East Tennessee State University
Department of Technology

ENTC 2200 • Machine Tool Technology

C-Clamp Assembly
Laboratory Project Instructions

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Laboratory Project Instructions

NOTES

A. The purpose of these instructions is to tell you ***WHAT*** to do and the order in which to do it, rather than how to do it. It is expected that you will attend ***ALL*** of the class lectures and demonstrations so that ***you will learn how to perform all necessary procedures***. When procedural questions arise, consult your instructor or lab supervisor.

B. Follow laboratory safety procedures at all times.

C. ***Deburr*** and/or break all sharp edges using a file after all sawing, milling, or drilling operations.

D. When you make an error, ***DO NOT AUTOMATICALLY START OVER***. If you scrap your workpiece and start over every time you make an error, you'll never finish your project! Consult with your instructor to determine whether the error is catastrophic and requires starting over. If it isn't catastrophic, live with the error(s) and continue on to finish your project. You can have several errors and still get an "A" in the course. Failure to complete your project yields ½ credit at best!

E. Where appropriate, either figures have been directly inserted into the body of the document or drawing numbers have been provided. If using a web browser to view the electronic version of this document, clicking on a hot-linked URL should launch the appropriate viewer and/or load the document directly.

F. Some steps of this project require some form of calculation, decision, or observation by the student. Such instructions can be identified by an underline (i.e., _____).

C-Clamp Frame
Drawing No. 2200-51

01. Study Drawing 2200-51 to determine the kind and size of stock required.

    Material type: _____

02. Measure and cut frame blank from bar stock (see Figure 1) using power hacksaw.

    A. Calculate Length: Length = print dimension plus 1/16" per end.

       Length = _____ inches

    B. Locate appropriate flat bar stock in rack. Measure and secure stock in power hacksaw vice. Cut frame blank using coolant. When the cut is complete, carefully wipe coolant from stock (Watch for burrs!)and return stock to rack. Carefully clean frame blank.

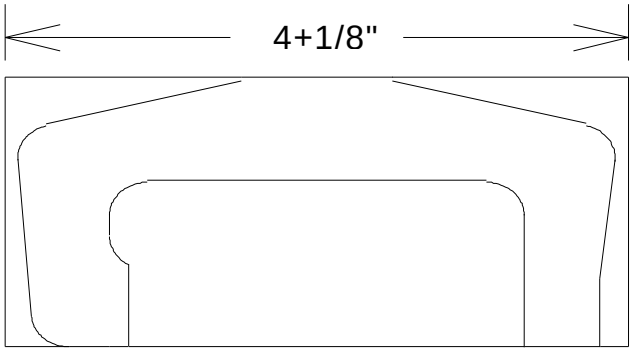

Fig. 1 Saw Stock to Length

03. Use a 10" mill file to remove all burrs and break all sharp edges. ***Remember to do this after every operation that produces sharp edges or burrs***.

04. Mill the ends square to the edges, maintaining the overall length per Dwg. 2200-51 (see Figure 2):

    A. Stone and clean vertical mill table and vice bottom. Install and indicate vice in parallel to the X-axis within 0.001" runout. Secure vice.

    B. Clean vice jaws. Install frame blank and square one end. Deburr part. Flip blank and square second end to length. Deburr part.

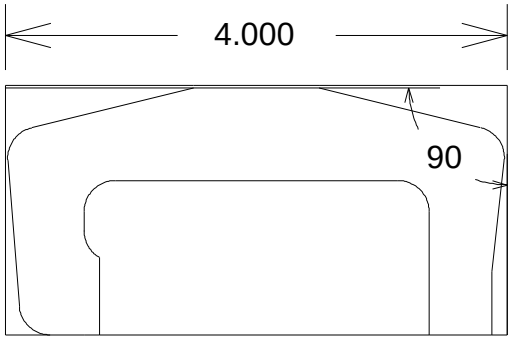

Fig. 2 Square Ends & Cut to Length

05. Lay out the throat geometry (see Fig. 3):

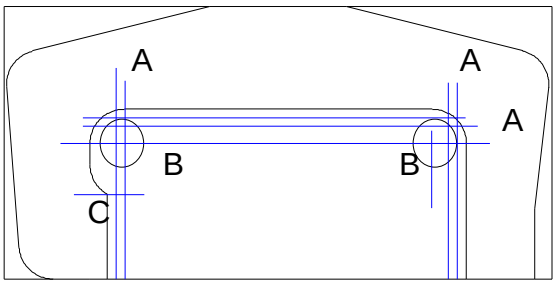

Fig. 3 Layout Holes/Bandsaw Path

A. Scribe the lines to allow 1/16" stock ***per side*** for machining. It is suggested that two lines 1/16" apart be scribed as a path for the saw blade to follow.

B. Lay out the center point of each corner fillet per the drawing's location specifications. You'll later drill holes 1/8" undersize to allow the 1/16" of finishing stock for the fillets.

C. Lay out a line on the face of the clamp frame representing the location of the anvil undercut breakout.

06. Drill two 3/8" diameter holes at the location specified in the drawing for the throat corner fillets.

07. Saw out the excess stock from the throat, using the bandsaw.

A. Use a sharp 1/4" 10-tooth blade running at 100 sfpm.

08. Using a vertical mill, machine the throat geometry:

A. Make sure the vise is clean and has been indicated in parallel to the X-axis within 0.001" runout.

B. Using the throat milling fixture (see Figure 4) and appropriate parallels, mount the workpiece in a mill vise such that the top of the workpiece protrudes above the vise's fixed jaw approximately 1/8".

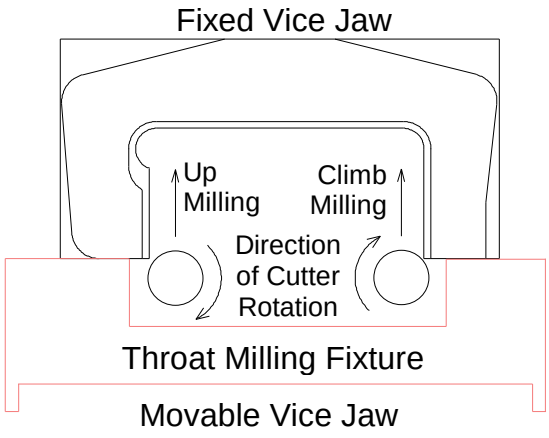

Fig. 4 Throat Milling Set-up & Milling Modes

C. Draw a "C" shaped diagram on a piece of paper and then keep the paper handy for noting the dial readings as you machine each side of the throat opening.

D. Mount your sharp ½" (0.500") 2-flute end mill in the spindle.

E. Rough machine the throat opening, feeding the cutter in the conventional (up-milling) mode (see Figure 4), traversing around the throat surfaces in a clockwise direction.

i. Start the spindle, making certain its running in the correct direction, and bring the cutter into contact with the left-hand throat surface. Then move the cutter back beyond the starting point for the cut.

ii. Dial in for about a 0.020" depth of cut, lock the table (X axis), and ***record the dial reading***.

iii. Feed the cutter in the Y+ direction towards the center (back) throat surface until it becomes tangent plus 0.020" to the saw-cut surface. Then lock the saddle (Y axis) and ***record the dial reading***.

iv. Loosen the table lock and feed the cutter in the X+ direction towards the right hand throat surface until it becomes tangent plus 0.020" to the saw-cut right-hand surface. Then lock the table and ***record the dial reading***.

v. Loosen the saddle lock and feed the cutter in the Y-direction towards the front of the throat opening.

F. Semi-finish machine the throat opening, feeding the cutter in the ***opposite*** direction, in the ***climb*** (down-milling) mode (See Figure 4), traversing around the throat surfaces in a counter-clockwise direction.

i. Utilizing the previously-recorded dial readings from the roughing operation, take an additional 0.010" from each of the three surfaces.

G. Brush away the chips and measure the dimensions.

i. Using a micrometer and a vernier caliper or other appropriate instruments, measure the dimensions and compare to drawing specifications.

ii. Calculate how much remains to be removed from each of the three surfaces to bring the dimensions into tolerance.

iii. Then calculate and note what the dial readings will be for each surface's finish cut.

H. If more than 0.010" remains on any of the surfaces, make a second roughing pass, feeding the cutter in the conventional (up-milling) mode, traversing around the throat surfaces in a clockwise direction, leaving 0.010" on each surface for a finishing pass.

i. ***Record the dial readings*** for each surface as needed.

I. To finish machine the throat opening (see Figure 5), feed the cutter in the ***climb*** (down-milling) mode, traversing around the throat surfaces in a counter-clockwise direction, using the previously-calculated dial readings.

J. Machine the 1/8" undercut around the anvil.

i. Using the dial readings from the finish cut, position the cutter near the left-hand side and tangent to the center surface

ii. Lock the saddle (Y axis).

iii. Feed the cutter in the X-direction into the left-hand side, entering 0.125" beyond the finished surface's dial reading.

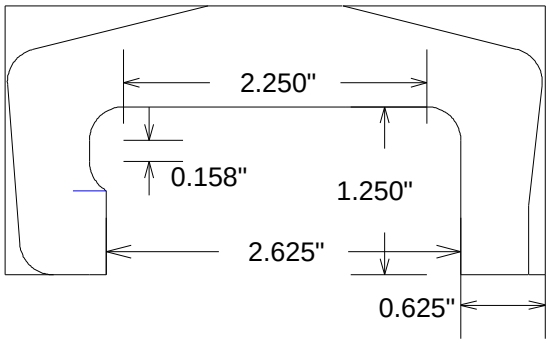

Fig. 5 Final Throat Geometry

iv. Lock the table (X axis).

v. Release the saddle lock, but not completely. Leave enough tension on the lock to act as a brake.

vi. ***Gently*** feed the cutter toward the front of the throat (in the Y- direction) until the cut "breaks out" at the anvil undercut boundary layout line.

vii. Stop the spindle and retract the cutter.

K. Brush away the chips and check all of the dimensions before removing the workpiece so that errors can be corrected using the still-valid dial readings.

L. Remove the workpiece from the vise and deburr the workpiece.

09. Drill and tap the screw hole.

A. Lay out the location of the screw hole on the appropriate end of the clamp frame.

B. Use a sharp prick punch followed by a sharp center punch to make an indentation at the screw hole location suitable for engaging the point of the pilot drill.

C. Determine the size of the tap drill (= nominal screw diameter minus the pitch).

i. Tap drill size = _____.

D. Mount the workpiece vertically in a drill press vise (see Figure 6).

> ***CAUTION!***
>
> In the next step, ***do not bolt the vise itself to the table***.
> The vise must be allowed to "float should the drill or tap seize."

E. Secure two tee bolts/washers/nuts in such positions as to act as barriers to prevent the vise from rotating in either direction

F. Drill a pilot hole approximately 1/16" smaller than the tap drill size.

   i. Calculate RPM:
   Spindle RPM = CS * 4/D

   RPM = _____.

G. Enlarge the pilot hole with the tap drill.

H. Countersink the tap drill hole to a chamfer diameter 1/32" larger than the screw's nominal diameter. Run the countersink at about 300 RPM to avoid chatter.

I. Tap the hole.

   i. Mount the tap (check to be sure it is in good condition) in the drill chuck ***very*** tightly so it will not slip.

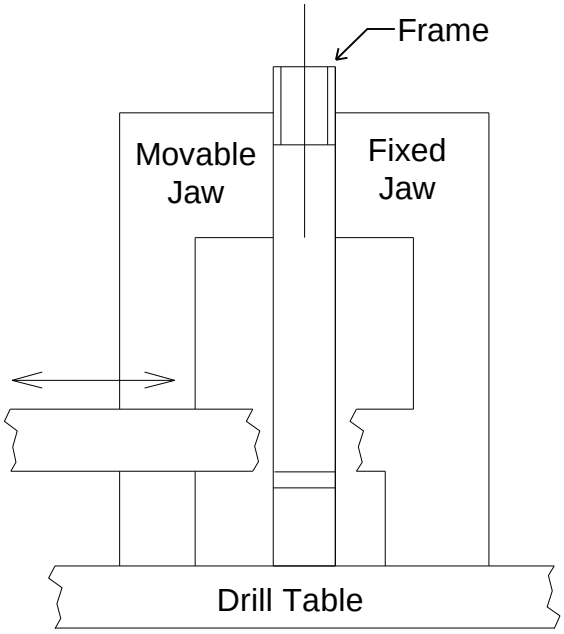

Fig. 6 Drill Thru Hole

   ii. Set the spindle speed at about 200 RPM for tapping. Why so slow????

   iii. Start the spindle and apply a little TAP MAGIC tapping fluid to the tap and hole.

> ***CAUTION!***
>
> In the next procedure, ***do not stop applying downward pressure on the tap or else the workpiece will "climb up" on the tap,*** cocking the vise and workpiece and probably breaking the tap.

   iv. Feed the tap into the hole, keeping a firm downward pressure on the tap.

> ***CAUTION!***
>
> In the next procedure, ***continue to apply SLIGHT downward pressure on the tap while backing it out to prevent the workpiece and vise from lifting off the table***, again cocking the vise and workpiece and probably breaking the tap.

   v. As soon as the tap has achieved the desired depth, reverse the spindle to back the tap out. As the end of the tap emerges from the hole, gradually decrease the downward pressure to avoid damaging the newly-tapped thread.

10. Machine the angles on the ends of the clamp frame.

    A. Note that each end's geometry is different. One end has a right-angle section, yielding a dog-leg shape. That right-angle section should be machined first.

    B. Using trig, calculate the angle of each end (again, they are not the same).

        i. Angle on left (anvil) end = _____ degrees.

        ii. Angle on right (tapped) end = _____ degrees.

    C. Lay out lines on the face of the clamp frame representing the angle's boundaries.

    D. Mill the right-angle section on the (tapped end) to the length specified in the drawing.

        i. The cutter's Y axis position at the intersection of the angled surface and the right-angle surface can be determined using a wiggler--***or***:

        ii. With the spindle stopped, "touch off" the cutter using a piece of paper as a feeler (c. 0.004" thick) against the Y- edge of the workpiece. At this point the cutter's center is 0.254" from the edge, so set the Y-axis dial to read negative 0.254—so that the dial will read exactly zero when the cutter is centered over the Y- edge of the workpiece. Then simply feed the cutter along the end of the workpiece the required distance.

        iii. Take trial cuts and measure with a micrometer to maintain the required width dimension.

    E. Set a combination set's bevel protractor to the desired angle (see illustration).

        i. Begin by setting a sine bar on the surface plate. Insert the required height of gage blocks to achieve the desired angle.

        ii. Place the bevel protractor's base on the sine bar.

        iii. Using a dial indicator attached to a height gage, adjust the orientation of the blade until it is parallel to the surface plate.

        iv. Secure the lock screws to preserve the angle setting.

    F. Prepare to machine the right-hand end slope by offsetting the mill vise at the desired angle.

        i. Clean the vise.

        ii. Mount the protractor in the vise by clamping on the base lip.

        iii. Loosen the vise at the swivel base (or at the table if it has no swivel base).

iv. Rotate the vise until the protractor's blade is parallel to the table's axis as determined by a dial indicator over a 4-inch travel.

v. Tighten the vise swivel base (or, if it has no swivel base, use a strap clamp) to secure the vise.

G. Position the workpiece on its side (face up) in the vise, on parallels, and protruding out beyond the edge of the vise by approximately 1/4".

H. Using your sharp 1/2" 2-flute end mill, machine the angle surface until it blends in with the previously-machined right-angle section.

I. Repeat the process to machine the angle on the other end.

J. Re-countersink the tapped hole.

11. Machine the angles along the clamp's long axis.

A. Using trig, calculate each angle.

i. Angles = _____ degrees.

B. Lay out lines on the edge (long axis) of the clamp representing the two angle's apex breakouts.

C. As shown in the diagram, calculate the height of a block (adjustable parallel) needed to set under the end of the clamp frame to incline it for each angle (they're not necessarily the same).

i. Block height for right hand angle = _____.

ii. Block height for left hand angle = _____.

D. Secure an adjustable parallel and set it for the desired height.

E. Clean and indicate the mill vise parallel to the X axis within 0.001" runout.

F. Mount the workpiece in the vise on its edge with the adjustable parallel under the appropriate end to achieve the desired slope.

G. Using your sharp 1/2" 2-flute end mill, machine the angle surface until it breaks out at the apex layout line. Take passes at a depth of approximately 0.050".

H. Deburr the workpiece.

I. Repeat the process for the remaining angle.

12. Machine the groove into which your name will be stamped.

A. The length of the groove should be proportional to the length of your name.

B. Make a trial name stamping on a piece of scrap material and measure its length. Transfer the measurements to the frame to center your name.

13. File the three convex (external) radii.

A. Use a sharp and clean 10" mill file.

B. Use radius (fillet) gages representing the high and low radius limits as templates to gage the radius size. Each radius should be larger than the low limit and smaller than the high limit.

C. ***DO NOT*** file any other surfaces other than convex radii except to remove burrs and break sharp edges. ***Points of intersection between adjacent planes must be measurable***.

14. Surface grind the clamp frame faces to the dimensions shown in the drawing.

A. Use the hand-operated Free Port surface grinder for the first face and the K. O. Lee hydraulic surface grinder for the second face.

i. Try to take equal amounts off each face.

B. Inspect the grinding wheel for damage. If suspect, see your instructor.

C. When it is necessary to dress the wheel:

i. Make certain that the dressing diamond is slightly off center to the wheel in the direction of the wheel's rotation.

> ***NOTE***
>
> In the case of the Free Port hand-operated grinder, have the table resting against the left-hand table stop.

ii. Make certain the magnet is engaged.

iii. Take no more than 0.002" per pass with the dressing diamond.

D. Never put your hands hear the wheel while its rotating. Always let the spindle stop first!

E. Make certain both the chuck surface and the workpiece surfaces are clean and free from burrs and bulges before mounting the workpiece on the chuck.

F. On the dry (Free Port) abrasive surface grinder, orient the workpiece diagonally to avoid heat buildup. However, on the wet (K. O. Lee) grinder, orient the workpiece parallel to the table's axis because the coolant dissipates the heat.

> ***WARNING!***:
>
> ***Always lay the workpiece flat upon the magnetic table.***
>
> Never attempt to grind a workpiece that is placed on its side or end on the chuck because the chuck isn't strong enough to hold the workpiece in such a position. The workpiece will come flying off the chuck, probably wedging against and shattering the wheel, with severe injury to the operator very likely.

G. Verify that the magnet is engaged before attempting to grind.

H. When using the K. O. Lee surface grinder, adjust the table-reversing dogs (or adjust the workpiece's position) such that the wheel overtravels each end of the workpiece by about an inch.

   i. Set the table speed control to the wide-open (30) position.

> ***WARNING!***
>
> I. To avoid any threat to future generations, when using the K. O. Lee surface grinder, ***make certain that BOTH the handwheel crank is disengaged AND the table feed engagement lever is in the left-hand (OFF) position BEFORE powering-up the hydraulic system***.

J. Measure the thickness of the workpiece in several places to determine the thickest point. Then touch-off the wheel on that point.

K. Take no more than 0.001" per pass to avoid premature wheel breakdown.

L. Use a cross feed of about 1/16" per stroke of the table to achieve the best surface finish.

15. Apply a thin coat of oil to all surfaces to prevent surface oxidation.

C-Clamp Screw
Drawing No. 2200-52

01. Study Drawing No. 2200-52 to determine the diameter and length of stock required to make the part, including the pilot and the spherical radius crown. Add 2" for chucking stock.

    Stock diameter = _____.

    Total length including chucking stock = _____.

02. Study the drawing to determine the kind of material required.

    Material type = _____

03. Select a bar from the stock rack. Measure its diameter carefully to make certain it is the correct size. Verify that it is the correct ***type*** of material.

    Verification method = _____.

04. Cut stock off from bar using power hacksaw.

05. Mount the stock in an engine lathe using a 3-jaw chuck, with the stock protruding out from the chuck jaws approximately 3/4".

06. Face off the end to clean-up and deburr.

07. Move the stock out until it protrudes enough to permit the entire length of the screw to be machined. Allow an additional 3/8" stick-out to provide clearance for the knurling tool. Tighten the chuck jaws very tight!

08. Mount a #3 center drill in a drill chuck installed in the tail stock quill and drill a center hole to the diameter specified in the drawing. Use cutting oil and a gentle feed.

09. Install a live center in the tailstock. Engage the center's point in the center hole. Apply just enough tension on the center to cause the point to rotate with the workpiece while your finger exerts a slight drag on the center's point.

10. Mount your right hand tool bit in a tool block, with the nose protruding approximately 3/4". Orient the tool bit (either in the tool block or by rotating the tool post) so it points slightly to the left--for shoulder clearance.

11. Adjust the height of the tool block so the tool bit nose is exactly at the same height as the spindle axis.

12. Start the spindle and machine a small reference groove at the head shoulder location.

13. Machine the screw shank.

    A. The lathe can handle pass depths of 0.100" in terms of diameter reduction.

    B. Recommended feedrate = 0.005" for roughing and 0.003" for finishing.

    C. Maximum allowable taper = 0.002".

        i. Check for taper when the shank is about 1/16" oversize. Adjust the tailstock's lateral position (using a dial indicator) as needed to eliminate excessive taper.

14. Cut the thread.

    A. Allow at least a full hour to machine the thread. The thread must be completed in the same class session as it is started.

    B. Set the compound rest at 30 degrees to the right of the cross feed axis.

    C. Verify that the shank's rotational runout at the head shoulder does not exceed 0.002" Total Indicator Reading (TIR). If necessary, mount the workpiece in a 4-jaw chuck.

    D. With a live center engaged in the center hole (as in #9 above), verify the saddle's axis of motion is parallel to the workpiece axis within 0.001". If necessary, adjust the tailstock's lateral position.

    E. Mount the threading tool such that its 60 degree point is normal to the workpiece axis and its height coincides exactly with the workpiece axis.

    F. Machine a small (barely visible) groove at the location where the threads end--near the shoulder.

    G. Set the quick change gearbox for the desired number of threads per inch.

    H. Set the spindle speed for approximately 125 RPM.

    I. Set the cross feed dial at its zero position with the crank handle at a 5:00 o'clock position.

    J. Start the spindle and verify that the lead screw is rotating and that its thread is progressing right-to-left.

    K. With the cross feed dial set at zero, feed in on the compound rest until the cutting tool makes contact with the workpiece.

    L. Move the cutting tool just slightly beyond the right hand end of the workpiece. Be super careful not to crash the tool into the lathe center--you'll damage the cutting tool and possibly have to start over.

M. Feed in 0.010" ***on the compound rest*** for the first pass.

N. Watch the threading dial and engage the split nut lever sharply and all the way when a line on the dial becomes aligned to the index mark. Keep your hand on the handle so you won't have to hunt for it at the end of the cut.

O. When the threading tool reaches the end-of-thread reference mark, quickly and simultaneously retract the cutting tool ***and*** disengage the split nut (lifting up on both handles).

P. Return the tool to the starting position, just beyond the end of the workpiece, and return the cross feed dial to its zero position.

Q. Feed in the compound rest 0.005" for the second pass (then 0.003, 0.002, and then 0.001 for all subsequent passes) and make additional passes until the screw's pitch diameter is at the desired size. Use cutting oil.

   i. Measure the pitch diameter using the three wire method.

R. Remove burrs from the thread crest with a mill file.

S. Thoroughly clean the thread and verify that it is the correct size by:

   i. Measuring the pitch diameter using the 3-wire method.

   ii. Make sure a test nut or ring gage or the clamp frame fits the screw thread along its entire length.

15. Machine the pilot diameter.

A. Use the threading tool oriented in a direction such that the tool's left cutting edge is normal to the workpiece axis. This can be accomplished by aligning the tool's RIGHT edge to the lathe center's 60-degree point.

16. Knurl the head.

A. The diameter to be knurled must run fairly true, so take a light clean-up cut on the outside diameter if the diameter runs eccentrically more than 0.005" TIR.

B. Install the knurling tool in the tool post.

   i. Adjust its orientation so it is normal to the workpiece.

   ii. Adjust the height so both knurl wheels contact the workpiece simultaneously.

C. Position the knurl wheels so they extend out from the shoulder (overhang) by about 1/2 their width.

D. Start the spindle, running at about 250 RPM.

E. Feed in on the cross slide until the hardened knurl rolls penetrate into the head and establish a clear, clean, uniform cross-hatch pattern.

i. Keep in mind that knurling is a plastic deformation process, not a cutting process, and hence requires considerable pressure.

ii. Use cutting oil.

F. Hand feed the carriage left and right, with the knurls traversing back and forth across the head diameter until the desired degree of knurl definition and sharpness is obtained.

17. File the chamfer on the corner of the head per the drawing's specifications.

18. Cut the workpiece off from the chucking stock using a cutoff tool or the bandsaw or a hand hack saw.

A. Allow 1/16" extra stock in addition to the spherical crown.

19. Machine the spherical radius crown on the head.

A. Mount the head in a 5/8" or 41/64" type 5-C collet in the Republic lathe.

B. Adjust the compound rest until it is parallel to the spindle axis.

C. Face off the end until it is cleaned up.

D. Remove the workpiece and measure the length of the head. Calculate how much stock remains to be removed to make the length, ***including the height of the crown***, conform to the drawing's specifications.

E. Remount the head in the collet and remove the excess stock by dialing the desired amount on the compound rest dial.

F. Make a series of stepped cuts to approximate the spherical radius contour as shown in the diagram.

G. Use a 10" mill file to blend the steps in to a smooth spherical radius.

i. Use radius gages representing the high and low limits of the radius as templates. The finished spherical radius should be larger than the low limit and smaller than the high limit.

20. Apply a thin film of oil to prevent surface oxidation.

Screw Handle & Cap
Drawing No. 2200-53

01. Note that the cap must be a 0.001" press fit on the handle. It is far easier to machine an external diameter to an exact size than it is for an internal diameter. Therefore it makes sense to make the cap first, measure its internal diameter, and then make the handle's external diameter 0.001" larger.

02. Both the handle and its end cap can be made from the same piece of stock. Study the drawing to determine the diameter and length of stock required to make both parts. Add approximately 2" for chucking stock.

    Stock diameter = _____.

    Total length including chucking stock = _____.

03. Study the drawing to determine the kind of material required.

    Material type = _____

04. Search the scrap box to find a suitable piece of material. Keep in mind that you can easily make a larger diameter rod smaller. Verify that it is the correct ***type*** of material.

    Verification method = _____.

05. Mount the stock in a lathe in a 3-jaw chuck, with the stock protruding out from the jaws approximately 3/4".

06. Machine the end cap.

    A. Face off the end to clean-up and turn down the outside diameter if required.

    B. File the external radius per the drawing specification.

    C. Cut the end cap off to the required length plus 1/16" using a hand hacksaw.

    D. Mount the cut off end cap in a type 5-C collet using one of the Republic engine lathes.

    E. Face off and clean up the saw-cut surface.

    F. Remove the workpiece from the collet, measure the length, and calculate the amount of material remaining to be removed.

    G. Reinstall the workpiece in the collet and remove the remaining excess material, if any.

    H. Mount a #3 center drill in a drill chuck and drill a small pilot hole.

I. Drill a hole 1/32" smaller than the final hole diameter to the depth specified in the drawing.

J. Enlarge that hole using a drill approximately 0.008" smaller than the final hole diameter.

K. Ream the hole to its final size using a spindle speed of approximately 300 RPM (about 20% of the drilling RPM), a fairly heavy feed (a reamer has six cutting edges instead of two), and small amount of Tap Magic fluid.

L. Deburr the workpiece.

M. Thoroughly clean the bore and accurately measure its diameter using a small hole gage and a micrometer. Record the reading.

07. Machine the handle.

A. Using a 3-jaw chuck, position the stock so it protrudes about 1/2". Face off the end and deburr. Then reposition the stock so it protrudes enough to permit the entire length of the handle to be machined. Allow an additional 3/8" stick-out to provide some clearance.

B. Mount a #3 center drill in a drill chuck installed in the tail stock quill and drill a small center hole. Use cutting oil and a gentle feed.

C. Install a live center in the tailstock to support the workpiece during machining. Engage the center's point in the center hole. Apply just enough tension on the center to cause the point to rotate with the workpiece while your finger exerts a slight drag on the center's point.

D. Mount your right hand tool bit in a tool block, with the nose protruding approximately 3/4". Orient the tool bit (either in the tool block or by rotating the tool post) so it points slightly to the left--for shoulder clearance.

E. Adjust the height of the tool block so the tool bit nose is exactly at the same height as the spindle axis.

F. Start the spindle and machine a small reference groove at the head shoulder location.

G. Machine the shank.

i. The lathe can handle pass depths of 0.100" in terms of diameter reduction.

ii. Recommended feedrate = 0.005" for roughing and 0.003" for finishing.

iii. Taper, *per se* is unimportant because there is 1/64" clearance between the handle the hole in which it fits. However, the handle's specifications must be within tolerance throughout its entire geometry.

> ***NOTE***
>
> If checking the fit of the cap on the handle shank, be careful to not press the cap on the handle past the pilot onto the larger press fit area.

iv. Provide a slight lead on the external diameter to serve as a pilot to guide the handle into the cap without misalignment.

v. Be certain that the external diameter, where it fits in the end cap, is 0.001" larger than the end cap's internal diameter, to assure a 0.001" press fit.

vi. Make sure the shoulder fillet is within the drawing specification. Use the threading tool's sharp point to remove any excess fillet material.

H. Cut off the handle from the parent material allowing 1/16" of extra material for finishing the head.

I. Mount the handle's shank in the chuck and machine the head's end to the length specified in the drawing.

J. File the external radius on the head.

K. Deburr as needed.

Swivel Pad
Drawing No. 2200-54

01. Study the drawing to determine the diameter and length of stock required to make the part. Add approximately 2" for chucking stock.

    Stock diameter = _____.

    Total length including chucking stock = _____.

02. Study the drawing to determine the kind of material required.

    Material type = _____.

03. Search the scrap box to find a suitable piece of material. Keep in mind that you can easily make a larger diameter rod smaller. Verify that it is the correct ***type*** of material.

    Verification method = _____.

04. Mount the stock in a lathe in a 3-jaw chuck, with the stock protruding out from the jaws approximately 3/4 to 1".

05. Face off the end to clean-up and turn down the outside diameter if required.

    A. Break the sharp edge with a file.

06. Center drill the end to approximately 3/16" diameter using a #3 center drill. Feed it gently and use cutting oil.

07. Drill a hole (diameter per drawing specifications) to a depth equal to the length of the swivel pad plus 1/4 inch.

08. Counter drill the hole to the diameter and depth specified in the drawing.

    A. Lightly break the sharp edge with a hand-held countersink.

09. Set the compound rest to an angle of 45 degrees to the right of the cross slide axis.

10. Mount a type P-3 (1/8" wide) cutoff tool (often called a parting tool) in the tool post.

11. Align the blade so it is normal to the workpiece axis.

12. Adjust the height of the cutoff blade to coincide with the spindle axis.

13. Position the cutoff blade so it is offset to the left of the end of the workpiece by a distance corresponding to the start point of the chamfer and just barely touching the outside diameter of the workpiece.

14. To generate the chamfer, start the spindle and gently feed the cutoff tool in on the compound rest (at a 45 degree angle) until its lateral (Z axis) position corresponds to the desired overall length of the workpiece.

15. Feed the cutoff tool in on the cross feed (X axis) to cut off the workpiece from the parent material.

16. Retrieve the workpiece from the chip pan and remove the cutoff burr.

    A. Mount the workpiece in a small 3-jaw chuck or collet using the Republic lathe.

    B. Mount a countersink in a drill chuck and just barely remove the burr. Be careful not to generate a chamfer larger than 1/64" wide.

C-Clamp Assy Assembly Instructions
Drawing No. 2200-50

01. Insert the screw into the frame approximately half the throat opening.

02. Orient and place the swivel pad on the screw. Make sure that the end of the screw extends beyond the swivel pad and the pad had enough clearance to not bind when the screw end is deformed to capture the swivel pad.

03. Place a small steel ball bearing on the end of the screw and carefully hand tighten the screw until the ball bearing is seated firmly against the frame and screw end.

    A. Make sure that the swivel pad remains free to rotate. If the swivel pad binds, replace the ball bearing with a smaller one. If a smaller ball bearing is not available, contact your instructor.

    B. Continue to hand tighten the screw until it can travel no further. Once again, ensure that the swivel pad remains free.

04. Cover each jaw of a table vice with a few layers of paper towel to prevent damaging the ground surface finish of the frame. Place the frame into the vice with the screw facing down and the frame resting on the vice. Carefully tighten the vice to hold the C-clamp assembly.

05. Use the brass hammer to deliver a sharp blow to the frame to swage the end of the screw and capture the swivel pad.

    A. Remove the C-Clamp from the vice and check if the screw was successfully swaged.

    B. If required, mount the screw in a lathe collet and use a center drill installed in the tail stock to thin out the end of the screw. Take care to not remove too much material.

06. Repeat steps 03 - 05 as required until the swivel pad is successfully captured.

07. Insert the screw handle through the screw.

08. Check the fit of the cap by pressing it onto the screw handle past the pilot diameter and up to the press fit diameter. Gently tap the cap on to the handle until it hits bottom.

09. Print your name on a provided paper bag and place the final C-clamp assembly in it. Place the bag in the container provided.

