeth to the nominal size. The O. D. is also found by adding two addendum to the pitch diameter.

The cutting depth is the whole depth, which is also the sum of the addendum plus the dedendum plus clearance. Refer to standard manuals for worm gear calculations.

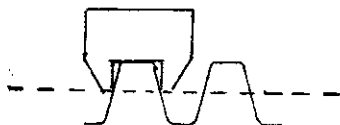
CUTTING RACK TEETH

The pitch of a rack corresponds to the circular pitch of the pinion gear.

$$\frac{3.1416}{D. P.} = \text{RACK PITCH}$$



The thickness of a gear tooth measured at the pitch circle is one half the circular pitch. A simple sheet metal gauge can be made to check circular pitch.



TOOTH FORM

The form of standard involute gear teeth varies with the number of teeth in a gear. There is a noticeable difference between large gears and small gears. The form for a hand ground fly cutter is best taken from a gear that has a greater tooth count than the gear to be made.

The approximate form for a non-standard pitch gear can be found by cutting a worm to match the circular pitch of the gear. An acme formed threading tool is very nearly the same as a straight sided rack tooth.

HOBGING WORM GEARS

A worm can be cut as described above, fluted like a threading tap, and case hardened to make a light duty hob for use in soft metals.

The worm wheel teeth are gashed to the correct count and approximate form with the dividing head. The gashed blank is mounted to turn on a spindle as it is fed to the hob. The result is a well formed involute tooth on the worm wheel.

Refer to standard manuals for worm pitch diameters.

DIVIDING CHART

SINGLE THREAD WORM
40 TOOTH WORM GEAR

BASIC PLATE SET

PLATE #1- 15, 17, 18, 19, 20, 21

PLATE #2- 23, 24, 27, 29, 31, 33

PLATE #3- 37, 39, 41, 43, 47, 49

D = DIVISIONS

C = CIRCLE

T = TURNS

H = NUMBER OF HOLES

D	C	T	H	D	C	T	H
2		20		33	33	1	7
3	21	13	7	34	17	1	3
4		10		35	21	1	3
5		8		36	27	1	3
6	21	6	14	37	37	1	3
7	21	5	15	38	19	1	1
8		5		39	39	1	1
9	18	4	8	40	ANY	1	
10		4		41	41		40
11	33	3	21	42	21		20
12	21	3	7	43	43		40
13	39	3	3	44	33		30
14	21	2	18	45	27		24
15	21	2	14	46	23		20
16	20	2	10	47	47		40
17	17	2	6	48	24		20
18	27	2	6	49	49		40
19	19	2	2	50	20		16
20	ANY	2		52	39		30
21	21	1	19	54	27		20
22	33	1	27	55	33		24
23	23	1	17	56	21		15
24	21	1	14	58	29		20
25	20	1	12	60	21		14
26	39	1	21	62	31		20
27	27	1	13	64	24		15
28	21	1	9	65	39		24
29	29	1	11	66	33		20
30	21	1	7	68	17		10
31	31	1	9	70	21		12
32	20	1	5	72	27		15

D	C	T	H	D	C	T	H
74	37		20	184	23		5
75	15		8	185	37		8
76	19		10	190	19		4
78	39		20	195	39		8
80	20		10	196	49		10
82	41		20	200	20		4
84	21		10	205	41		8
85	17		8	210	21		4
86	43		20	215	43		8
88	33		15	216	27		5
90	27		12	220	33		6
92	23		10	230	23		4
94	47		20	232	29		5
95	19		8	235	47		8
96	24		10	240	24		4
98	49		20	245	49		8
100	20		8	248	31		5
104	39		15	260	39		6
105	21		8	264	33		5
108	27		10	270	27		4
110	33		12	280	49		7
115	23		8	290	29		4
116	29		10	296	37		5
120	21		7	300	15		2
124	31		10	310	31		4
130	39		12	312	39		5
132	33		10	320	24		3
135	27		8	328	41		5
136	17		5	330	33		4
140	49		14	340	17		2
144	18		5	344	43		5
145	29		8	360	18		2
148	37		10				
150	15		4				
155	31		8				
156	39		10				
160	20		5				
164	41		10				
165	33		8				
168	21		6				
170	17		4				
172	43		10				
180	18		4				

CHANGE GEAR THREADING CHART

T.P.I. = THREADS PER INCH

S.T. = SINGLE TRAIN

+ = STEP UP COMPOUND

- = STEP DOWN COMPOUND

T.P.I	CHANGE GEAR	IDLER GEAR	STUD GEAR
8	32	2:1 +	64
9	36	"	"
10	40	"	"
11	44	"	"
12	48	"	"
13	52	"	"
14	28	ANY S.T	"
16	32	"	"
18	36	"	"
20	40	"	"
24	48	"	"
28	56	"	"
32	32	"	32
36	36	"	"
40	40	"	"
48	48	"	"
56	56	"	"
64	64	"	"
72	72	"	"
80	80	"	"

FINE FEEDS

.000" PER REV.	CHANGE GEAR	IDLER GEAR	STUD GEAR
.0025"	100	4:1 -	32
.003"	100	3:1 -	"
.004"	84	"	"
.0046"	72	"	"
.005"	64	"	"

4:1 STEP DOWN IDLER - 100/25 OR 96/24

3:1 STEP DOWN IDLER - 84/28 OR 72/24

2:1 STEP UP IDLER --- 56/28 OR 48/24

The complete " Metal Shop From Scrap " series is designed for the serious hobbyist in metal who can't justify the cost of commercially manufactured machinery for a hobby.

With the exception of the sheet metal brake, all of the projects in the manuals require metal castings in aluminum and pot metal. Book 1, " The Charcoal Foundry " , will show you how to set up a compact foundry at home to turn out the needed castings at low cost.

Each manual has additional instruction on foundry to show you how to make the needed patterns and castings. The shop is built progressively, and each phase helps to add more capacity to the shop.

Begin with basic hand skills and use ordinary tools and materials to convert your scrap pile to a full machine shop at little cost.

" BUILD YOUR OWN METAL WORKING SHOP FROM SCRAP "

BOOK 1. THE CHARCOAL FOUNDRY

BOOK 2. THE METAL LATHE

BOOK 3. THE METAL SHAPER

BOOK 4. THE MILLING MACHINE

BOOK 5. THE DRILL PRESS

BOOK 5. THE DIVIDING HEAD & DELUXE ACCESSORIES

BOOK 7. DESIGNING & BUILDING THE SHEET METAL BRAKE

Now that you have a machine shop you need accessories for the machines. This manual will show you how to tool up your shop to produce the things you want. Making your own tools and accessories is rewarding both in product and pleasure, and it helps greatly to develop your skill.

An angle plate, a set screw chuck and an expanding arbor are only the beginning. A clamp dog, threaded mandrels and simple hand reamers are needed in all shops for many operations. Certainly any lathe is improved by a two or four jaw chuck, and a center steady rest for the lathe enables you to do machining operations on the tail end of the stock as well as expanding the capacity of the lathe.

Building a worm wheel dividing head will enable you to do precise indexing for gear making and other dividing jobs on your milling machine. This one functions as a rotary table for the drill press too. This is an accessory seldom found in a home shop. You will be amazed at its simplicity, durability and accuracy.

Learn basic gear calculations and how to prepare the blanks, index them and mill the tooth spaces. Make your own gear tooth cutters from ordinary lathe tool bits at a fraction of the cost of commercially made gear tooth cutters.

Add change gears to the lathe to cut all standard threads from 8 to 80 per inch, both right and left hand and internal or external. A threading indicator is added to the carriage so that you can do accurate threading without reversing the motor to return the carriage after each pass. You'll find that the gear driven fine feeds are much better than the original round belt carriage feed drive on the home built lathe.

You won't want to stop here for much more is easily possible. The dividing head not only divides gears but will also do graduated feed collars and protractors. All divisions through 50 and all even numbers and multiples of 5 through 100. Many numbers beyond are available up to 1,960, and you can easily make a special plate for any number of divisions in a special job. Now that you have your own foundry and machine shop you can have any item of equipment you want, and you can build it yourself from scrap materials.

The "Build Your Own Metal Working Shop From Scrap" Series:

- Book 1 The Charcoal Foundry
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