

**RB-She-01**

**Sherline CNC-Ready 3-Axis Milling Machine**

SHERLINE Lathe and Mill Setup Instructions ..... 3

    Getting answers to your questions about machining ..... 3

    An introduction to the world of miniature machining ..... 3

        What new machinists like most and least ..... 3

        There are no shortcuts ..... 4

        Anticipation of a tool's limitations is the craftsman's strength ..... 4

        You don't become a machinist by buying a machine ..... 4

SAFETY RULES FOR POWER TOOLS ..... 5

    Electrical connections ..... 6

    General precautions ..... 8

        Avoid overtightening! ..... 8

        Don't overstress the motor! ..... 8

        Customer's responsibilities ..... 8

        Learning more about machining ..... 9

    Lubrication ..... 9

    Initial assembly of a new machine ..... 9

    Lathe-crossslide mounting procedure ..... 10

    Mill-column mounting procedure ..... 11

    Assembly of the model 2000 and related model 8-direction mill columns ..... 12

        Check tightness of all bolts ..... 12

        Mounting the motor and speed control unit to the headstock ..... 13

    The advantages of Sherline's DC motor and electronic speed control ..... 15

        What to do if the motor shuts down ..... 15

    Operation of the motor and electronic speed control ..... 16

        Motors are pre-tested at the factory ..... 16

    Mounting the headstock to the lathe or mill ..... 17

    Mounting the mill and lathe to a board ..... 19

    Converting machines from inch to metric or vice versa ..... 20

ADJUSTMENTS ..... 21

    Two-speed pulley ..... 21

    Preload adjustment ..... 21

    Gib adjustment ..... 22

    Backlash adjustment ..... 22

    Handwheel adjustment ..... 23

Movement of the handwheels .....	23
Aligning the head and tailstock.....	24
Use of cutting oils and lubricants.....	25
General machining terms .....	25
General rules for feed rates and cutting speeds .....	26
"If the tool chatters, decrease speed and increase feed." .....	26
VERTICAL MILLING MACHINE OPERATION.....	28
CAUTION! .....	28
Read all operating instructions carefully before attempting any machining operations!.....	28
Review Safety Rules for Power Tools before beginning.....	28
GENERAL DESCRIPTION.....	29
HELPFUL TIPS FOR MILLING .....	30
SECURING THE WORKPIECE .....	31
THINGS TO CONSIDER BEFORE YOU START CUTTING .....	32
THREE TYPES OF WORK.....	34
CAUTION! Because the tool spins on a mill, hot chips can be thrown much farther than when using a lathe. Safety glasses and proper clothing are a must for all milling operations.....	34
STANDARD MILLING VS. CLIMB MILLING .....	35
WORKING TO SCRIBED LAYOUT LINES .....	36
USE OF A DIAL INDICATOR .....	36
LOCATING THE EDGE OF A PART IN RELATION TO THE SPINDLE.....	40
DETERMINING DEPTH OF CUT .....	41
WORK ACCURATELY .....	41
CUTTING SPEEDS FOR MILLING.....	41
SPEED ADJUSTMENT FORMULA.....	41
SPEED ADJUSTMENT CHART.....	42
END MILLS (Slot and side milling) .....	42
DRILLS.....	42
CUTTING TOOLS AND STANDARD ACCESSORIES.....	43
END MILLS .....	43
RESHARPENING END MILLS .....	43
3/8" END MILL HOLDER (P/N 3079).....	44
MILL COLLET SET (P/N 3060) .....	44
BORING HEAD (P/N 3054) AND BORING TOOLS .....	44
FLYCUTTERS (P/N 3052 and P/N 7620) .....	46
DRILLS AND DRILL CHUCK (P/N 3072) .....	47
To drill a 1/8" diameter hole 1" deep:.....	48
MILL VISE SET (P/N 3551).....	49
4" ROTARY TABLE (P/N 3700).....	50
HORIZONTAL MILLING CONVERSION (P/N 6100) .....	51
USE OF ACCESSORIES AND ATTACHMENTS.....	51
MILL EXPLODED VIEW PARTS DIAGRAM.....	52
PART NUMBERS AND DESCRIPTIONS, SHERLINE LATHES AND MILLS.....	54

# SHERLINE Lathe and Mill Setup Instructions

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## Getting answers to your questions about machining

Over the years we have found that the majority of our customers are both highly intelligent and skilled craftsmen. Often they are also new to machining. The instructions we have included in this book, while far more extensive than anything included with other machine tools, even ones costing thousands of dollars, still only scratch the surface when it comes to machining. We have tried to anticipate the most common problems and questions asked by a new machinist. What we have provided in this book and with each accessory, when combined with a liberal amount of common sense, is more than enough to get you started. If you apply what you learn here, you will be well on your way to making good parts. No doubt you will also have many questions specific to your project that simply can't be addressed in a booklet of this type.

Answers to questions beyond the scope of this booklet will have to come from your own research. Book stores and libraries are full of excellent books on machining, and the Internet is forming some great user groups that can put you in direct contact with others who share your specific interests. Our own World Wide Web site is a great source of information as well, as we have published there all the instructions for all our tools and accessories for you to read and print out for free. We feel we have written the best book available on miniature machining with Sherline tools. It is called [\*Tabletop Machining\*](#) by Sherline's owner and long-time toolmaker Joe Martin. We also sell Doug Briney's [\*Home Machinist's Handbook\*](#) as well as a very informative [steam engine project video](#) by Rudy Kouhopt, both of which are packed with knowledge for new machinists. For the past 35 years I have found *Machinery's Handbook* to be the source I turn to for answers to my own questions. May your journey toward becoming a skilled machinist be an enjoyable one.

## An introduction to the world of miniature machining

What new machinists like most and least

If you are new to machining, you may find it to be either one of the most rewarding skills one can learn or the most frustrating thing you have ever attempted. What makes machining fun for some is the complexity and challenge. The same thing will drive others up the wall. One customer may be overjoyed because he can now make parts that were not available for purchase. Another may wonder why he just spent all day making a part that is similar to one he could have purchased for two dollars. (The difference is that it is not the same as the two dollar part-it is exactly the part needed.)

### **There are no shortcuts**

Machining is a slow process if parts are made one at a time. The interesting thing is, a skilled machinist may take almost as long to make the same part as a novice. Shortcuts usually end in failure. Unlike some other trades, mistakes cannot be covered up. There are no erasers, white-out or "putting-on tools" for machinists; you simply start over. To expand a little on an old rule:

*"Think three times, measure twice and cut once!"*

### **Anticipation of a tool's limitations is the craftsman's strength**

The skill in machining isn't just "moving the dials". It is a combination of engineering and craftsmanship. A file is just as useful a tool to a good machinist as a multi-thousand dollar machine tool. Tools "deflect" or bend under load, and anticipating this bend is what it is all about. Sharp tools deflect less than dull tools, but with each pass the tool dulls a little and the deflection becomes greater. If you try to machine a long shaft with a small diameter, the center will always have a larger diameter than the ends because the part deflects away from the tool where it has less support. You can go crazy trying to machine it straight, or you can simply pick up a good flat mill file and file it straight in a few moments. Machine tools will never replace the "craftsman's touch", and machining is a combination of both good tools and good technique.

### **You don't become a machinist by buying a machine**

You should strive from the beginning to make better and more accurate parts than you think you need. Work to closer tolerances than the job demands. Be on the lookout for ways to make a job easier or better. Having a selection of appropriate materials on hand and a good cutoff saw to get them to rough size is a good start. Take some time and read through this instruction book before you try machining anything. We want you to enjoy the process of creating accurate parts from raw metal. Buying a machine didn't make you a machinist, but using it along with the skill and knowledge you acquire along the way eventually will. With the purchase of SHERLINE equipment, you have taken your first step toward many years of machining satisfaction. We at SHERLINE thank you for letting us be a part of that.

Joe Martin  
President and Owner

# SAFETY RULES FOR POWER TOOLS

1. **KNOW YOUR POWER TOOL**-Read the owner's manual carefully. Learn its application and limitations as well as the specific potential hazards peculiar to this tool.
2. **GROUND ALL TOOLS**-If tool is equipped with a three-prong plug, it should be plugged into a three-hole receptacle. If an adapter is used to accommodate a two-prong receptacle, the adapter wire must be attached to a KNOWN GROUND. Never remove third the prong. (See Figure 1.)
3. **KEEP GUARDS IN PLACE**-and in working order.
4. **REMOVE ADJUSTING KEYS AND WRENCHES**-Form a habit of checking to see that keys and adjusting wrenches are removed from tool before turning on machine.
5. **KEEP WORK AREA CLEAN**-Cluttered areas and benches invite accidents.
6. **AVOID DANGEROUS ENVIRONMENT**-Do not use power tools in damp or wet locations. Keep work area well illuminated.
7. **KEEP CHILDREN AWAY**-All visitors should be kept a safe distance from the work area.
8. **MAKE WORKSHOP KID PROOF**-with padlocks, master switches or by removing starter keys.
9. **DO NOT FORCE TOOL**-Do not force tool or attachment to do a job for which it was not designed. Use the proper tool for the job.
10. **WEAR PROPER APPAREL**-Avoid loose clothing, neckties, gloves or jewelry that could become caught in moving parts. Wear protective head gear to keep long hair styles away from moving parts.
11. **USE SAFETY GLASSES**-Also use face or dust mask if cutting operation is dusty.
12. **SECURE WORK**-Use clamps or a vise to hold work when practicable. It is safer than using your hand and frees both hands to operate the tool.
13. **DO NOT OVERREACH**-Keep your proper footing and balance at all times.
14. **MAINTAIN TOOLS IN TOP CONDITION**-Keep tools sharp and clean for best and safest performance. Follow instructions for lubrication and changing accessories.
15. **DISCONNECT TOOLS**-Unplug tool before servicing and when changing accessories such as blades, bits or cutters.
16. **AVOID ACCIDENTAL STARTING**-Make sure switch is "OFF" before plugging in power cord.
17. **USE RECOMMENDED ACCESSORIES**-Consult the owner's manual. Use of improper accessories may be hazardous.
18. **TURN SPINDLE BY HAND BEFORE SWITCHING ON MOTOR**-This ensures that the workpiece or chuck jaws will not hit the lathe bed, saddle or crossslide, and also ensures that they clear the cutting tool.
19. **CHECK THAT ALL HOLDING, LOCKING AND DRIVING DEVICES ARE TIGHTENED**-At the same time, be careful not to overtighten these

- adjustments. They should be just tight enough to do the job. Overtightening may damage threads or warp parts, thereby reducing accuracy and effectiveness.
20. **It is not recommended that the lathe be used for grinding.** The fine dust that results from the grinding operation is extremely hard on bearings and other moving parts of your tool. For the same reason, if the lathe or any other precision tool is kept near an operating grinder, it should be kept covered when not in use.
  21. **DON'T LET LONG, THIN STOCK PROTRUDE FROM THE BACK OF THE SPINDLE**—Long, thin stock that is unsupported and turned at high RPM can suddenly bend and whip around.
  22. **WEAR YOUR SAFETY GLASSES**-*Foresight is better than NO SIGHT!* The operation of any power tool can result in foreign objects being thrown into the eyes, which can result in severe eye damage. Always wear safety glasses or eye shields before commencing power tool operation. We recommend a Wide Vision Safety Mask for use over spectacles or standard safety glasses.

## Electrical connections

The power cord used is equipped with a 3-prong grounding plug which should only be connected to a properly grounded receptacle for your safety. Should an electrical failure occur in the motor, the grounded plug and receptacle will protect the user from electrical shock. If a properly grounded receptacle is not available, use a grounding adapter to adapt the 3-prong plug to a properly grounded receptacle by attaching the grounding lead from the adapter to the receptacle cover screw.

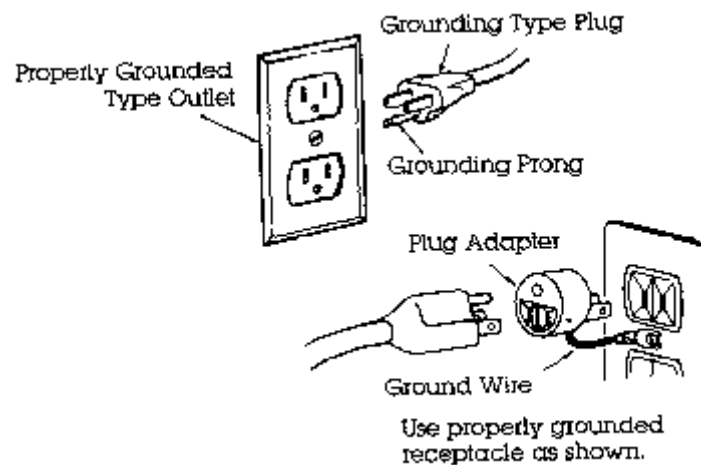


FIGURE 1-Always use a properly grounded receptacle.

NOTE: The electrical circuits designed into the speed control of your lathe or mill reads incoming current from 100 to 240 volts AC and 50 or 60 Hz. and automatically adapts to supply the correct 90 volts DC to the motor. As long as you have a properly wired, grounded connector cord for your source, the machine will operate anywhere in the world without a transformer. This has been true for all SHERLINE machines built since 1994.

Prior to that, we used an AC/DC motor. Use that motor ONLY with the power source for which it was intended. It will not automatically adapt to any other current and using it with an improper power source will burn out the motor or speed control. Also, the first few DC units built did not include the circuits to adapt to other currents. If you have an early DC model, remove the plastic speed control housing and look for a label on the aluminum speed control frame. If it has a small metallic label on top of the frame that lists input voltage as 120VAC, DO NOT ATTEMPT TO CONVERT TO OTHER CURRENTS. Models that can be used with any current have a paper label on the end of the speed control frame which lists the model number as KBLC-240DS.

The machines are normally supplied with a USA type plug but can be easily rewired to accept a European or U.K. type plug by attaching the wires using the color codes provided below.

WIRE	USA	EUROPE
100/240 V	BLACK	BROWN
COMMON	WHITE	BLUE
GROUND (EARTH)	GREEN	GREEN W/YELLOW

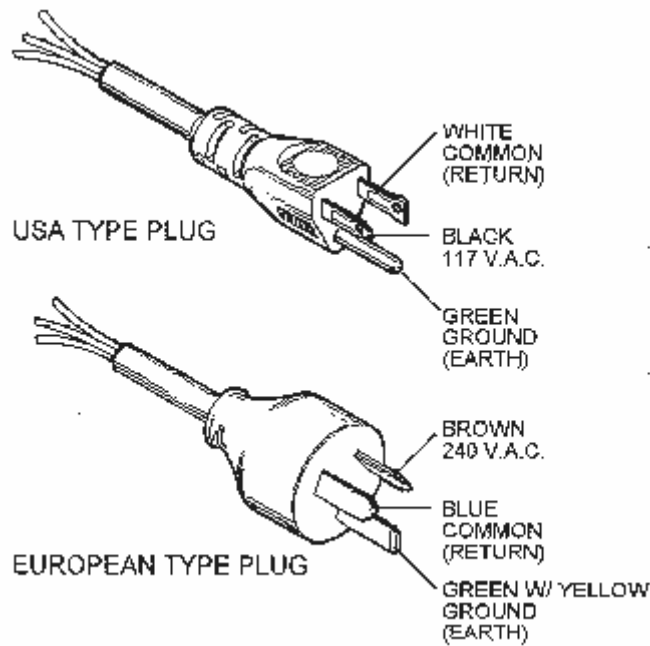


FIGURE1a-Wire color codes for USA and European connectors.

## General precautions

- DO NOT attempt to operate the lathe or mill without first mounting them to a secure base. (See page 6.)
- DO NOT turn on the motor with a 3-jaw chuck mounted if the jaws are not tightened on themselves or on a part.
- A chip guard (P/N 4360) is now available that offers additional protection from flying chips when working near the spindle. It is not a substitute for wearing proper eye protection but is an excellent level of additional protection. It will also contain cutting oil to help keep your work area cleaner.

### Avoid overtightening!

One of the problems with designing and manufacturing metal cutting equipment of this size is that the operator can physically be stronger than the machine, which is not normally the case with larger tools. For example, a 10-pound force applied a couple of inches out on a hex key becomes a 650-pound force at the tip of the screw. If you tighten both screws on the tool post this tight, it becomes approximately 1300 pounds of force on relatively small parts! Tools and/or parts can become distorted and accuracy will be lost. **Overtightening hold down screws and T-nuts in their slots can distort the crossslide or mill table.** It is not necessary to overtighten parts and tools because loads are smaller on equipment of this size. Save your equipment and increase accuracy by not overtightening and by taking light cuts.

### Don't overstress the motor!

It is also important to realize that you can overload the motor supplied with this lathe or mill.\* The many variables involved in machining, such as materials being machined, size of cutter, shape of cutter, diameter of stock, etc., can leave but one rule to follow...**COMMON SENSE!**

\*The motor is thermally protected, so if it is overloaded it will simply shut down until it cools. See section on thermal protection.

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#### CAUTION!

Read all operating instructions and safety rules carefully before attempting any machining operations.

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### Customer's responsibilities

Always use care when operating the lathe and mill. Follow safety rules for power tools. Turn off motor before attempting adjustments or maintenance. (Do not simply turn the speed control down to zero RPM but leave the motor switch on.) Be sure the work piece is firmly supported on the lathe or mill. Accessories should be mounted and operated



following instructions carefully. Keep your machine clean, lubricated and adjusted as instructed. Do not leave cleaning rags, tools or other materials on the lathe bed or around moving parts of the machine.

## **Learning more about machining**

Many fine books have been written on machining techniques and are available at your local library or book store. Although these books will be referring to machines many times larger than Sherline's tools, the principle remains the same. For the best reference that is specific to Sherline tools, see Joe Martin's book, [Tabletop Machining](#).

## **Lubrication**

- **MACHINE SLIDES**-Use a light oil such as sewing machine oil on all points where there is sliding contact. This should be done immediately after each cleanup. (We grease the slides at the factory to ensure the lubrication stays in place during shipping, but light oil will work fine once you begin using the machine.)
- **LEAD SCREW, TAILSTOCK SCREW, CROSSLIDE SCREW**-Sewing machine oil should be placed along all threads regularly. At the same time, check that the threads are free from any metal chips. Use an air hose or paint brush to keep them clean.
- **TAILSTOCK SPINDLE**-Wind out the spindle as far as it will go and lightly oil it with sewing machine oil.
- **HANDWHEEL**-A few drops of light oil behind the handwheel will reduce friction between the surfaces and make operation easier and smoother.
- **HEADSTOCK BEARINGS**-These bearings are lubricated at the factory for the lifetime of the machine and should not need further lubrication. DO NOT break the seals.
- **MOTOR**-Sealed ball bearings require no maintenance.

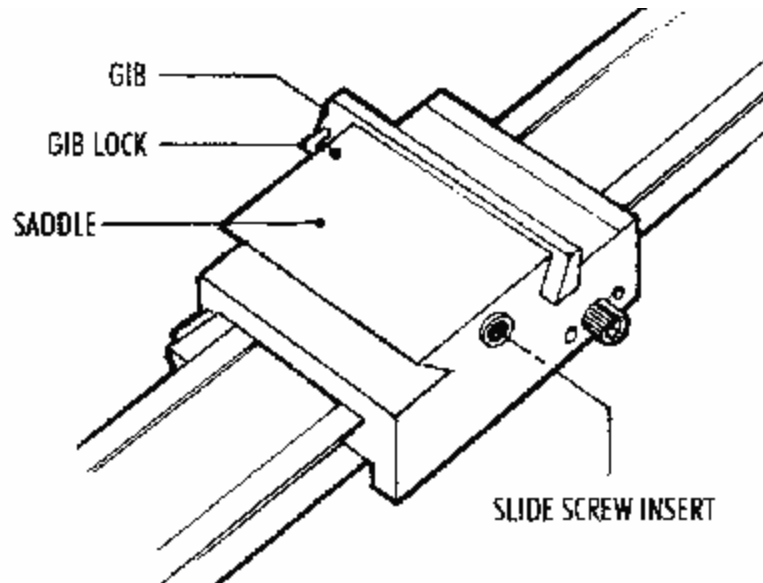
## **Initial assembly of a new machine**

Your new lathe or mill will come packed in a box with some items disassembled for shipping purposes. On the lathe you will install the crossslide table onto the saddle. On the mill you will install the "Z" axis column onto the base. On both machines you will need to install the motor and speed control. The machines are completely assembled and tested for fit at the factory prior to shipping. They are then disassembled and packaged, so everything should go together easily when you reassemble it. The motors are "run in" for approximately one hour to assure proper function and seating of the brushes.

Before you call us and say a part is missing, please look carefully through the packaging. Some parts are in bags taped to the bottom of cardboard flaps or spacers and you may not notice them when you open the box and remove the major components.

## Lathe-crossslide mounting procedure

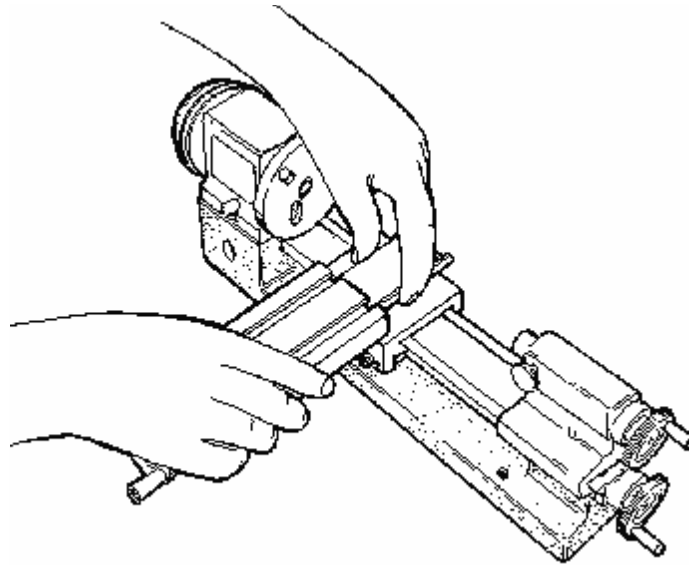
Installation of the crossslide requires no tools. First, make sure the bottom of the crossslide has a light coat of grease on all the sliding surfaces. This will have been applied at the factory, just make sure it has not been wiped off and that it is evenly distributed.



*FIGURE 2*

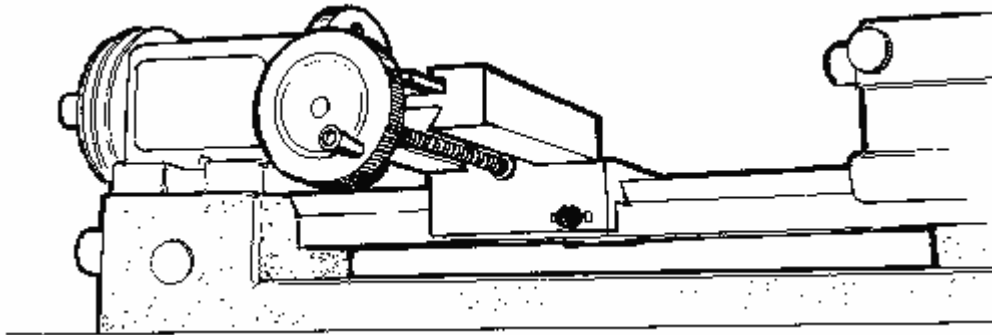
Next, see that the gib is in the proper position on the saddle. (See Figure 2.) It is taped into position for shipping. Remove the tape holding it in place. If the gib has come off, position it on the gib lock as shown.

Set the dovetail of the crossslide over the gib and matching dovetail on the saddle. Slide it onto the saddle about 1/4" (6-7mm) until it stops. (See Figure 3.)



*FIGURE 3*

Look underneath and align the slide screw with the threads on the brass slide screw insert on the side of the saddle. (See Figure 4.) Turn the crossslide handwheel clockwise to engage the threads. Continue to crank the handwheel clockwise until the crossslide is in the desired position on the saddle.



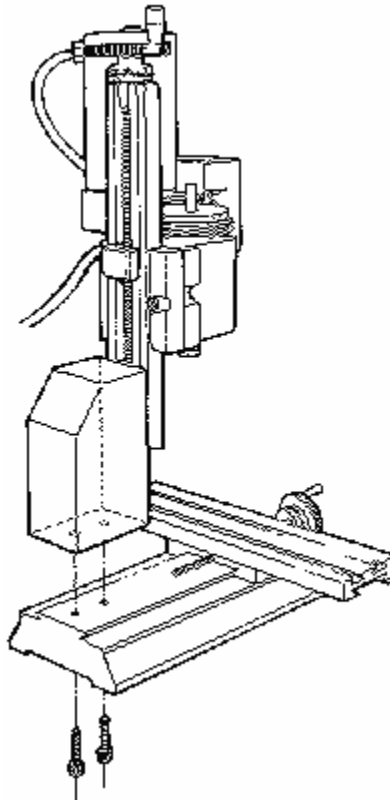
*FIGURE 4*

## **Mill-column mounting procedure**

The mill is shipped attached to a piece of plywood to keep it from moving in the box. Before you begin, remove the screws holding the mill base to the plywood. It was installed strictly for packing purposes and will need to be removed so that the column can be installed.

The "Z" axis column is mounted to the base with two 1-3/4" long 1/4-20 socket head screws. These screws and the hex key tool you will need to tighten them are packaged in

the bag with the motor mounting bracket and drive belt. It is much easier to mount the column to the base before you mount the motor and speed control to the saddle.



*FIGURE 5*

Set the column on the base aligned with the mounting holes and hold it in position while you insert the first screw up from the bottom of the base. Hand turn the first screw part way in and then start the second screw. This can be done with the machine upright by letting the base hang over the edge of your table or bench just far enough to expose the first hole. Using the hex key, snug up both screws lightly first, and then tighten evenly.

## **Assembly of the model 2000 and related model 8-direction mill columns**

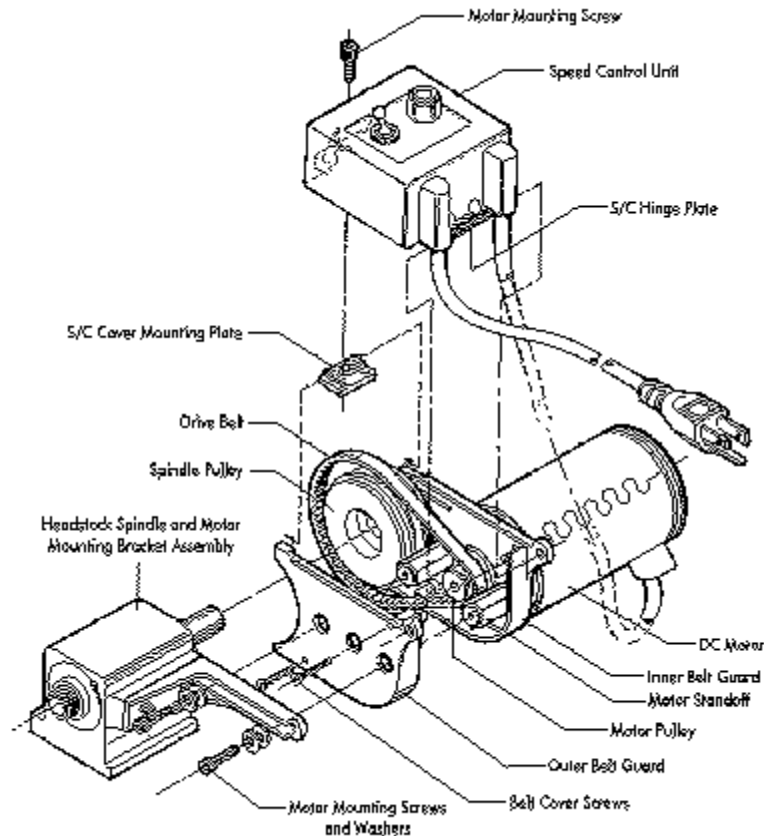
For specific directions on assembly of the various 8-direction columns and upgrades introduced in August, 1998, [click here](#). The Model 2000 mill and the related upgrades that convert standard mills into 8-direction mills offer the ability to drill holes or do machining operations from an almost infinite number of angles on parts mounted square to the table.

**Check tightness of all bolts**

Vibration in shipping can cause some bolts or screws to loosen up. Before using your new machine, check the tightness of all fasteners. It is also a good idea to check tightness periodically when using the machine, as vibration from operation may cause some fasteners to loosen up.

## Mounting the motor and speed control unit to the headstock

(Refer to the exploded views and number list for part number references.)



*FIGURE 6-DC Motor and Speed Control Assembly*

1. Remove motor pulley from motor shaft. Mount the inner belt guard to the motor using the two standoffs (P/N 4310). Next install the motor pulley (P/N 4336) to the motor shaft and tighten the set screw. The end of the pulley should be just about even with the end of the motor shaft with the smaller pulley toward the end of the shaft.
2. Place drive belt over motor pulley.
3. Place round post on speed control hinge plate in hole on inner belt guard.
4. Set outer belt guard in place locating other post of hinge plate in its pivot hole. Motor standoff ends will register in holes in outer belt guard. Make sure the drive

- belt is routed properly. Then secure the cover with (2) 1-3/8" pan head screws which go into nuts pressed into the back of the inner belt guard.
5. Attach motor mounting bracket to rear of headstock with two 10-32 x 3/8" socket head screws. There is enough "play" in the mounting holes to allow you to ensure the motor is visually mounted parallel with the spindle axis. (Note: If chip guard is to be mounted, its attachment screw replaces one of these mounting screws. It can be mounted at this time or after the headstock is in place. See instructions that come with the chip guard.)
  6. Place drive belt over spindle pulley and insert 10-32 x 3/4" socket head screws (with 2 washers on each) through motor mount slot and into holes in the ends of the motor standoffs. (These standoff ends should be exposed through locating holes in the outer belt guard.) NOTE: The normal operating position for the drive belt is on the large diameter groove on the motor pulley and the small diameter groove on the spindle pulley. Use of the other (low RPM) position is discussed elsewhere in these instructions. (See Figure 11.)
  7. Tighten motor mount screws, tilt speed control unit out of the way and check the alignment of the drive belt. It should be perpendicular to the drive pulleys. If it is not, loosen the set screw on the motor pulley and adjust it in or out on its shaft until the drive belt is square with the motor.
  8. Pull desired tension into drive belt by sliding the motor unit out in the bracket slot. Tighten mounting screws to hold the motor/speed control unit in place. NOTE: Do not overtension the drive belt. Just make sure it has enough tension to drive the spindle pulley without slipping under normal load. By not overtightening the belt you will not only extend its life, but will also provide a margin of safety for belt slippage should a tool jam in a part or an accident occur. The belt must be a little tighter when used in the low speed range because small diameter pulleys are not as efficient.
  9. Set mounting plate into top of belt guard housing so it rests on rails molded onto inside surfaces of housing. (The pressed-in nut goes down and to the outside.) Slide the plate toward the outside (toward the spindle pulley) until it stops. NOTE: The mounting plate was designed to be easily removable so it is out of the way when changing the drive belt position.
  10. Rotate speed control unit into place and insert the single 10-32 x 1/2"\* socket head screw through hole in speed control housing and into nut in mounting plate. Tighten enough to hold in place. Do not overtighten.

\*Changed from 3/8" long screws 1/5/05 for stronger engagement.

NOTE: Those of you who machine a lot of wood or brass may want to purchase and install a switch cover (P/N 3015) to keep the fine dust out of the power switch. The wood dust can gum up the switch causing intermittent operation. Brass dust can short out the switch or cause a risk of electric shock to the operator.

## **The advantages of Sherline's DC motor and electronic speed control**

Sherline's 90 volt DC motor is very smooth and powerful, particularly at low RPM. The specially designed electronics package also provides some unique advantages in addition to smooth speed control with a usable speed range of 70 to 2800 RPM. A special circuit compensates for load, helping to keep RPM constant. The machines can also be used on any current world wide from 100 VAC to 240 VAC, 50 or 60 Hz without any further adjustment other than seeing that the proper wall plug is used. The control reads the incoming current and automatically adjusts to the proper settings.

We offer the motor and speed control along with the headstock and spindle as a package to builders of special machinery at a very reasonable price. They are especially popular for custom tooling in small industrial applications because of the large number of Sherline accessories that fit the spindle. We use them in our own production facility for a number of operations.

### **CAUTION—Motor is thermally protected**

Thermal protection means there is a built-in circuit breaker that will shut down the motor if it gets too hot. This keeps the motor from burning out. The breaker will automatically reset as soon as the motor cools and you can go back to cutting, but you should be aware of how it works and what to do if the machine suddenly shuts itself down. If your motor is shutting down from overheating on a regular basis, it means you are taking too heavy a cut or operating at too high an RPM for long periods. Slow your speed down, reduce your cut or feed rate and you should have no further problems.

Due to the nature of miniature machining, overloading the machine is a common problem. It is often tempting to try to speed up the process by working faster. Keep in mind this is a small machine and work with patience and precision-don't be in a hurry. Your parts will come out better and your machine will last much longer if it is not overstressed.

### **What to do if the motor shuts down**

If your thermal protection circuit shuts down the motor while work is in progress, immediately shut off the power switch and then back the tool out of the work. It should only take 10 seconds or less for the circuit breaker to reset, then you can turn the motor on and start the cut again, this time putting a little less stress on the motor. If you leave the tool engaged in the part and the power on, when the circuit breaker kicks back on, the motor must start under load. This can be very hard on your motor.

Remember that the circuit breaker turns the speed control off which turns off the motor. If power were to be applied to the speed control with the motor disconnected, it could damage the speed control.

Thermal protection is built into your motor to make sure it is not damaged by overloading. Use good common sense when operating the motor, and it will provide many years of trouble free operation.

## **Operation of the motor and electronic speed control**

The lathe is supplied with an electronic speed control that produces a comprehensive range of speeds suitable for all operations. Special circuitry designed into the DC motor speed control automatically compensates for speed changes due to increased load. If the spindle RPM drops noticeably when cutting, you are taking too heavy a cut. The speed range of the spindle using the speed control is from 70 to 2800 RPM. This is achieved without the inconvenience of changing belt positions or gear ratios as is often the case with other designs. A second belt position is offered as an additional feature to provide extra torque at low RPM for larger diameter parts should your job require it.

To operate the motor, turn the speed control knob counter-clockwise as far as it will go. Then turn the toggle switch to "ON" and select the speed by turning the speed control knob clockwise.

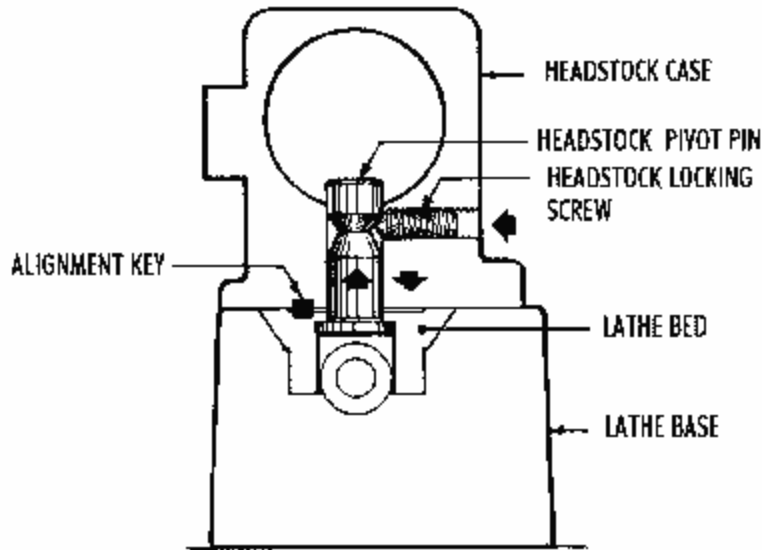
### **Motors are pre-tested at the factory**

Your new motor should run smoothly the first time you use it as it has been "run in" for about an hour before being shipped to you. Despite our secure packaging, there have been cases where extremely rough handling by a shipper has damaged the magnets in the motor. If the motor does not run when plugged in, turn the motor by hand. If it does not turn smoothly, it may have been damaged in shipment. Call Sherline for instructions on making a damage claim with the shipper. Do not attempt to repair the motor yourself.



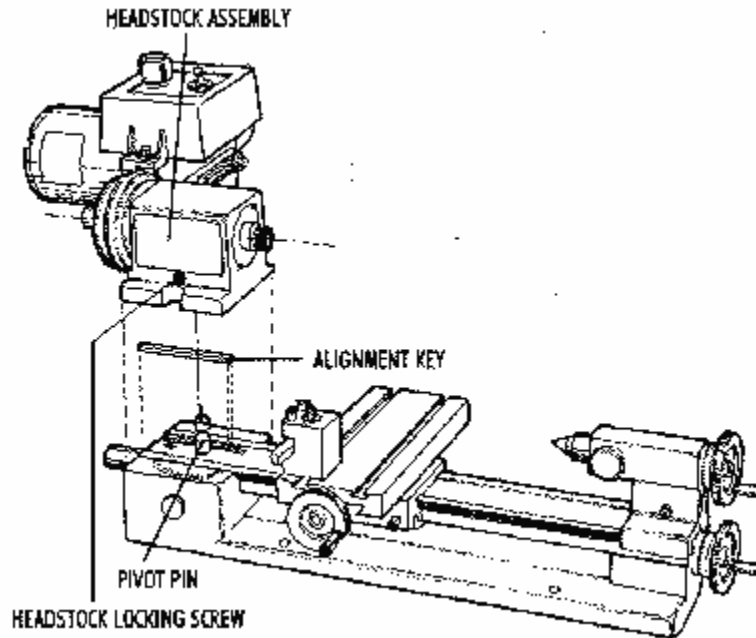
## Mounting the headstock to the lathe or mill

You may notice that the post onto which the headstock mounts is a loose fit where it projects from the lathe bed or column saddle. This is normal, and the diagram below will help you understand how it works.



*FIGURE 7-Cross section of headstock showing locking screw.*

The screw in the front center of the headstock has a cone point. The pivot pin has a tapered slot with a corresponding angle. When the screw is tightened, its angled face engages the groove and, because the pivot pin can not come up, it draws the headstock down into position, clamping it into place. If the pin were rigid, it could keep the headstock from pulling down squarely.



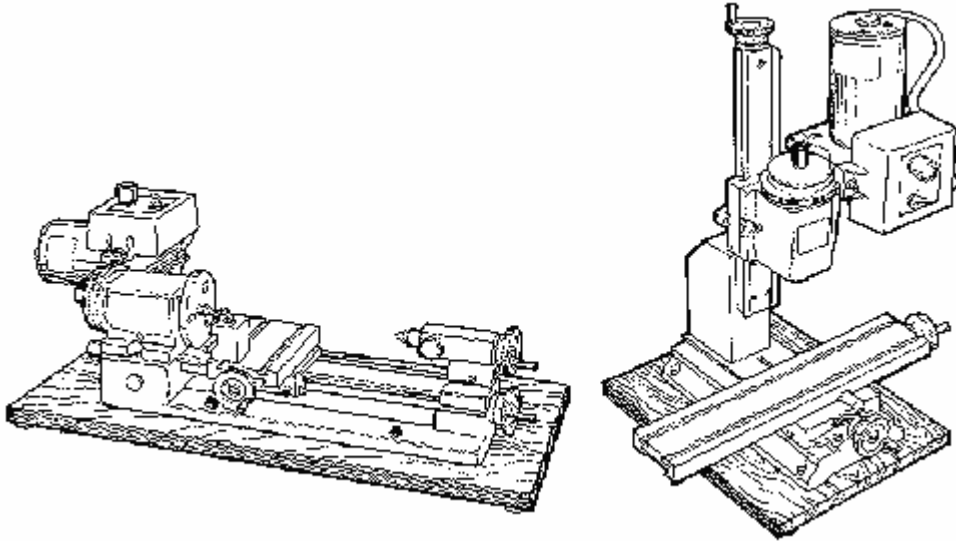
*FIGURE 8-Headstock and alignment key in position over lathe.*

The headstock is aligned with the lathe bed or column saddle with a precision ground key that fits into keyways in both parts. It is not square in cross section so it will fit in only one direction. Push the headstock firmly against it as you tighten the hold down screw. The mill headstock has two keyways milled into it so it can be mounted in conventional fashion or at a 90° angle for horizontal milling.

**CAUTION! Always make sure the key, slot and mating surfaces are free from dirt and chips before locking down the headstock.**

Removing the headstock alignment key allows the headstock to be mounted in positions other than square. This allows you to mill parts at an angle or turn tapers on the lathe. When using the lathe or mill without the alignment key, keep cutting loads light.

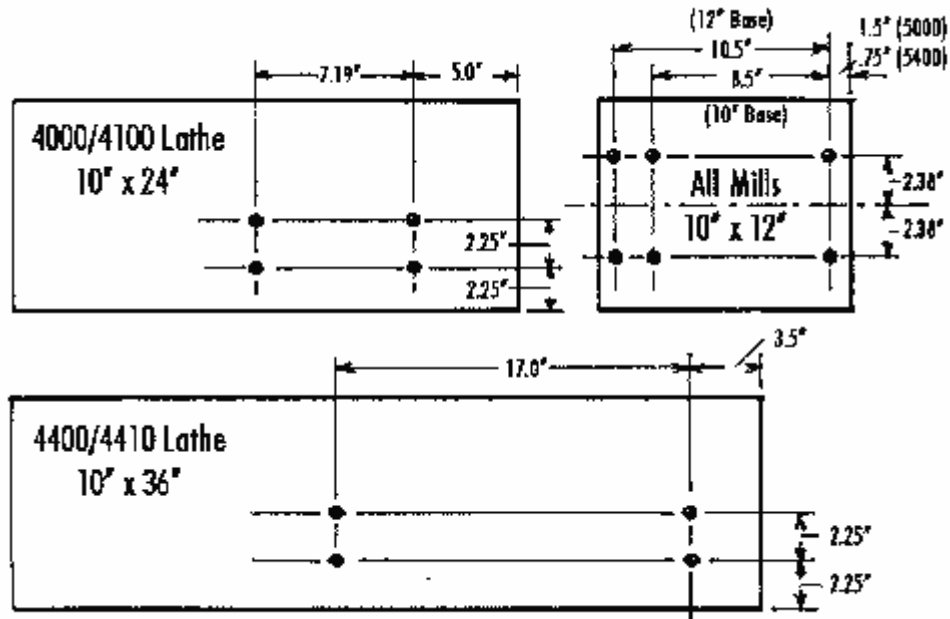
## Mounting the mill and lathe to a board



*FIGURE 9-Machines mounted to a base board for stability.*

Mounting the lathe to a board is necessary because of the narrow base. This keeps the machine from tipping. We recommend mounting the lathe on a piece of pre-finished shelf material which should be available from your local hardware store. (See below for sizes.) The machine can be secured to the board using four 10-32 screws with washers and nuts. Lengths should be 1-1/2" for short bed lathes and 1-7/8" for long bed lathes. Rubber feet should be attached at each corner on the bottom of the mounting boards. They are also readily available in hardware stores.

This arrangement gives the machines a stable platform for operation yet still allows for easy storage. The rubber feet help minimize the noise and vibration from the motor. Mounting the tool directly to the workbench can cause vibration of the bench itself which acts as a "speaker" and actually amplifies the motor noise. Bench mounting also eliminates one of the best features of Sherline machines...the ability to easily be put away for storage.



*FIGURE 10-Plans for mounting board hole patterns. Confirm actual dimensions from your lathe or mill before drilling. The newly added model 2000 multi-direction mill can be mounted to a board 12" x 18" in a similar fashion.*

The mill may be mounted in a similar manner on a 10" x 12" to 12" x 24" pre-finished shelf board with rubber feet using 10-32 x 1" screws to attach the mill to the board.

To keep your Sherline tools clean, soft plastic dust covers are available. The lathe cover is P/N 4150 for the Model 4000/4100 and 4500/4530 short bed lathes and P/N 4151 for the Model 4400/4410 long bed lathe. A mill dust cover is available as P/N 5150.

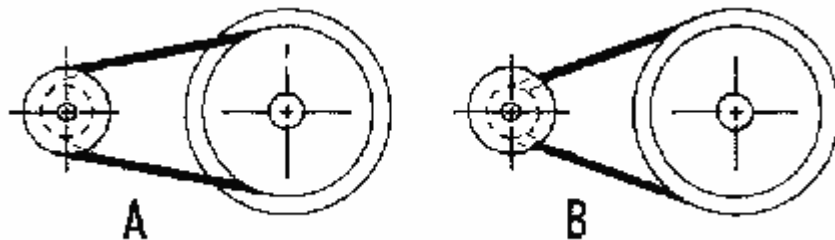
## **Converting machines from inch to metric or vice versa**

All Sherline tools and accessories are manufactured in your choice of inch or metric calibrations. Converting a lathe or mill from one measurement system to the other is possible, but it takes more than changing the handwheels. The leadscrews, nuts and inserts must also be changed. A look at the exploded views of the machines on pages 27 and 28 will show which parts need to be purchased. (Look for parts that have both a metric and inch version in the parts listing.) Conversion kits with all the necessary parts are available. If you are a good mechanic, you can do the conversion yourself, or you can return your machine to the factory for conversion.

# ADJUSTMENTS

## Two-speed pulley

The normal pulley position, which is placing the belt on the larger motor pulley and smaller headstock pulley, will suffice for most of your machining work. Moving the belt to the other position (smaller motor pulley, larger headstock pulley) will provide additional torque at lower RPM. It is particularly useful when turning larger diameter parts with the optional riser block in place.



*FIGURE 11-The two pulley positions. Position A is the conventional setting, position B offers more torque at low RPM. (Seen from pulley end of headstock.)*

To change the pulley position, remove the speed control hold down screw and pivot the speed control housing up out of the way. Remove the mounting plate from its position on the rails of the two halves of the belt guard housing. Loosen the two nuts that hold the motor to the motor mounting bracket and take the tension off the belt. With your finger, push the belt off the larger groove of the pulley and into the smaller one. (Depending on which way you are changing it, this could be either the motor or spindle pulley.) Then move the belt to the larger diameter groove on the other pulley and rotate the headstock by hand to get it to seat. Push the motor outward on the motor mounting bracket to put the proper tension on the belt and retighten the two motor mounting screws. Now you can replace the mounting plate, pivot the speed control back down and refasten it. Moving the belt back to the other position is simply a reverse of the above procedure.

## Preload adjustment

**SPINDLE ADJUSTMENT**-If any end play develops in the main spindle, it can be easily eliminated by readjusting the preload nut. (See part number 4016 in the exploded view.) When the headstocks are assembled at the factory, the preload nut is adjusted to .0002" (.005mm) of end play. This is controlled by the outer races of the bearing being held apart by the headstock case and the inner races being pulled together by the preload nut. This setting was determined through experience and, like everything in engineering, it is a compromise. If the machine is only to be run at high speed, this setting may be too "tight". The headstock will run fairly warm to the touch normally, but extended periods

of high speed operation may bring about excessive temperature. If this is your case, the preload may be reduced slightly.

To change the adjustment, remove the spindle pulley, loosen the set screw in the preload nut and back the preload nut off four degrees of rotation (counter clockwise). The bearings are lightly pressed into the case, so the inner race will not move without a sharp tap with a plastic mallet to the end of the spindle where the pulley is attached.

If you find your bearings are set too loose, you may want to take up on the end play. You can check them with an indicator or by spinning the spindle without the motor belt engaged. If the spindle spins freely with a chuck or faceplate on it, it is too loose for normal work. Adjust the preload nut until it turns approximately one and a half revolutions when spun by hand.

## **Gib adjustment**

Gibs (tapered synthetic adjustment shims) are fitted to the mill headstock, saddle and table and to the lathe saddle and crossslide. Correct adjustment of the gibs will ensure smooth and steady operation of the slides. The gib is effectively a taper with an angle corresponding to the one machined into the saddle. It is held in place by an "L" wire gib lock which is secured with a locking screw. It is adjusted by loosening the gib locking screw and pushing the gib in until "play" is removed. After adjusting, retighten the locking screw. Milling operations require a tighter adjustment of the gibs than lathe operations.

## **Backlash adjustment**

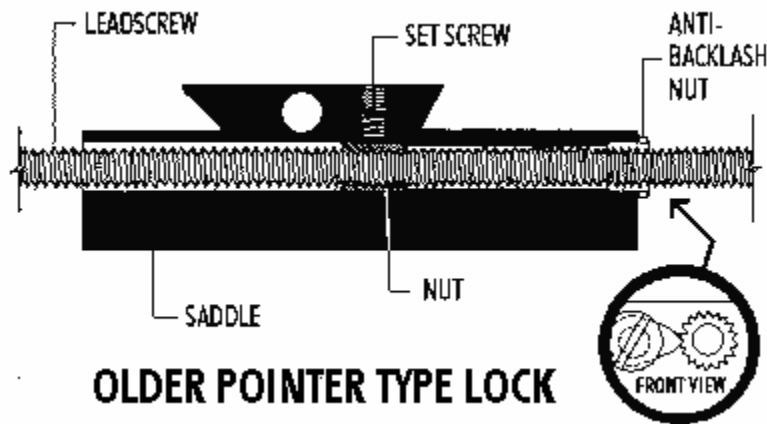
Backlash is the amount the handwheel can turn before the slide starts to move when changing directions. This is a fact of life on any machine tool and on machines of this type it should be about .003" to .005" (.08mm to .12mm).

Backlash must be allowed for by feeding in one direction only. Example: You are turning a bar to .600" diameter. The bar now measures .622" which requires a cut of .011" to bring it to a finished diameter of .600". If the user inadvertently turns the handwheel .012" instead of .011", he couldn't reverse the handwheel just .001" to correct the error. The handwheel would have to be reversed for an amount greater than the backlash in the feed screws before resetting the handwheel to its proper position.

Backlash on the "X" and "Y" axes of the mill may be reduced to a minimum by adjustment on the anti-backlash nuts. These nuts are located on the handwheel ends of the mill saddle. The nuts are secured by slotted pan head screws which hold a pointed locking plate that interlocks with teeth on the nut.

To adjust backlash, simply loosen the pan head screw and slide the locking plate to one side. Rotate the anti-backlash nut clockwise on the "X" axis and counterclockwise on the

"Y" axis until snug. Replace the locking plate and tighten the pan head screw. With the anti-backlash nuts properly adjusted, the lead screws will turn smoothly and have no more than the proper .003" to .005" of backlash.



*FIGURE 12-Backlash Adjustment. NOTE: A new lock now uses a star gear rather than the pointer to locate the anti-backlash nut, and a button head socket screw locks it in place. This system is easier to use, but the function is essentially the same. (The hole centers are different, which means the star gear cannot be used to replace the pointer on older models.)*

## Handwheel adjustment

The handwheels are secured to their corresponding leadscrew shafts by a small set screw in the side of the handwheel base. Check them periodically to make sure they have not been loosened by vibration. On the "zero" adjustable handwheels, you must first release the rotating collar by loosening the locking wheel. Then rotate the collar until you can see the set screw through the small hole in the side of the collar and adjust the screw as necessary.

If excessive backlash develops at the handwheel and thrust collar junctions, adjust by first loosening the handwheel set screw. Index (rotate) the handwheel so the set screw tightens on a different part of the shaft. (If you don't, it may tend to keep picking up the previous tightening indentation and returning to the same spot.) Push the handwheel in tightly while holding the mill saddle and retighten the handwheel set screw.

## Movement of the handwheels

Turning the appropriate handwheel moves the saddle, crossslide and tailstock spindle. For the inch version, one complete turn of the handwheel gives a movement of .050". For the metric model, one complete turn of the handwheel gives a movement of 1mm. Handwheels are calibrated in .001" (1/1000") for inch models and .01mm (1/100mm) for

metric models. Keep the screws clean, oiled and free from chips. The handwheels are quite accurate and should be used accordingly.

## Aligning the head and tailstock

The versatile feature of Sherline machines that allows the headstock to be removed or rotated for taper turning and angle milling keeps us from being able to lock the headstock in perfect alignment. Precision ground alignment keys and accurate adjustment at the factory, however, make the machines highly accurate. In standard form, alignment should be within .003" (.08mm). This should be more than acceptable for most jobs you will attempt.

Only someone new to machining would talk about "perfect" alignment. Machinists speak instead in terms of "tolerances", because no method of measurement is totally without error. We believe the tolerances of your machine are close enough for the work for which it was intended, however, for those searching for maximum accuracy, here are some tips for maximizing the accuracy of your machine.

Loosen the headstock, push it back evenly against the alignment key and retighten. This will maximize the accuracy of the factory setting. To achieve greater accuracy, you will have to be willing to sacrifice one of the better features of your lathe or mill; that is, its ability to turn tapers and mill angles in such a simple manner.

**HEADSTOCK**-If you choose total accuracy over versatility or need it for a particular job, proceed as follows. Remove the headstock and clean any oil from the alignment key and slot and from the area of contact between bed and headstock. Replace the headstock, pushing squarely against the key and retighten. Take a light test cut on a piece of 1/2" to 3/4" diameter by 3" long aluminum stock held in a 3-jaw chuck. Use a sharp pointed tool to keep cutting loads low so as not to cause any deflection of the part. Measure the diameter of both machined ends. If there is a difference, the headstock is not perfectly square. Now, without removing the key, tap the headstock on the left front side if the part is larger at the outer end. (Tap on the right side if the part is larger at the headstock end.) You are trying to rotate the headstock ever so slightly when viewed from the top until the machine cuts as straight as you can measure. There should be enough movement available without removing the key, as its factory placement is quite accurate.

Take another test cut and remeasure. Repeat this procedure until you have achieved the level of perfection you seek. Then stand the lathe on end with the alignment key pointing up and put a few drops of LocTite™ on the joint between key and headstock. Capillary action will draw the sealant in, and when it hardens, the key will be locked in place. We prefer this method to "pinning" the head with 1/8" dowel pins, because it offers you the option to change your mind. The headstock can be removed by prying with a screwdriver blade in the slot between the bottom of the headstock and the lathe bed to break the LocTite™ loose should you wish to be able to rotate the headstock again.



***TAILSTOCK***-To maximize the machine's tailstock alignment, first make sure that there are no chips caught in the dovetail of the bed and no chips or dents in the taper of your tailstock center. Now put a 6" long piece between centers and take a long, light test cut. Measurements at either end will tell you if you need to use an adjustable tailstock tool holder in the tailstock to achieve better tailstock alignment. We manufacture adjustable tailstock tool holders (P/N [1202 & 1203](#)) and an adjustable live center (P/N 1201) which can help you attain near perfect alignment at the tailstock should your job require it. Instructions for their use are included with each item.

Remember that unless you drill very small holes (less than 1/64") or turn a lot of long shafts, you are giving up a very useful feature to solve a problem which can usually be handled with a few passes of a good mill file. The inaccuracy inherent in any drill chuck is such that perfect machine alignment is meaningless unless you use adjustable tailstock tool holders.

## Use of cutting oils and lubricants

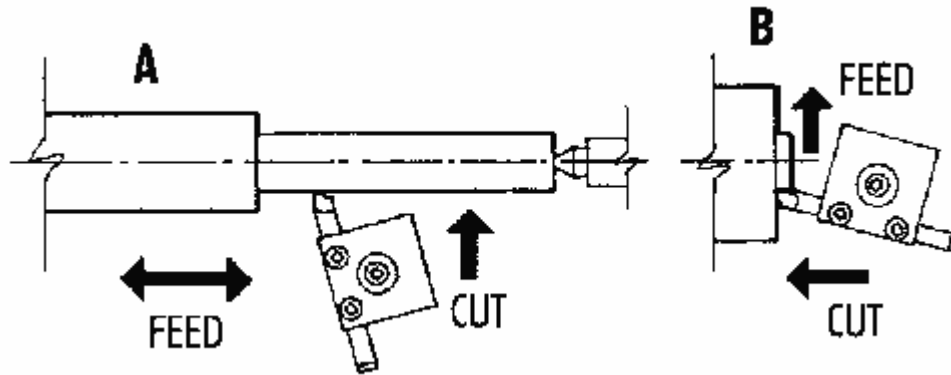
Much can be written about the use of lubricants, but they may usually be dispensed with where production rates are not very important. A small amount of any kind of oil applied with a small brush will be sufficient. Aluminum and its alloys may require the use of cutting oils to prevent the chips from welding to the tool's point. Do not use oils with a low flash point or a bad smell. If desired, a mixture of one part soluble oil to six parts water may be used on steel to assist in producing a smoother finish and reduce tool chatter when parting off. Brass and cast iron are always turned dry. Cutting lubricants should be cleaned off the tools after use.

Cutting oils can be purchased at an industrial supply store. We used to sell cutting oil, but dropped it from the line because we received so few orders. We assume our customers prefer to purchase their cutting oil from local sources. Do not use high sulfur pipe thread cutting oil. It is good for hard to machine materials, but is so dirty to work with we do not recommend it. We also find some of the tap cutting fluids are too smelly and unpleasant to use for general machining.

The main purpose of using lubricants is to keep the chips from sticking to the cutting tool. When used properly, modern high speed tool bits are not likely to be affected by heat on the type of work usually done on Sherline tools.

## General machining terms

Two terms frequently used in machining are "Feed" and "Cut". Reference to the diagrams below will show what is meant by these terms. Normal turning on a lathe, when used to reduce the diameter of a work piece, involves advancing the cutting tool **perpendicular to** the lathe bed by an appropriate amount (depth of **cut**) and **feeding** the tool along parallel to the lathe bed to remove material over the desired length. (See Figure 13A below.)



*FIGURE 13-Directions of Feed and Cut showing (A) Turning work between centers and (B) Facing off a work piece.*

In normal machining, the depth of **cut** is set by the crossslide handwheel, and the **feed** is provided by the handwheel on the end of the bed. When facing off the end of a work piece held in a chuck or faceplate, the depth of **cut** is set by the handwheel on the end of the bed, and the **feed** is provided by the crossslide handwheel. (See Figure 13B above.)

When using a mill, **cut** is determined by the amount of depth the cutter is set to by the "Z" axis handwheel. **Feed** is supplied by either or both the "X" or "Y" axis handwheels depending on the desired direction of the cut.

## General rules for feed rates and cutting speeds

Before attempting to machine any metal, please try to remember this simple rule about machining:

**"If the tool chatters, decrease speed and increase feed."**

Understanding this simple rule can save you many hours of grief. When the tool "chatters", it is not cutting in a continuous fashion. Metal likes to be machined in a way that allows the material to come off in a continuous strip while the tool is in contact with the metal. If the tool is not fed at a rate that is fast enough, the tool skips along the surface, occasionally digging in. The surface of the tool that is doing the most cutting will find a frequency of vibration that is a product of all the variables involved. This can cause anything from a high pitched whine on light, high speed cuts to a resonating racket that can rip the work out of the chuck on heavy cuts. If you maintain the same feed rate and reduce the RPM, the feed will increase because chip will be thicker. (If that sounds wrong at first, think of it this way: At the same feed rate, if you cut the RPM in half, twice as much metal must be removed with each rotation to get to the end of the cut in the same amount of time. The chip is twice as thick, so the feed is **GREATER** at lower RPM if the feed **RATE** stays constant.)

When a tool chatters it gets dull faster because it must keep cutting through the previously machined surface that has been "work hardened" by machining. As you can imagine, there are limits to how much you can increase feed rate, so the answer lies in adjusting both speed and feed to achieve the proper cut.

Proper cutting speed is the rate a particular material can be machined without damaging the cutting edge of the tool that is machining it. It is based on the surface speed of the material in relation to the cutter. This speed is a function of both the RPM of the spindle as well as the diameter of the part or size of the cutter, because, as the part diameter or cutter size increases, the surface moves a greater distance in a single rotation. If you exceed this ideal speed, you can damage the cutting tool. In the lathe and mill instructions, we give some examples of suggested cutting speeds, but what I wanted to get across here is that it isn't a slow process. A tool can be destroyed in just a few seconds. It isn't a case of getting only one hour of use instead of two. The cutting edge actually melts. If you machine tough materials like stainless steel, you will ruin more tools than you care to buy if you don't pay a lot of attention to cutting speeds. Charts showing suggested cutting speeds for various materials are included in both the lathe and mill sections that follow.

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**PRODUCTS**  
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## VERTICAL MILLING MACHINE OPERATION

(Reprinted from the *Sherline Assembly and Instruction Guide, Fourth Edition* (1997))

[CLICK HERE](#) to download the complete *Assembly and Instruction Guide, Fifth Edition* as a .pdf file.

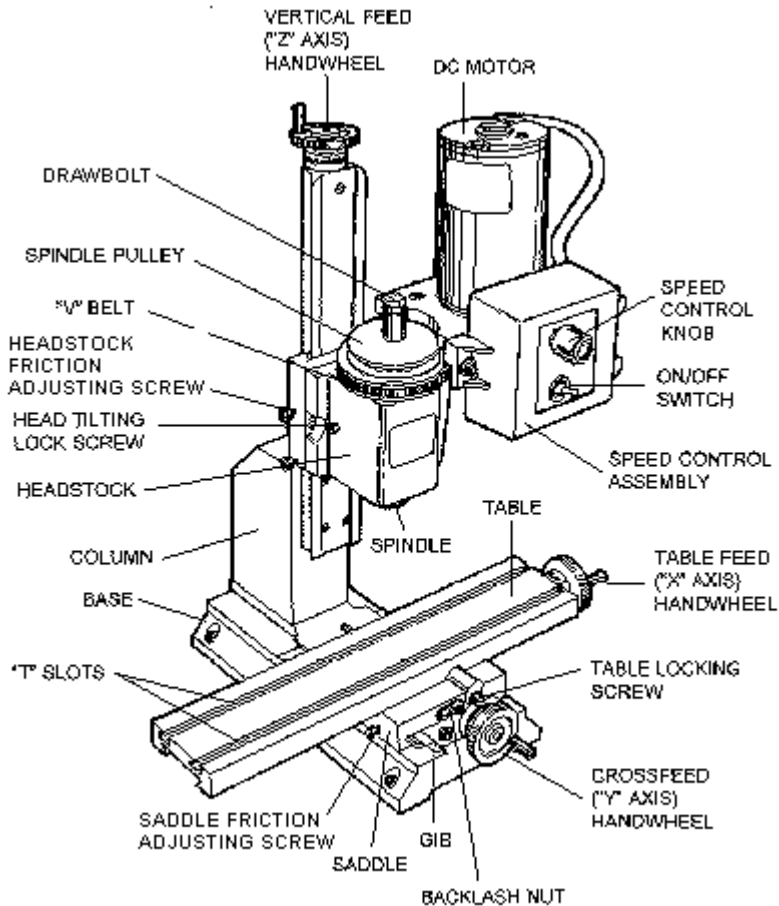
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**CAUTION!**

**Read all operating instructions carefully  
before attempting any machining operations!**

Review [Safety Rules for Power Tools](#) before beginning.

NOTE: See [general machine setup section](#) for lubrication and general machining instructions.



*FIGURE 1-Milling Machine part terminology. Note that newer lathes now have an improved, more positive locking lever on the Z-axis leadscrew that replaces the Headstock Friction Adjusting Screw shown in this older diagram.*

## **GENERAL DESCRIPTION**

At first glance, a vertical mill looks similar to a drill press, but there are some important design differences; for example, a spindle that can take side loads as well as end loads and an accurate method of moving work in relation to the spindle on all three axes. It is wise to memorize these "X", "Y" and "Z" axes, because since the advent of complex electronically controlled milling machines, these terms have become common "shop talk", even outside engineering departments. (See Figure 2.) Feed screws with calibrated handwheels control movements on these three axes. The handwheel calibrations are quite accurate and should be used whenever possible. Counting handwheel revolutions and/or the marks on the handwheel is a more accurate way to move from one location to another than "eyeballing" a cut to a scribed line.

Angles can be machined by removing the headstock alignment key and rotating the milling head to the appropriate angle to the work or by holding the work at an angle to

the spindle. (Note: Lighter than normal cuts should be taken when the alignment key is not in place.) The latter method must be used for drilling to keep the drill movement parallel with the machine slide. All machine slides have an adjustable gib to compensate for any "play" that may develop. (See section on adjusting gibs in the "Adjustments" section of the [setup instructions.](#))

In August, 1998, Sherline introduced the Model 2000 mill and related upgrades that allows for eight directions of adjustment. For instructions specific to this machine, [click here.](#)

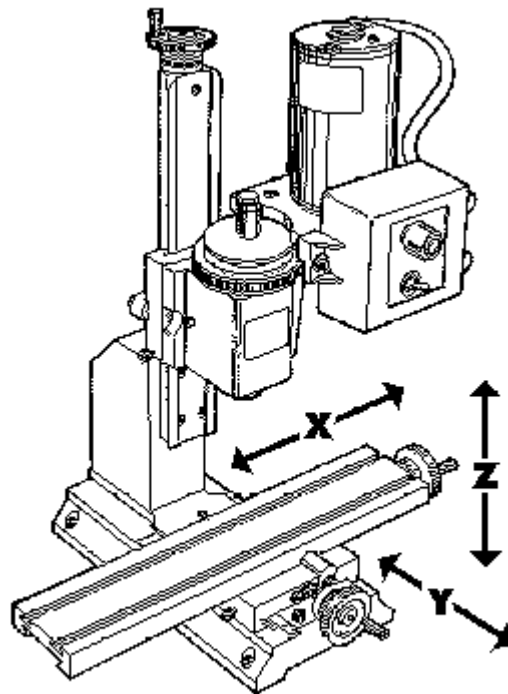
It is assumed that anyone purchasing a vertical milling machine has had some experience working with metal cutting tools; therefore, these instructions are somewhat limited for a beginner. There is enough information, however, to enable a good craftsman to get started. Using a vertical mill correctly takes more skill and experience than is required for lathe operation because of the additional axis (vertical) and the more varied type of work which can be performed. For those wanting to learn more, we have written a 350-page color book called *Tabletop Machining* (P/N 5301) that covers the subject in much greater detail.

The machine must be well maintained, for it is subject to higher stresses than a lathe. This particular mill is one of the smallest being manufactured and is an extremely useful tool. However, it would be unreasonable to clamp a 3-pound piece of stainless steel to the work table and expect to make a 1-pound part from it. The key point is to work within the capabilities of the machine, and those limitations can only be determined by the operator.

## HELPFUL TIPS FOR MILLING

- This is a small, light duty mill and should not be used to remove large amounts of stock that could be easily removed with a hacksaw. For efficiency, select a piece of stock as close to finished size as possible.
- Stresses on a mill are quite high when cutting most materials; therefore, gib and backlash adjustments must be properly maintained. (See "Adjustments" section beginning on page 6.)
- End mills must run true and be sharp. Holding end mills in a drill chuck is a poor practice. Use collets or an end mill holder instead. The 3/8" end mill holder ([P/N 3079](#)) allows you to use a large range of readily available 3/8" end mills with your machine. (1/4" and 3/16" end mill holders are also available.)
- Flycutting is an excellent way of removing stock from flat surfaces and leaves a good finish.
- Normal machine alignment is adequate for most work, but if the work is exceptionally large or requires extreme accuracy, shims may be employed to improve machine alignment.
- For accurate setups you should have and know how to use a dial indicator.
- Often, more time will be spent making fixtures to hold work than doing the actual machining.
- To help save time on many simple setups a good mill vise is a must.

- Always try to have one point from which to measure. Do not machine this point off part way through the job. This would leave you with no way of measuring the next operation. Plan ahead.
- Remember the basic machining rule that says: "If the tool chatters, reduce speed and increase feed."
- It takes a long time to accumulate the knowledge, tools and fixtures required for many different types of milling operations. Do not become discouraged by starting with a job that is too complex or by using materials that are extremely difficult to machine.



*FIGURE 2-- The three axes of movement on a vertical milling machine.*

## **SECURING THE WORKPIECE**

The first problem encountered will be holding the work and aligning it to the machine. It is important for reasons of safety and accuracy that the workpiece be solidly secured. This may be the most difficult task, since once the work is clamped in position, the method of doing the entire job has been established. Usually, a rectangular block can be easily held in a vise. Note that round stock may also be held in a "V" shaped vise slot. Mill vises are specially designed to pull the movable jaw down as they tighten on it.

Certain objects can be secured with a 4-jaw lathe chuck, which is in turn clamped to the machine. Some irregular shapes, such as steam engine castings, may present greater difficulties. Often they may be clamped directly to the table. Very small or irregular

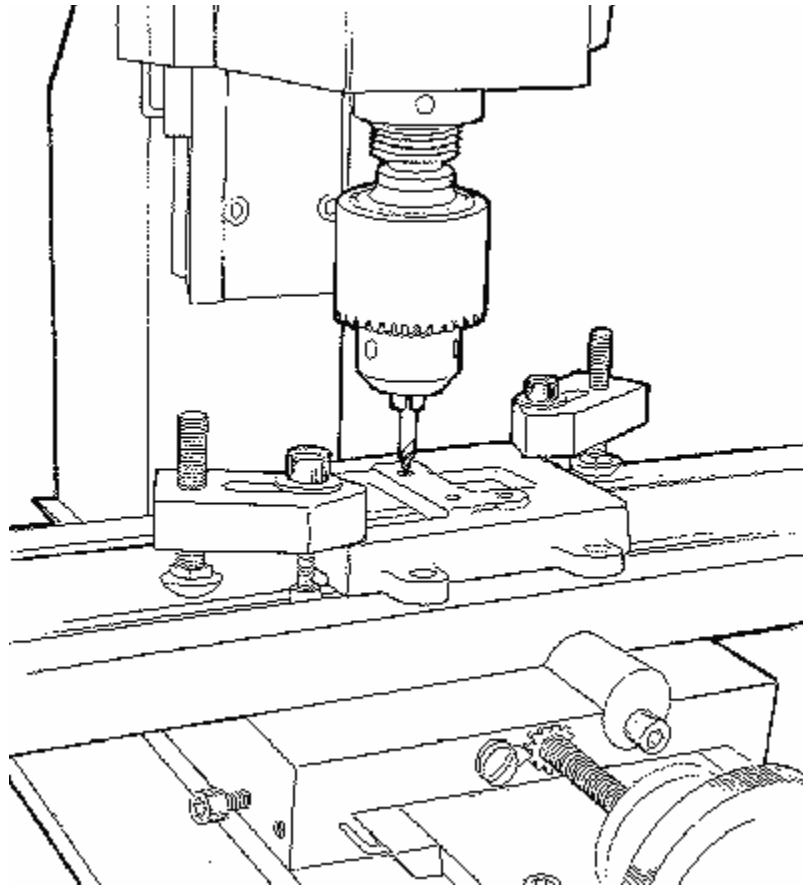
shapes can be secured by epoxying them to a second, more easily held piece of material. The part is then broken loose from the material after machining. A tooling plate (P/N 3560) offers a drillable surface with a predrilled pattern of holes to help mount parts and fixtures while also protecting the mill table and adding further stiffness.

## **THINGS TO CONSIDER BEFORE YOU START CUTTING**

The following steps should be considered before commencing any part:

- Is the material about to be machined best suited for the job, and is it machinable with available cutting tools and equipment? Work with aluminum, brass, plastic or cast iron whenever possible. Too often a hobbyist will pick up the first correctly sized piece of material he finds at his local salvage dealer thinking that if it is rusty, it's steel, and that all steels are pretty much the same. Not so! Anyone who has ever tried to machine an old automobile axle can attest to this. If the part must be steel, grade 12L14, commonly called "lead-loy", is about the best material for machining. It was developed for screw machine use and is available in round stock only. However, it works so well that many times it may be advisable to machine rectangular parts from it. It can also be case hardened. Your local screw machine shop will usually have scrap pieces available and may be a good source for obtaining it.





*Figure 3-Center drilling a part clamped to the table with the P/N 3012 hold-down set. The newer P/N 3013 step block hold-down set is more quickly adjustable for height and covers a wider clamping range.*

- Avoid exotic materials, such as stainless steel, unless absolutely necessary because of machining difficulty and poor milling cutter life. (Probably, if each new mechanical engineer were given a block of stainless steel to mill, drill and tap upon his graduation, stainless steel sales would drop considerably!)
- Before beginning, carefully study the part to be machined. Select the best surface from which to work (usually the flattest).
- Pick a point from which to measure that will not be machined off part way through the job.
- Decide if work should be "rough cut" to size. Some materials will warp while being machined. Close tolerance parts can be destroyed by attempting heavy machining at the end of the job rather than at the beginning.
- The method of holding the work is also determined by the type of machining to be performed. For instance, work that involves only small drilling jobs does not have to be held as securely as work to be milled.
- Lay the job out so that it can be machined with the minimum number of setups.
- Be sure to have all needed cutting tools available before beginning a job.

- Do not start off with a job so complex that the odds of success are limited. Making complex machined parts requires a great deal of intelligence, planning and skill.

In summary, you should become aware of the fact that milling is difficult, but not impossible. There are many more considerations than just moving the handwheels, and you should not start your first step until your last step has been determined.

## THREE TYPES OF WORK

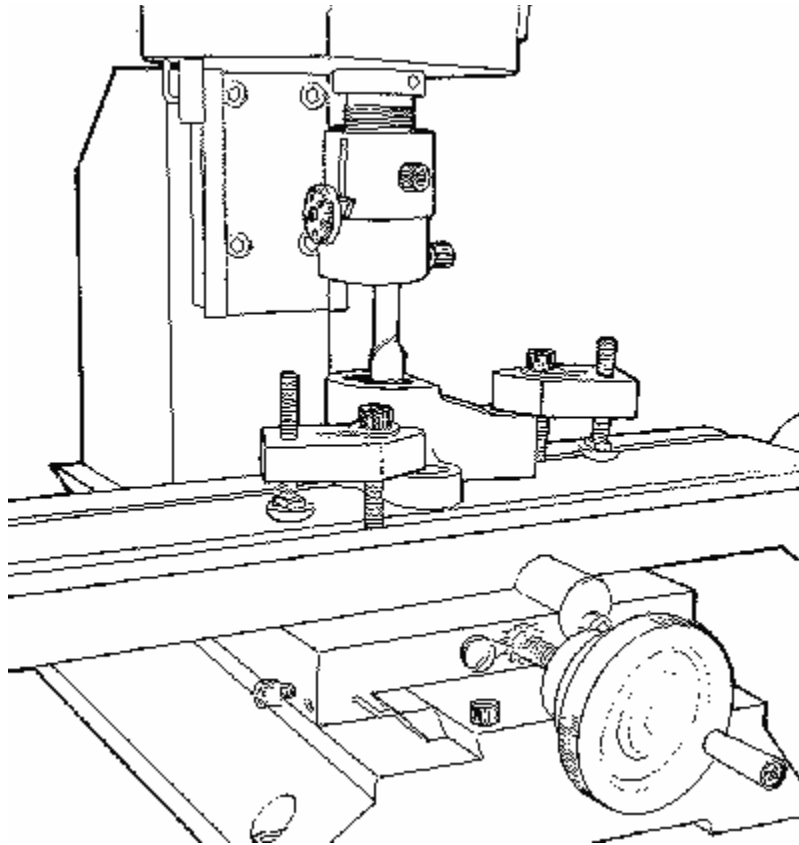
There are three basic types of work which can be performed with a vertical milling machine: milling, drilling and boring. It would be extremely difficult to determine whether a vertical mill or a lathe would be the most valuable machine in a shop. Theoretically, most vertical mills are capable of reproducing themselves with standard milling accessories such as a rotary table and centers. This would be impossible on a lathe without exotic modifications and attachments. These instructions briefly describe standard vertical mill work. Many comprehensive books are available on this subject, and, although the machines they describe are much larger, the principles remain the same. A good starting point is *Tabletop Machining*. It is available through Sherline as P/N 5301 and uses Sherline tools throughout in all the setups and examples.

**CAUTION! Because the tool spins on a mill, hot chips can be thrown much farther than when using a lathe. Safety glasses and proper clothing are a must for all milling operations.**

Milling on a vertical mill is usually accomplished with end mills. These cutters are designed to cut with both their side and end. (See Figure 12.) Drilling is accomplished by raising and lowering the entire milling head with the "Z" axis feed screw. Center drills must be used before drilling to achieve any degree of accuracy. (See Figure 18.) Note that subsequent holes may be accurately "dialed in" from the first hole by using the calibrated handwheels. Each revolution of the wheel will yield .050" of travel on inch machines or 1 mm for metric machines. There is no need to start with the handwheel at "zero", although this can be easily accomplished with the optional "zero" resettable handwheels to make calculations easier.

Boring is a method of making accurate holes by rotating a tool with a single cutting edge, usually in an adjustable holder called a boring head. It is used to open up drilled holes or tubing to a desired diameter. (See Figure 4.)

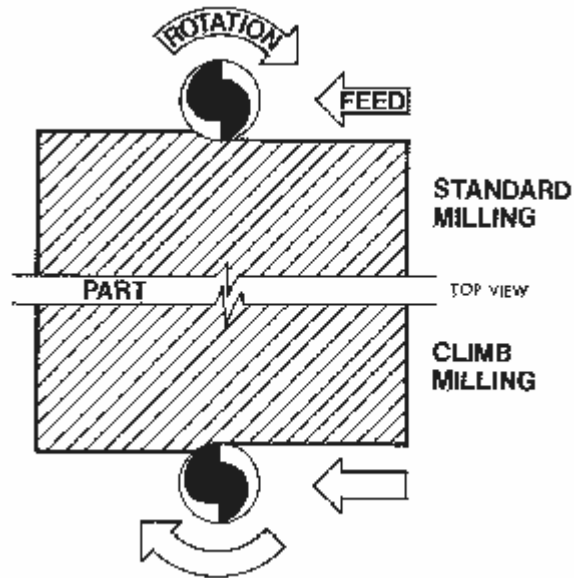
Another type of milling is performed with an adjustable flycutter, which may be used for surfacing. For maximum safety and rigidity, the cutting bit should project from the holder no further than necessary. A 1-1/2" diameter circle of cut is quite efficient, and multiple passes over a surface should overlap about 1/3 of the circle size. For machining aluminum, use a speed of 2000 RPM and remove about .010" (0.25mm) per pass. (See also the flycutter information in the *Sherline Tools & Accessories Catalog*.)



*FIGURE 4- Boring the inside of a hole to exact size with a boring tool held in a boring head.*

## **STANDARD MILLING VS. CLIMB MILLING**

It is important to understand that the cutting action of a milling cutter varies depending upon the direction of feed. Study the relationship of cutting edges to the material being cut as shown in Figure 5. Note that in one case the tool will tend to climb onto the work, whereas in the other case the tool will tend to move away from the cut. The result is that climb milling should be avoided except for very light finishing cuts.



*FIGURE 5-Standard vs. climb milling. (For clarity, consider the cutter moving, although it is actually the part that moves while the cutter remains in one place.)*

## WORKING TO SCRIBED LAYOUT LINES

A common practice when working with a mill is to lay out the hole centers and other key locations using a height gauge and a surface plate. A coloring (usually deep blue) called layout fluid or "Dykem" is brushed or sprayed on a clean surface of the part. A thin layer is best because it dries quicker and won't chip when a line is scribed. The purpose of this fluid is to highlight the scribed line.

Don't prick punch the scribed crossed lines representing a hole center. Using a center drill in the mill spindle and a magnifying glass, bring the headstock down until the center drill just barely touches the scribed cross. Examine the mark left with a magnifying glass and make any corrections needed to get it perfectly on center. You should be able to locate the spindle within .002" (.05mm) of the center using this method.

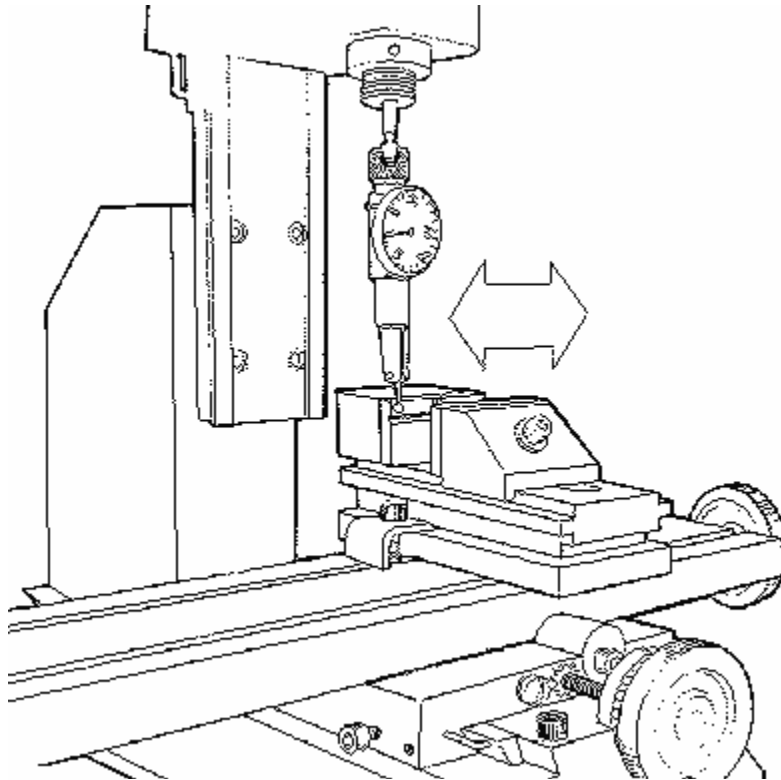
Once the first hole is located in this manner, the additional holes can be located using the handwheels. (This is where the optional resettable "zero" handwheels are handy.) Now the scribe marks are used as a double check and the handwheels take care of the accuracy. Don't forget the rules of backlash and always turn the handwheels in the same direction as you go from one point to the next.

## USE OF A DIAL INDICATOR

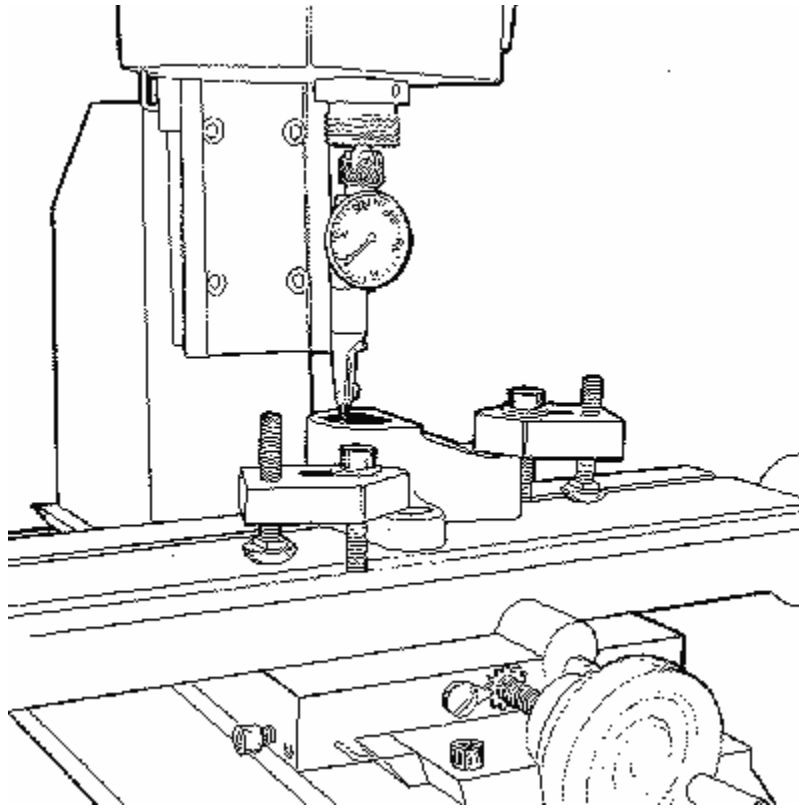
The basis of most accurate machining involves the use of a universal dial test indicator; a small, inexpensive indicator which is calibrated in .001" or .01mm divisions. An

indicator with a large face or one that reads in finer divisions is not necessary for use with this mill. Three major tasks that can be accomplished with an indicator are:

1. Checking the squareness of a setup.
2. Finding the center of a hole.
3. Aligning the work with the machine.



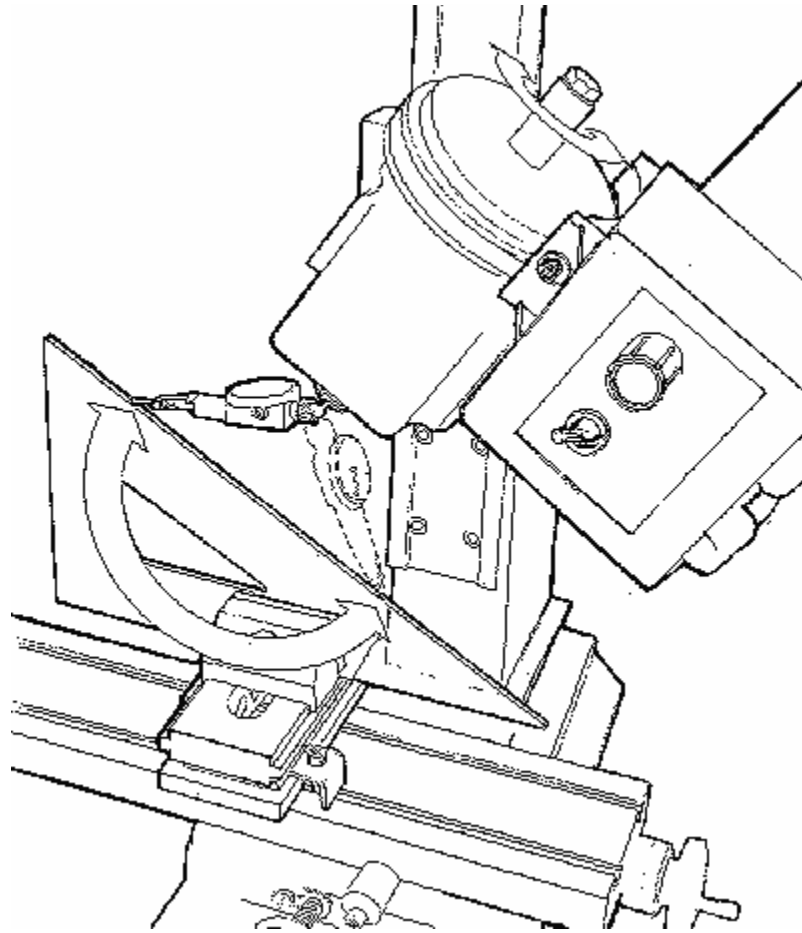
*FIGURE 6-Indicating in the jaws of a vise. Shown is a Starret "Last Word" Indicator. Starret gauges are available in numerous sizes and types. They are manufactured in Athol, Massachusetts and can be purchased from most industrial dealers.*



*FIGURE 7-Indicating in the center of a hole.*

A vise can be mounted or a part can be clamped down exactly parallel with the machine slides by holding the test indicator stationary and moving the slide with which you wish to align. When "indicating in" a vise, always take the reading on the fixed jaw. To start with, use approximately .005" indicator deflection from neutral. Remember that excessive pressure can cause inaccurate readings. Also, try to keep the indicator finger at a reasonable angle to the indicated part or surface. When the part is properly aligned there will not be any deflection on the indicator. If you wish to locate the spindle over an existing hole, place the indicator in the spindle and read the inside surface. Move the "X" and "Y" axes until there is no deflection when the spindle is rotated. At this point, the spindle is in perfect alignment with the hole's center.

When aligning the spindle to used bearing holes, remember that the hole may be worn out-of-round, and it may be impossible to attain zero indicator deflection reading. Boring out a worn bearing hole to a larger diameter and sleeving it with a simple bushing made on a lathe is a fairly common machining operation. With the new bushing pressed in, the bearing will be like new.



*FIGURE 8--Indicating in a 30° head tilt using a mill vise and draftsman's triangle.*

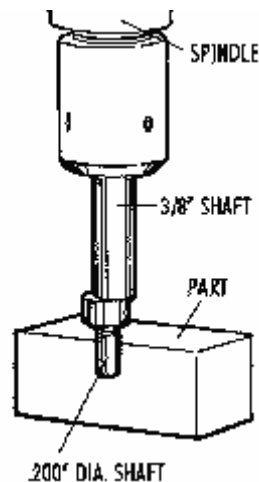
The squareness of your machine may also be checked with an indicator. For instance, alignment of the head can be checked by offsetting the indicator in the spindle so the tip will move on a 5-inch diameter circle. The amount of reading relative to the table is the amount of error. Don't be discouraged to find a few thousandths of an inch error in your machine. This machine has been designed to have the most accuracy commensurate with reasonable cost. In machine tool manufacturing, accuracy and cost run hand in hand. To increase accuracy only a few percentage points could double the selling price, because entirely different manufacturing processes would be required. However, you can personally improve the accuracy of your machine with a few shims if needed by employing your dial indicator.

The column bed is aligned with the column block at the factory. If you remove it, it will have to be realigned by mounting a known "square" on the mill table and adjusting placement of the bed by running an indicator on the square as the headstock is raised and lowered. The same method can be used to check alignment of the column bed to ensure it is square with the "Y" axis. To correct any error (which should be small), place a shim between the column block and the mill base.

## LOCATING THE EDGE OF A PART IN RELATION TO THE SPINDLE

There are two quick methods of "picking up an edge" of a part on a mill. The first is to put a shaft of known diameter in the spindle and see that it runs perfectly true. Using a depth micrometer against the edge of the part, measure the distance to the outside diameter of the shaft. To that dimension add 1/2 the known shaft diameter. You now have the distance from the edge of the part to the centerline of the spindle. Rotate the handwheel on the axis being set exactly this distance and you will have the centerline of the spindle lined up with the edge of the part from which you measured.

The second method is much easier. It involves the use of a clever tool called an "edge finder". These devices have been around for years and have two lapped surfaces held together by a spring. One surface is on the end of a shaft which fits in a 3/8" end mill holder and is held in the spindle. The other is a .200" diameter shaft held to the larger shaft with a spring so it is free to slide around. With the spindle running at approximately 2000 RPM the shorter shaft will be running way off center. As this shaft is brought into contact with the edge you are trying to locate in relation to the spindle, the .200" shaft will be tapped to the center as the spindle rotates. This keeps making the .200" shaft run continually truer. When the shaft runs perfectly true it makes contact with the part 100% of the time. This creates a drag on the surface of the shaft that will "kick" it off center. (See Figure 9.) At this point you know the part is exactly .100" (half the diameter) from the centerline of the spindle. Advancing the handwheel on a Sherline mill two revolutions (.050" per revolution) will bring the edge of the part into alignment with the spindle.



*FIGURE 9--Using an "edge finder" to accurately locate the edge of a part.*

It is important to use a high quality edge finder such as the Starrett 827A shown in the drawing. It must have a 3/8" shaft to fit the end mill holder on the Sherline mill. Metric sized edge finders are also available which work in the same manner.



## DETERMINING DEPTH OF CUT

There are no firm rules other than common sense for determining depth of cut. A .030" cut depth with a 3/16" end mill in aluminum could be considered light, but .003" cut depth in steel with a 1/32" diameter end mill would break to cutter. Start with very light cuts and gradually increase the depth until satisfactory results are achieved. Try to develop the skill of knowing how much cut is satisfactory without breaking the cutter or damaging the work.

Note that regular end mills should not be used for drilling; however, they may be employed to enlarge an existing hole. The cutting edges deserve more respect than those of drills even though similar in appearance; they are designed to cut with the sides.

## WORK ACCURATELY

It should be remembered that a good machinist is capable of making a part to much closer tolerances than those of the machine with which he is working. The accuracy of the parts you make is limited only by your skill as a craftsman and the quality of your measurement equipment. Accuracy should be the ultimate goal of every machinist!

## CUTTING SPEEDS FOR MILLING

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### SPEED ADJUSTMENT FORMULA

$$\text{SPINDLE RPM} = (3.82 \times \text{S.F.M.}) \div D$$

**S.F.M. = The rated Surface Feet for Milling. For drilling, use 60% of the rated surface feet.**

**RPM = The rated spindle speed in Revolutions Per Minute**

**D = The diameter of work in inches**

*FIGURE 10-Formula for adjusting spindle speed for cutting a given diameter.*

NOTE: To estimate RPM, remember that the speed range of your vertical mill is from 0 to 2800 RPM. (The lowest usable speed is about 70 RPM, so we use that in our specifications. To obtain much more torque at the lower speed ranges, the drive belt can be switched to the smaller diameter positions on the spindle and drive pulleys.) Therefore, in the normal belt position, half speed is approximately 1450 RPM and so on. You can estimate these speeds by a combination of the setting on the speed control knob and the sound of the motor itself.

---

## SPEED ADJUSTMENT CHART

### END MILLS (Slot and side milling)

MATERIAL	CUT SPEED (S.F.M.)	1/8" DIA.	1/4" DIA.	3/8" DIA.
Stainless Steel, 303	40	1200 RPM	600 RPM	400 RPM
Stainless Steel, 304	36	1100	500	350
Stainless Steel, 316	30	900	450	300
Steel, 12L14	67	2000	1000	650
Steel, 1018	34	1000	500	350
Steel, 4130	27	800	400	250
Gray Cast Iron	34	1000	500	350
Aluminum, 7075	300	2800	2500	2000
Aluminum, 6061	280	2800	2500	2000
Aluminum, 2024	200	2800	2500	2000
Aluminum, Cast	134	2800	2000	1300
Brass	400	2800	2800	2800

### DRILLS

MATERIAL	CUT SPEED (S.F.M.)	1/16" DIA.	1/4" DIA.
Carbon Steel	36	2000 RPM	550 RPM
Cast Iron, Soft	30	1800	450
Stainless Steel	24	1400	360
Copper	72	2000	1100
Aluminum, Bar	240	2000	2000
Aluminum, Cast	120	2000	2000

*FIGURE 11-End mill and drill speed adjustment chart.*

# CUTTING TOOLS AND STANDARD ACCESSORIES

## END MILLS

End mills are the standard vertical mill cutting tools. We recommend 3/8" shank end mills held in the [3/8" end mill holder P/N 3079](#). One of the benefits of 3/8" end mills is they are available in a large range of sizes. The end mill is held with a set screw on its flat surface and it can be easily changed. They are also lower in price than miniature cutters because of their popularity. You can also use miniature series end mills having 3/16" or 1/4" shank sizes which should be held in collets. (End mills held in collets must be single ended, while end mills held in our end mill holders may be double ended.) We recommend using 2-flute, high-speed steel end mills for aluminum because the flutes are less prone to clog with chips. Use 4-flute cutters for cutting steels with lower RPM. The solid carbide tools are not suggested since they are very expensive and the cutting edges will chip unless used with heavy duty production equipment.



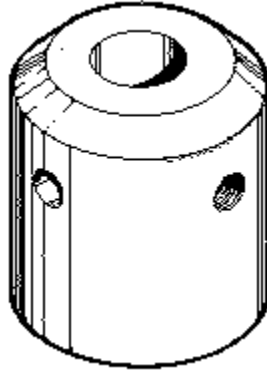
*FIGURE 12-A typical end mill*

As a convenience to our customers, SHERLINE keeps in inventory many of the popular sizes of end mills which are appropriate for use on our machines. See tooling price list for selection. End mills may also be purchased from your local industrial machine shop supply outlet (see yellow pages under "Machine Shop Supplies") or from mail order industrial suppliers.

Because small diameter cutters (less than 1/8") are quite fragile, the largest diameter cutter possible for the job requirements should be employed. Be certain that the RPM is appropriate before attempting to remove any metal. An end mill can be instantly damaged if a cut is attempted at excessive RPM. Like all cutting tools, end mills will have a short lifespan when used for machining steel or other exotic materials. Save new cutters for finish work. Do not use small diameter end mills with long flutes unless absolutely necessary because of excessive cutter deflection (bending).

## RESHARPENING END MILLS

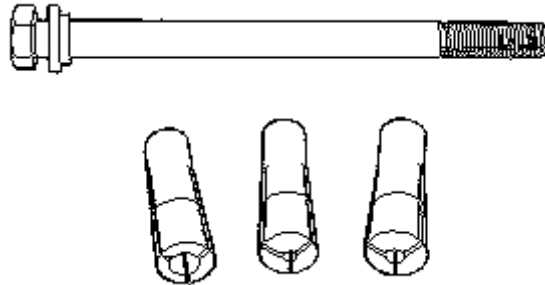
End mills can be resharpened by your local tool and cutter grinding shop. End mills lose their cutting edge clearance after a couple of sharpenings and should no longer be reused.



*FIGURE 13-3/8" End Mill Holder*

### **3/8" END MILL HOLDER (P/N 3079)**

The 3/8" end mill holder makes it easy to use the popular (and less expensive) 3/8" end mills. Using double ended end mills is economical and easy with this holder as tools are changed by simply loosening a set screw and changing the tool. The holder is now also available to hold smaller size tools in the same manner. The 3/16" end mill holder is P/N 6080 and the 1/4" end mill holder is P/N 6079.



*FIGURE 14-3/8" End Mill Holder*

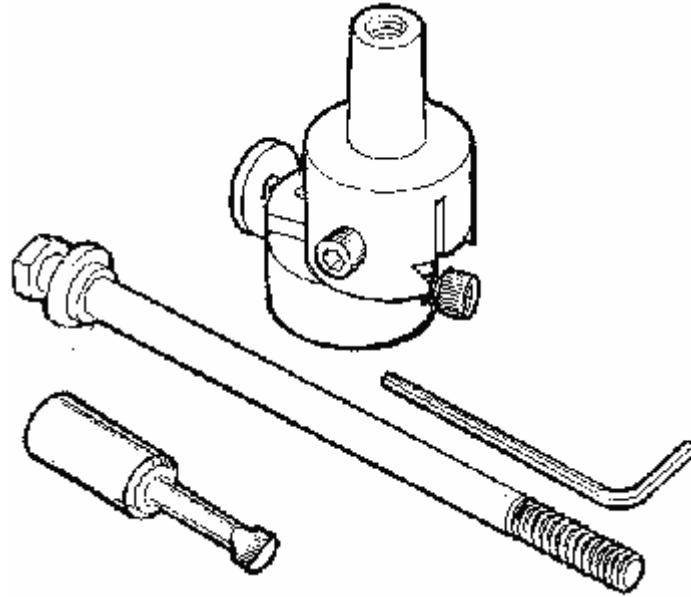
### **MILL COLLET SET (P/N 3060)**

The main purpose of the mill collet set is to hold end mills. The spindle nose has an internal Morse No. 1 taper, which closes the collet as the drawbolt is tightened. Morse tapers are approximately 5/8" per foot and are self-locking. Therefore, to loosen a collet, the drawbolt must be loosened a few turns and given a few light taps with a hammer.

### **BORING HEAD (P/N 3054) AND BORING TOOLS**

The main purpose of the boring head is to eliminate the need for a large inventory of drills and reamers. A small milling machine would not have the power or rigidity to turn

a one-inch diameter drill even if one could be obtained that would fit. However, holes of even larger diameters can be accurately bored to size with a little patience and care.

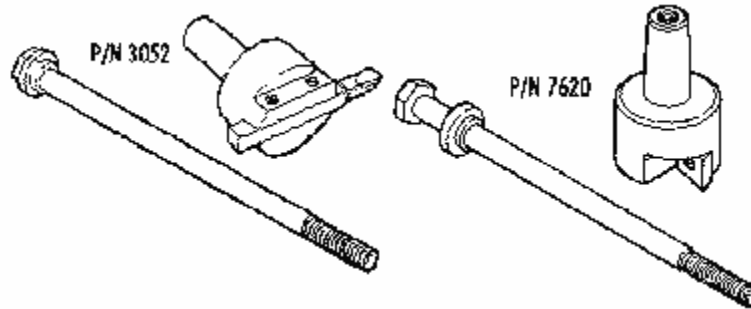


*FIGURE 15-Boring Head and **Boring Tool**. P/N 3061 is for 1/4" (6.4mm) min. diameter by .60" (15.2mm) max. depth hole. P/N 3063 is for 5/16" (7.0mm) min. dia. by 1.0"(25mm) max. depth hole. Both have a 3/8" diameter shaft.*

Boring heads work on the same cutting principle as lathe boring, except that the cutting tool turns while the work remains stationary. (In the case of a lathe, the work turns and the cutter remains stationary.) The boring head is designed to employ cutting tools with a 3/8" shank. SHERLINE offers two boring tools with lengths appropriate for the SHERLINE mill. It is sometimes advisable to remove excessive tool shank length from standard (non-SHERLINE) 3/8" boring tools in order to improve rigidity. (See Figure 4 for a boring tool in use.)

Tool sizes are listed indicating the smallest diameter hole that can be bored and the maximum depth that can be cut. For best results, use the largest diameter possible with the shortest lengths. A .010" cut represents a good starting point.

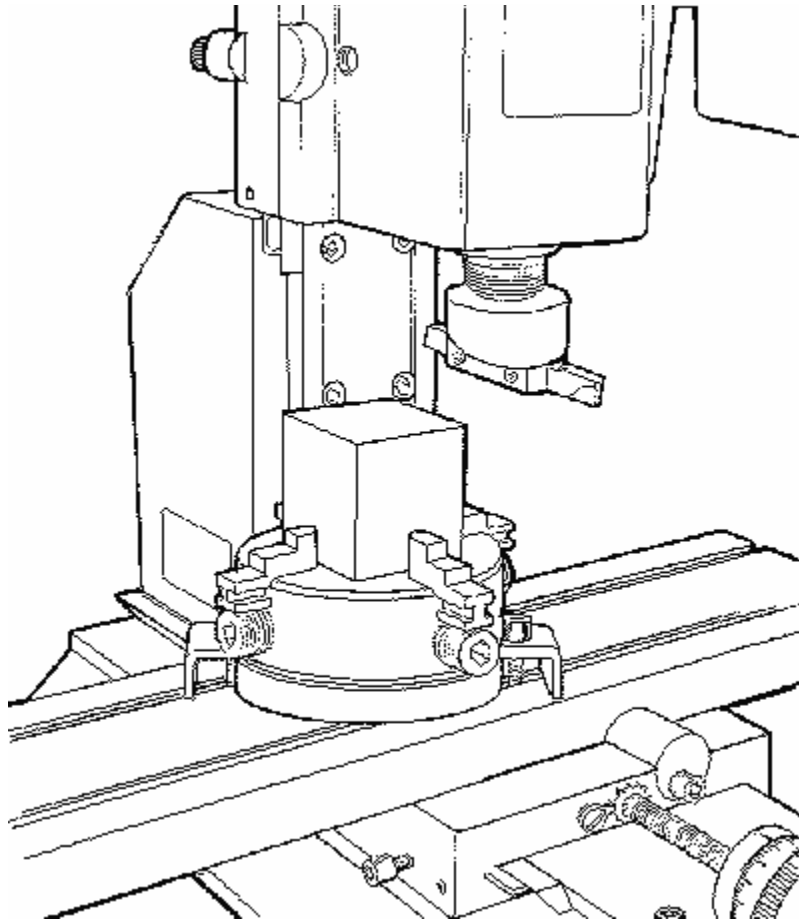
If boring a hole where a flat bottom is required, it is advisable to stop the down feed at about .002" above the desired depth, turn off the motor and cut the remaining distance by hand turning the spindle to eliminate any possibility of chatter.



*FIGURE 16-Standard flycutter (left) and inserted tip flycutter (right) with their drawbolts.*

## **FLYCUTTERS (P/N 3052 and P/N 7620)**

For machining flat surfaces, the flycutter shown in the SHERLINE Tool & Accessory Catalog is recommended. It is imperative that the tool be used with utmost care. EYE PROTECTION IS A MUST, and the work as well as the cutting tool must be properly held. The big advantage of a flycutter is its ability to take light cuts up to 2" wide and to give an excellent surface finish. It is ideal for squaring up work. Also, the machining stresses are lower than one might imagine, because very little crushing action takes place at the cutting edge, unlike an end mill. Flycutting tools look like left-hand lathe tools, and although the fly cutter (P/N 3052) comes with a brazed carbide tool, high speed tools work quite well and can be sharpened on any grinder.



*FIGURE 17-A typical setup for flycutting.*

For those who prefer the advantages of working with inserted carbide tip tools, the P/N 7620 flycutter is available. It uses replaceable carbide cutting inserts which last longer than steel tools without sharpening, plus they provide an excellent finish on hard to machine materials like cold rolled and stainless steels. The cutter shape allows it to cut a straight shoulder on a part, something not possible with a standard flycutter. Included is the toolholder, a drawbolt, a 2-edged carbide insert and Torx T-15 driver and mounting screw. Additional inserts are available (P/N 7622).

## **DRILLS AND DRILL CHUCK (P/N 3072)**

The 1/4" drill chuck available for this vertical mill is supplied complete with a Morse No. 1 arbor and a drawbolt to hold it securely in place. Drilling can be accomplished by raising and lowering the entire head with the vertical feed handwheel. This allows for very accurate control of feed rate and hole depth. For accurately located holes we again stress the importance of using center drills.

Drills should be kept in excellent condition, either by replacement or proper resharping. Good quality high speed steel drills should be employed. A dull or

improperly sharpened drill can cut oversize by as much as 10%. When you start to drill, the initial penetration should be no more than twice the diameter of the hole before you retract the drill, clear the chips and add coolant with the tip of a small brush. From then on, do not try to drill deeper than the diameter of the drill without clearing the chips and adding coolant. For example:

**To drill a 1/8" diameter hole 1" deep:**

<b>OPERATION</b>	<b>TOTAL DEPTH</b>
1st Pass: 2 times diameter or 1/4"	1/4"
2nd Pass: 1 times diameter or 1/8"	3/8"
3rd Pass: 1 times diameter or 1/8"	1/2"
Etc.	Etc.

You may encounter recommendations exceeding these figures, but they are meant for automatic equipment with pressurized coolant systems.

It is difficult to maintain tolerances of better than +.003"-.000" with a drill. If tolerances closer than these are required, a reamer must be employed. Try to use fractional size reamers whenever possible rather than decimal sizes, because the cost difference can amount to 2 or 3 times higher. (The length of reamers may prevent their use for some operations on machines of this size.)



*FIGURE 18-Typical Center Drill*

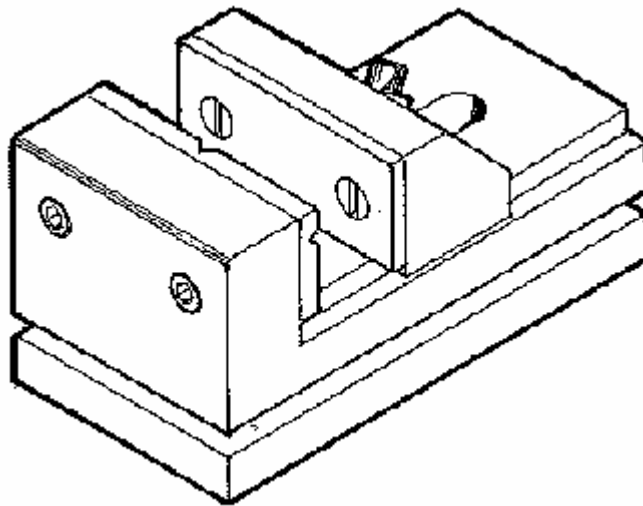
To accurately start holes, center drills must be used. They have a small tip which accurately starts the hole, and then the shaft widens with a 60° cutting face to the final diameter. Care must be taken to employ cutting oil and to clear the drill frequently. If this is not done, the fragile tip may load up and twist off even in soft materials. Center drills are available in a variety of sizes, but for general work we recommend No.1.

<b>SIZE</b>	<b>BODY DIA.</b>	<b>DRILL DIA.</b>	<b>DRILL LENGTH</b>	<b>LENGTH OVERALL</b>
000	1/8"	.020"	3/64"	1-1-4" </TD



00	1/8	.025	1/16	1-1/4
0	1/8	.031	1/16	1-1/4
1	3/16	.046	3/64	1-1/4
2	3/16	.078	5/64	1-7/8
3	1/4	.109	7/64	2

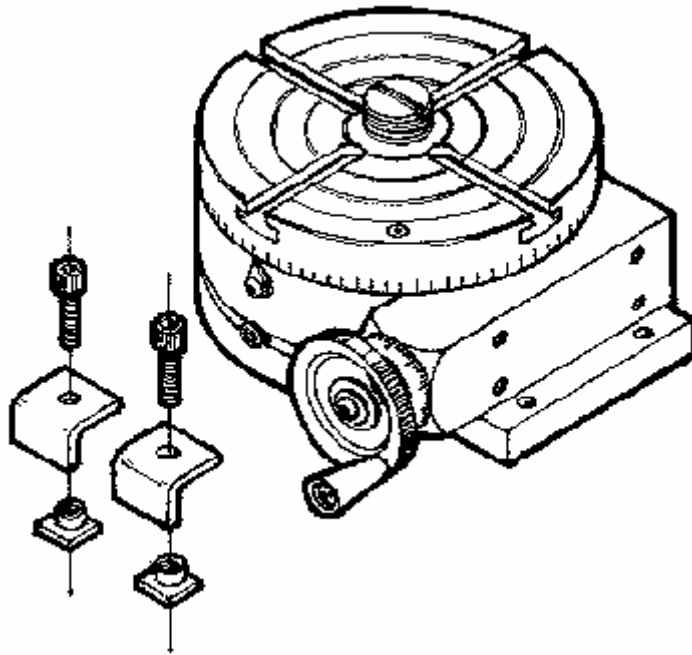
*FIGURE 19-Table of commonly available center drill sizes*



*FIGURE 20-The SHERLINE Mill vise*

### **MILL VISE SET (P/N 3551)**

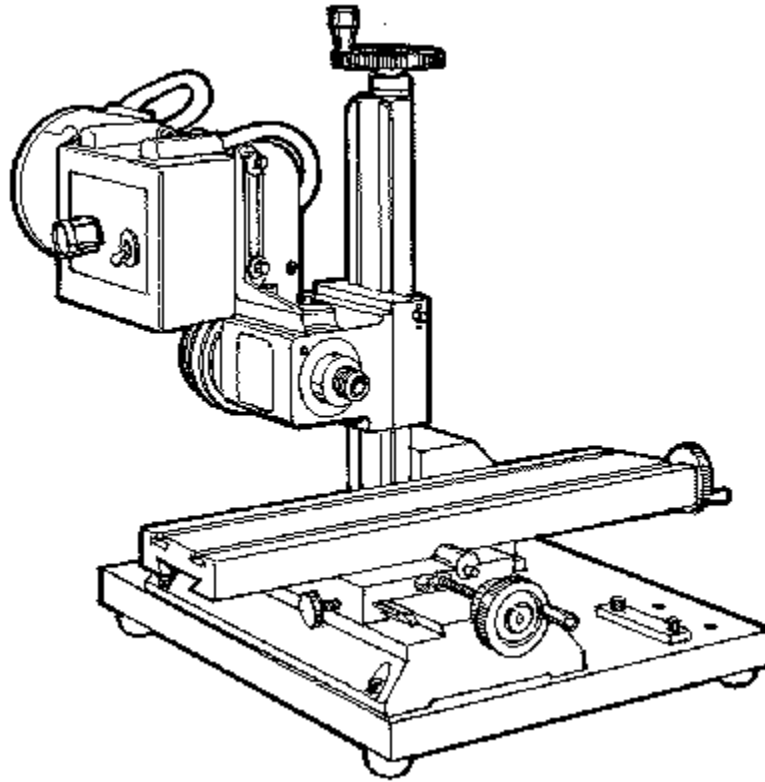
The vise shown here and in figures 42 and 44 is furnished with special clamps that allow it to be clamped in any position on the mill table. The vise capacity is 2 inches. It has a movable jaw which is pulled down while clamping, eliminating any chance for the jaw to lift. It is the most convenient way to hold small parts for milling.



*FIGURE 21-SHERLINE's 4" Rotary Table*

### **4" ROTARY TABLE (P/N 3700)**

The rotary table mounts to the mill table and provides a rotary axis for milling. Each increment on the handwheel represents  $1/10^\circ$  of rotation, so a circle can be divided into 3600 segments without interpolation. 72 handwheel revolutions rotate the table one time. It can be used to mill a radius on a part, cut a circular slot or drill precision circular hole patterns. Used with the right angle attachment (P/N 3701) and right angle tailstock (P/N 3702) it can also be used to cut gear teeth. A rotary table used with a mill allows a machinist to produce virtually any part he can design. The only limits are size, not complexity. The compact size of this high quality rotary table also make it a good choice for use on larger machines where its size would offer an advantage in working with small parts.



*FIGURE 22-The Horizontal Milling Conversion turns the standard SHERLINE vertical mill into a horizontal mill. This greatly expands the operations that can be completed on the mill.*

## **HORIZONTAL MILLING CONVERSION (P/N 6100)**

A number of milling operations require the application of the cutting tool from the side rather than from the top. A 3/4" thick aluminum base 10.5" x 12.5" allows the mill column to be mounted separately from the base for a variety of milling configurations. The headstock is rotated 90° and work is machined from the side, allowing larger surfaces to be worked on without having to reclamp the work.

The black anodized mounting plate is predrilled to mount the base and column in several possible locations. Alignment bars and a selection of appropriate bolts are included to make it easy to accurately relocate the column. Rubber feet insulate the table for quiet, vibration free operation. (Note: the column base should be shortened by 2" for best operation. Instructions are provided or we will shorten your column for you. The modification is listed as P/N 6101.)

## **USE OF ACCESSORIES AND ATTACHMENTS**

Your mill can be made more versatile with the addition of suitable attachments and accessories. These include various chucks and collets, a thread cutting attachment,

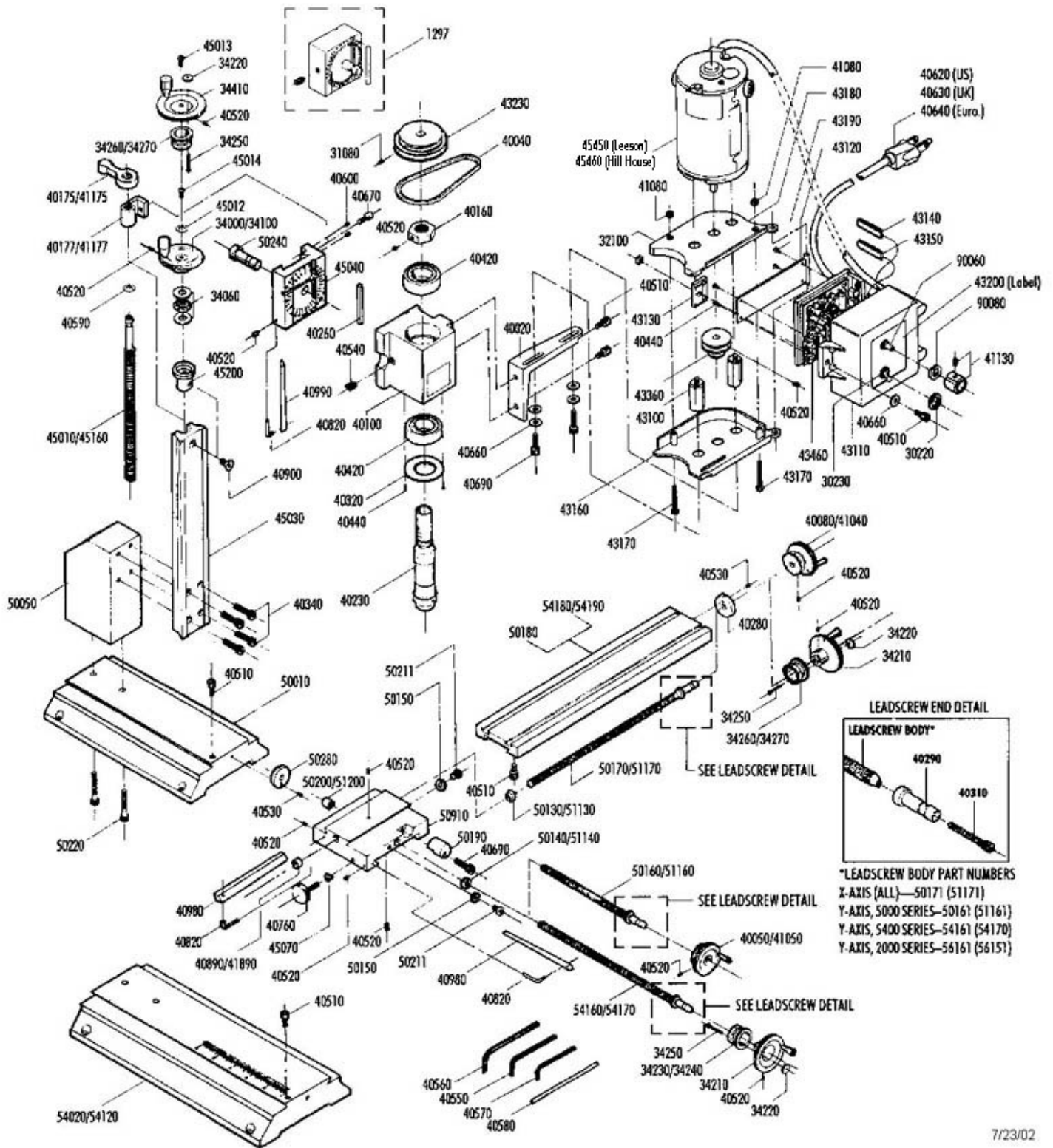
vertical milling column, knurling tool, a live center and many others. Remember that accessories and attachments must be cared for in the same way as the lathe. Always make sure that threads are free from metal chips and dirt. Chucks should be lightly oiled frequently so that they continue to function smoothly and accurately. Gears in the thread cutting attachment should be lightly greased when in operation. Some attachments have moving slides and these should be lubricated in the same way as the slides in your lathe. Each accessory comes with complete instructions for its use when it is purchased.

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## **MILL EXPLODED VIEW PARTS DIAGRAM**

*Refer to part number list below drawing for part number name and material.*

**EXPLODED VIEW ONLY:** To view and print out just the exploded view and part numbers for reference, [CLICK HERE](#) for exploded view only. (Note: Requires [Acrobat Reader](#) program to view.)



\*LEADSCREW BODY PART NUMBERS  
 X-AXIS (ALL)—50171 (51171)  
 Y-AXIS, 5000 SERIES—50161 (51161)  
 Y-AXIS, 5400 SERIES—54161 (54170)  
 Y-AXIS, 2000 SERIES—56161 (56151)

## **PART NUMBERS AND DESCRIPTIONS, SHERLINE LATHES AND MILLS**

KEY TO MATERIALS: A=Aluminum, B=Brass, C=Composite, DC=Die Cast,  
P=Plastic, U=Urethane, S=Steel

<b>PART NO.</b>	<b>DESCRIPTION</b>	<b>MATERIAL</b>
12970	Headstock Spacer Block (Deluxe Mill)	A/S
30220	Toggle Switch Retaining Ring	S
30230	Toggle Switch	--
31080	10-32 x 3/8" Flat Pt. Set Screw	S
34000 (34100)	Oversize Handwheel, Inch (Metric)	A
34060	Thrust Bearing Washer Set	Ball
34200 (34300)	2" Zero Adjust. Hndwhl. Asby., Inch (Metric)	A/S
34210	2" handwheel Body	A
34220	Handwheel locking Nut	S
34230 (34240)	Y Axis/Crossslide Collar, Inch (Metric)	A
34250	6-32 x 7/8" Pan Hd. Screw	S
34260 (34270)	X, Z Axis and Leadscrew Collar, Inch (Metric)	A
34400 (34500)	2-1/2" Zero Adjust. Hndwhl. Asby., Inch (Metric)	A/S
34410	2-1/2" Handwheel Body	A
40010	15" Lathe Bed	DC
40020	Motor Bracket	Diecast
40040	Drive Belt	Urethane
40050 (41050)	1-5/8" Handwheel, Y Axis/Crossslide, Inch (Metric)	A

40070	Faceplate	Diecast
40080 (41040)	1-5/8" Handwheel, X Axis/Leadscrew, Inch (Metric)	A
40090	Drive Dog	Diecast
40100	Headstock Casing	A
40120	15" Lathe Bed	S
40160	Preload Nut	S
40170 (41170)	Saddle Nut, Inch (Metric)	B
40180	Tool Post	A
40200 (41200)	Leadscrew, Inch (Metric)	S
40220 (41220)	Feed Screw, Inch (Metric)	S
40230	Headstock Spindle	S
40240	Headstock Pivot Pin, Lathe	S
40250	Tool Post Tee Nut	S
40260	Head Key	S
40270 (41270)	Tailstock Spindle, Inch (Metric)	S
40280	Thrust Collar	S
40300	Leadscrew Thrust	S
40320	Bearing Washer	S
40330	10-32 x 5/8" Skt. Hd. Cap Screw	S
40340	110-32 x 1" Skt. Hd. Cap Screw	S
40370	Leadscrew Support	S
40380	#1 Morse Center	S
40390	#0 Morse Center	S
40400	Plug Button	P

40420	Headstock Bearing	Ball
40440	Self Tapping Screw	S
40500	10-24 x 7/8" Skt. hd. Cap Screw	S
40510	10-32 x 3/8" Skt. Hd. Cap Screw	S
40520	10-32 x 3/16" Cup Pt. Set Screw	S
40530	5-40 x 3/8" Skt. Hd. Cap Screw	S
40540	5/16-18 x 3/4" Cone Pt. Set Screw	S
40550	5/32" Hex Key	S
40560	3/16" Hex Key	S
40570	3/32" Hex Key	S
40580	Spindle Bar	S
40590	1/4" I.D. Washer	S
40600	10-32 x 1/4" Flat Pt. Set Screw	S
40620	Power Cord, USA	--
40630	Power Cord, UK	--
40640	Power Cord, Europe	--
40660	3/16" I.D. Washer	S
40670	10-32 x 1/2" Skt. Hd. Cap Screw	S
40690	10-32 x 3/4" Skt. Hd. Cap Screw	S
40760	10-32 x 5/8" Thumbscrew	S
40820	Gib Lock	S
40860	Tailstock Locking Screw Grommet	P
40870	Tailstock Spindle Locking Screw	S
40890 (41890)	Slide Screw Insert, Inch (Metric)	B
40900	10-32 x 3/8" Flat Hd. Skt. Screw	S
40910	Saddle	A



40980	Crossslide Gib	Composite
40990	Saddle Gib	Composite
41080	6-32 Hex Nut	S
41110	Tailstock Casing	A
41130	DC Speed Control Knob and Set Screw	P/S
43100	DC Motor Standoff	A
43110	DC Speed Control Case	P
43120	DC Speed Control Hinge Plate	P
43130	DC Speed Control Cover Mounting Plate	P
43140	DC Speed Control Tab, Small	P
43150	DC Speed Control Tab, Large	P
43160	Belt Guard, Outer	P
43170	6-32 x 1-3/8" Pan Hd. Screw	S
43180	Belt Guard, Inner	P
43190	#2 x 1/4" Flat Hd. Sheet Metal Screw	S
43200	DC Speed Control Foil Label	Foil
43230	Stepped Main Spindle Pulley	A
43360	Stepped Motor Pulley	A
43460	DC Speed Control Electronics	--
44010	24" Lathe Base	DC
44120	24" Lathe Bed	S
44200 (44230)	24" Leadscrew, Inch (Metric)	S
44210 (44220)	Slide Screw, Inch (Metric)	S
44880	Crossslide	A
45010 (45160)	Leadscrew, Z Axis, Inch (Metric)	S

45030	Column Bed	S
45040	Saddle, Z Axis	A
45070	Lock, Teflon	P
45170	Column Saddle Lock	P
45180	3/16" Ball Bearing	S
45190	#10 Type B Washer	S
45200	Leadscrew Thrust, Bored	S
45450 or 45460	45450=DC Motor with externally replaceable brushes (Leeson) 45460=DC Motor with externally replaceable brushes (Hill House) (NOTE: We purchase motors from two different manufacturers to keep pricing competitive. Specifications on both are the same, but replacement motors should be ordered with the same part number as the original. Part number is printed on motor.)	Motor
50010	10" Mill Base	A
50050	Column Base	A
50120	Backlash Lock	S
50130 (51130)	Backlash Nut, X Axis, Inch (Metric)	S
50140 (51140)	Backlash Nut, Y Axis, Inch (Metric)	S
50160 (51160)	Leadscrew, Y Axis, Inch (Metric)	S
50170 (51170)	Leadscrew, X Axis, Inch (Metric)	S
50180	Mill Table	A
50190	X Axis Lock	S
50200 (51200)	Nut, Y Axis, Inch (Metric)	B
50210	8-32 x 1/4" Pan Hd. Screw	S

50220	1/4-20 x 1-3/4" Skt. Hd. Cap Screw	S
50240	Headstock Pivot Pin, Mill	S
50280	Thrust Collar, Mill	S
50910	Saddle	A
50980	Gib, X Axis	C
50990	Gib, Y Axis	C
54020 (54120)	12" Mill Base, Deluxe Engraved, Inch (Metric)	A
54160 (54170)	Leadscrew, Y Axis, Deluxe Mill, Inch (Metric)	S
54180 (54190)	Mill Table, Deluxe Engraved, Inch (Metric)	A
90060	DC Speed Control 5K Potentiometer	--
90080	3/8-32 Hex Nut	S

To find get more information on any SHERLINE accessory,