Scratch Building The "Nina": A Little 0-4-0 Live Steamer

BY

Bob Sorenson

Las Vegas, Nevada

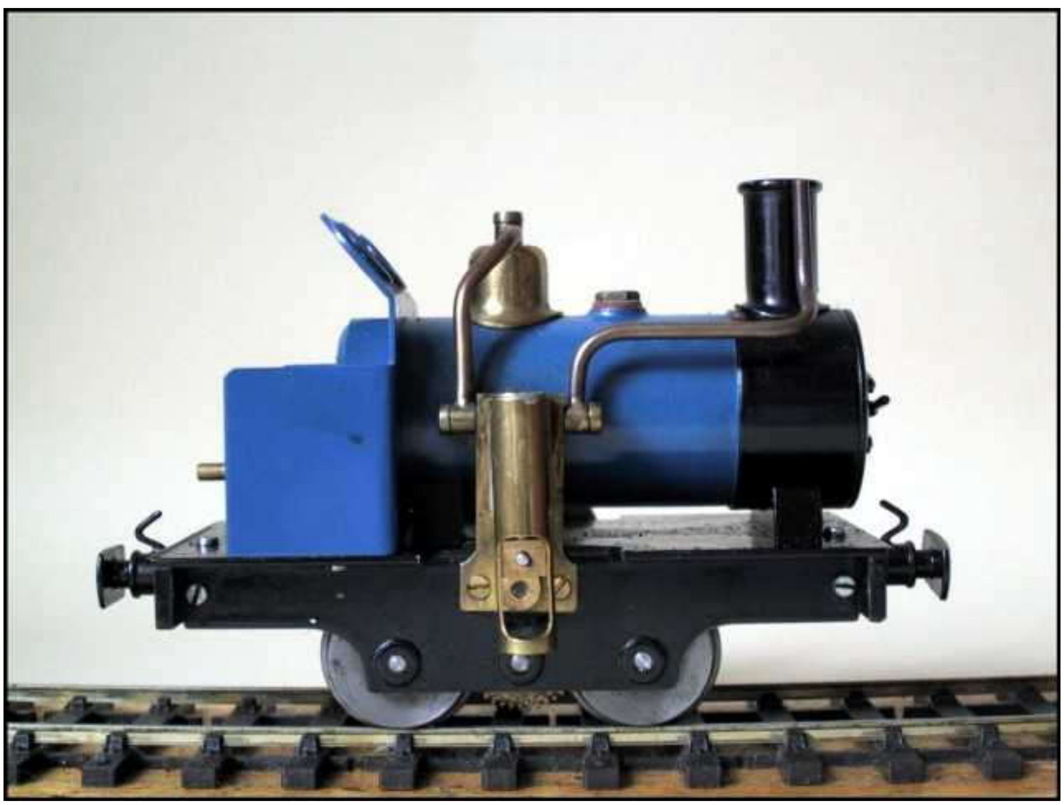
U.S.A.

(Live Steam Forum/Topic: "Nina" a Little 0-4-0 Live Steamer, Progress Updates)

This small steam loco project is a single cylinder oscillator, gear and chain driven, 0-4-0 in 7/8" scale. The engine is single acting with a 1/2" bore and 11/16" stroke. The transmission is by gear to an intermediate shaft and then ladder chain to the lead axle. Total gear reduction is 4.8 to 1. That should provide some power as well as speed. The boiler is a single flue, gas fired "T" boiler. The vertical leg of the boiler should provide a lot of water and steam space while the horizontal leg provides room for a larger than normal flue.

We will call this one "Nina".

The primary inspiration for the Nina project is from an engine by Mr. Earnest Glaser named "Cracker". This is Mr. Glaser's original Cracker.

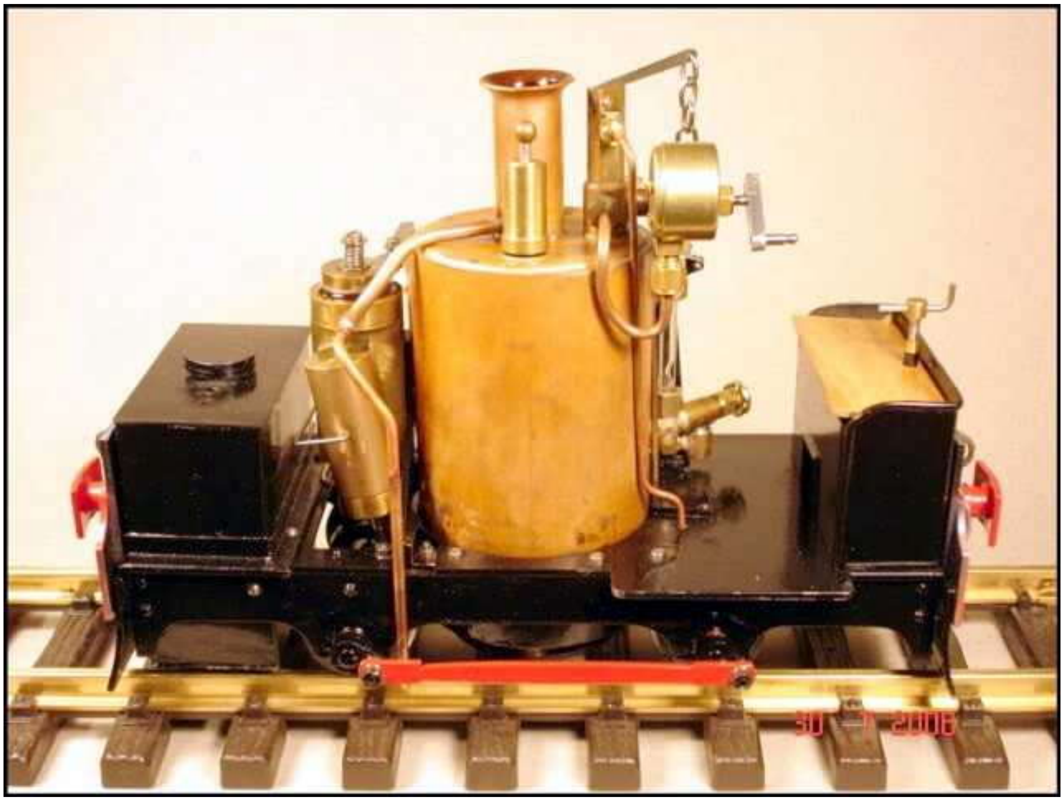


Here is a link to Mr. Glaser's plan set for Cracker.

http://home.iae.nl/users/summer/16m...racker.htm

Cracker is a Gauge 0 engine in metric dimension. For this project I plan to use the motor unit with a scale of 1mm = 1/16" to make it larger.

The chassis comes from an engine named "Idris" designed and built by Mr. Dave Watkins. This particular Idris was built by an old MLS friend "deWintonDave."



Mr. Watkin's original Idris is in 16mm scale. I scaled up the chassis by a factor of 1.4 to get it to 7/8" scale. The Idris chassis will give Nina a longer wheelbase then Cracker and more room for the boiler. Dave has a plan set for Idris and his other engine at his website.

http://www.davewatkins.pwp.blueyonder.co.uk/steam.htm

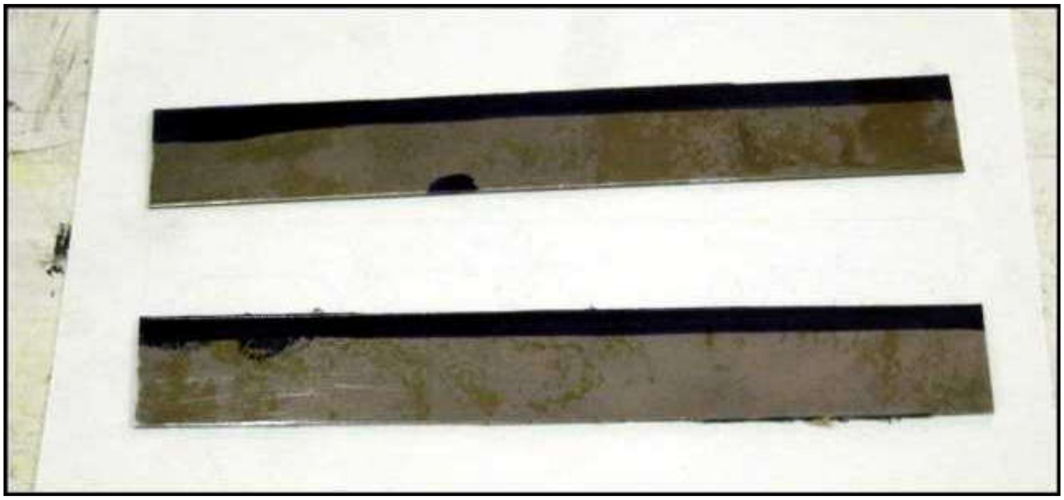
The rest of it will get "made-up" as we go along.

First parts to make are the main frames. They are from 16-gauge (.0598") cold roll steel (CSR), bright finished, plate. Here is the frame drawing (see end of this document **[Fig. 1]**):

Side Frame Shop Drawing

To start, saw out two rectangles, slightly over sized. 16-gauge plate is easy to cut. Clamp the sheet over the edge of the workbench with a piece of wood strip on top to keep it from chattering. Use a new blade in the hacksaw with a good shot of oil. Don't push down too hard; let the blade do the cutting.

Finish the frame blanks so the edges are flat, sharp and square all around. First, paint a line of blue Dykem layout fluid on one long edge. With a straight edge, scribe a line close to the rough-cut edge. Like this:



Use a bench grinder to off-hand grind the sawed edge, close to the line.

Your eye is very precise for this kind of work. You will get within .002” to .003” of the line with the grinder. If the grinder starts to chatter, it’s because the wheel is getting clogged with steel bits. Use a dresser to clean the edge of the wheel. Don’t let the steel get hot. If the Dykem blue gets hot, the line goes away.

After grinding, polish the frame edge with a technique called “draw filing”. Clamp the frame between slabs of wood in the vise. Squirt oil on a clean sharp file and hold it by both ends.

Gently rub the file forward and back. Here's my son Andy doing the draw filing. He's standing to the left, just out of the picture.

Work the entire length of the edge to remove the grinder marks. Draw filing removes metal fast, so don't push too hard. Little curly hairs of metal come off the edge like butter. The file teeth will clog up, so clean the file frequently.

Check your progress with a straight edge, holding it to the light. When you see a thin even line of light, the frame edge is flat.

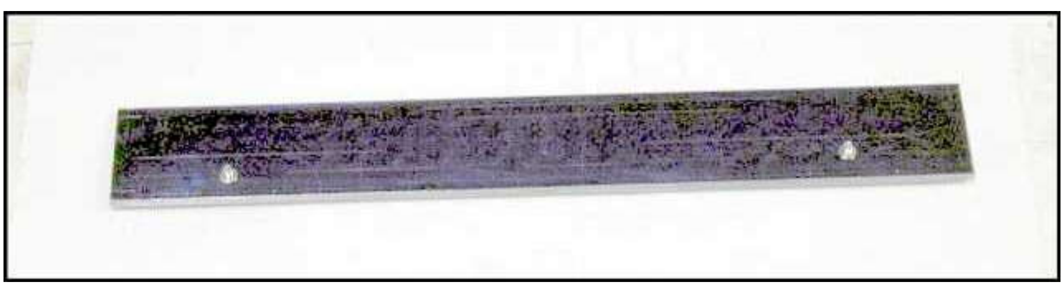
After draw filing, the frame edge is polished bright and razor sharp. Use a fine file to take the sharp edges off.

Use a square mark off one end. Just as before, grind and draw file the end. Use the square to check progress.

Grind and draw file the remaining edges. This takes a little more time because you have cut the frames to final length and width, as you make sure the edges are flat and square.

Clean up the frame blanks. Paint one side of one frame blank with Dykem blue. Measure and layout all hole centers and the curved out areas on the bottom edge.

From this point one we will work on both frames simultaneously. In the areas that eventually get wasted out on the bottom edge, drill holes for some #4-40 machine screws. Bolt the two frame blanks together.



The photo above does not show all the scribed lines in the Dykem blue showing all the hole centers. They are all in there, however. Lightly center-pop all the hole centers.

Admittedly, four-squaring stock is not much fun, but it’s essential. Next time we will drill and shape the frames in prep for assembly.

I've been thinking about this build for a long time. Cracker and Idris are both great little machines. I remember Havoc and deWintonDave building their versions. Dave Watkins also has a nice looking Bagnall named "Frog" on his website. I would like to do that too someday.

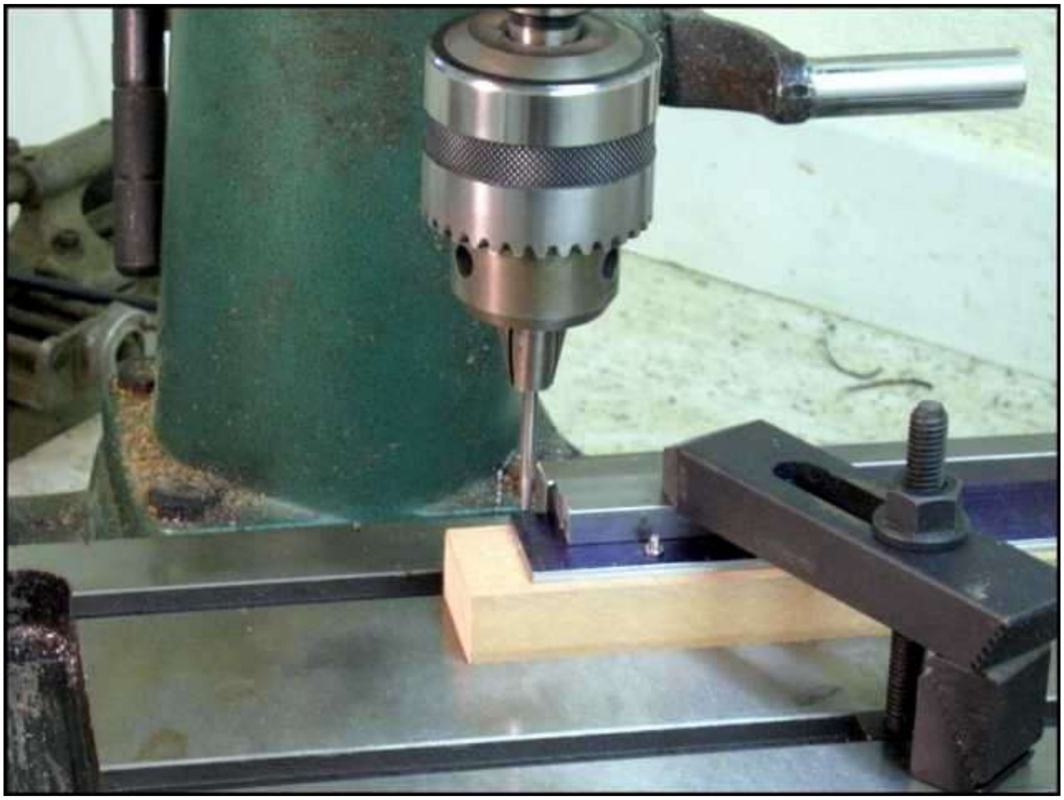
For more on the "Cracker" check out the fan club at:

http://groups.yahoo.com/group/Steammodelloco16mm/

I really like this shot. It tells me that these main line guys got nothing going on, huh Henner?

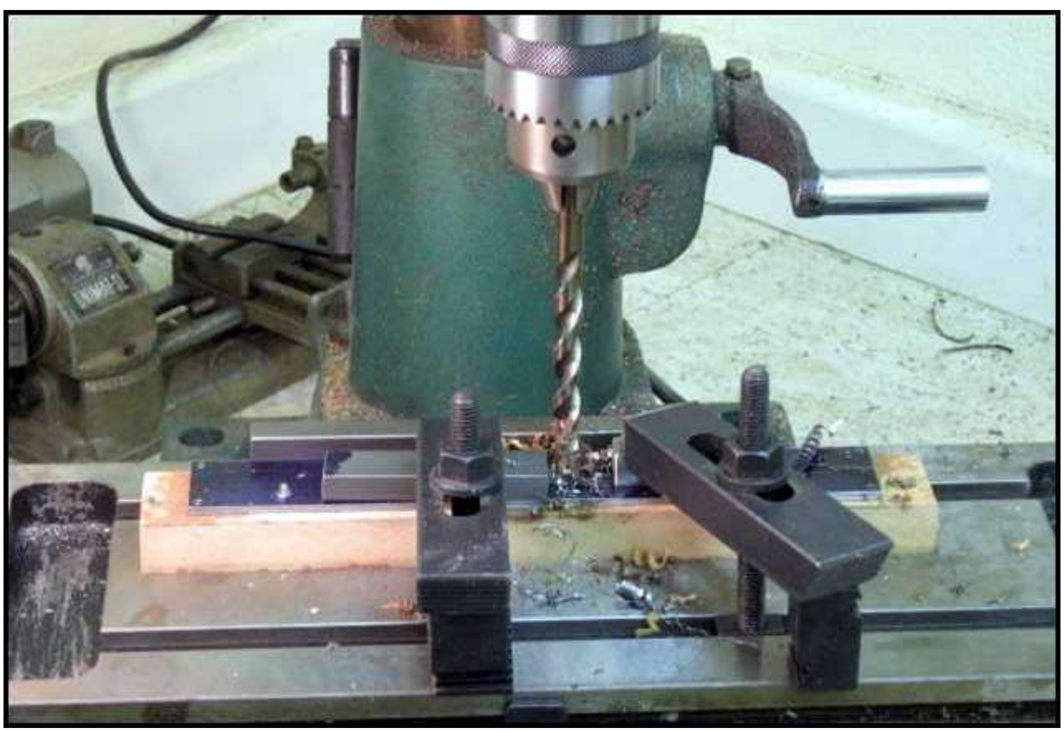
Back to work. It is time to drill all the frame holes. Of course, try to be as accurate as possible, but the most important thing is that both frames are identical. Since the frames are clamped together, the drilled holes will end up identical in both frames.

I drilled all the holes on the milling machine table, but a regular drill press will work too. Clamp the frames to the machine table with a piece of MDF board or clean plywood underneath. The MDF board provides good backing under the frames. Use a steel bar to distribute clamping pressure. A center point in the drill chuck helps locate the hole directly in line with the spindle.



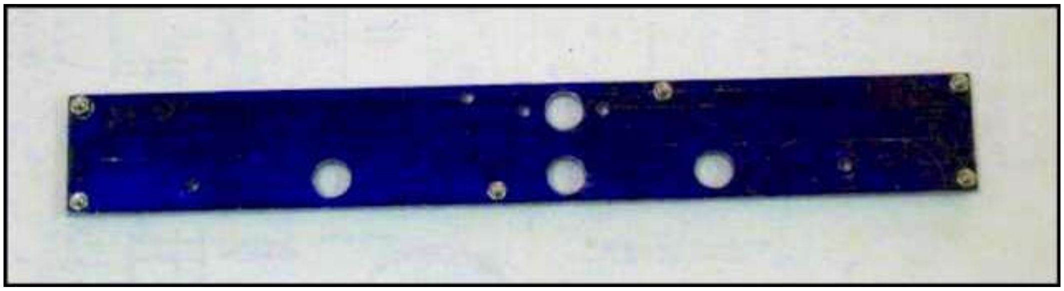
Use a magnifying glass to ensure the center point and hole center is lined up. Your eye is very precise for this work too. Use a center drill first to start the hole. Don't rely on the drill bit alone, is may wander off center.

The larger holes for the bearing are a bit scary to drill. Set the drill to the lowest speed. Use clamps on both sides of the hole.

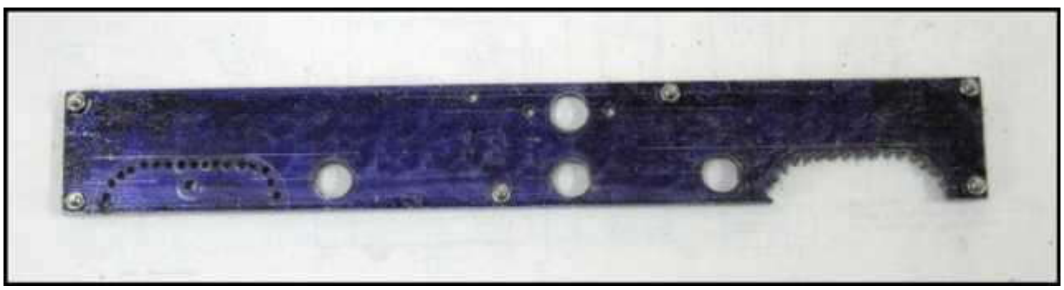


Use plenty of oil on the bigger bit. Feed the drill at a steady slow pace. You will feel the cut and get a nice curly chip.

With all the holes drilled, insert #4-40 machine screws in each hole and remove the screws in the wasted area.

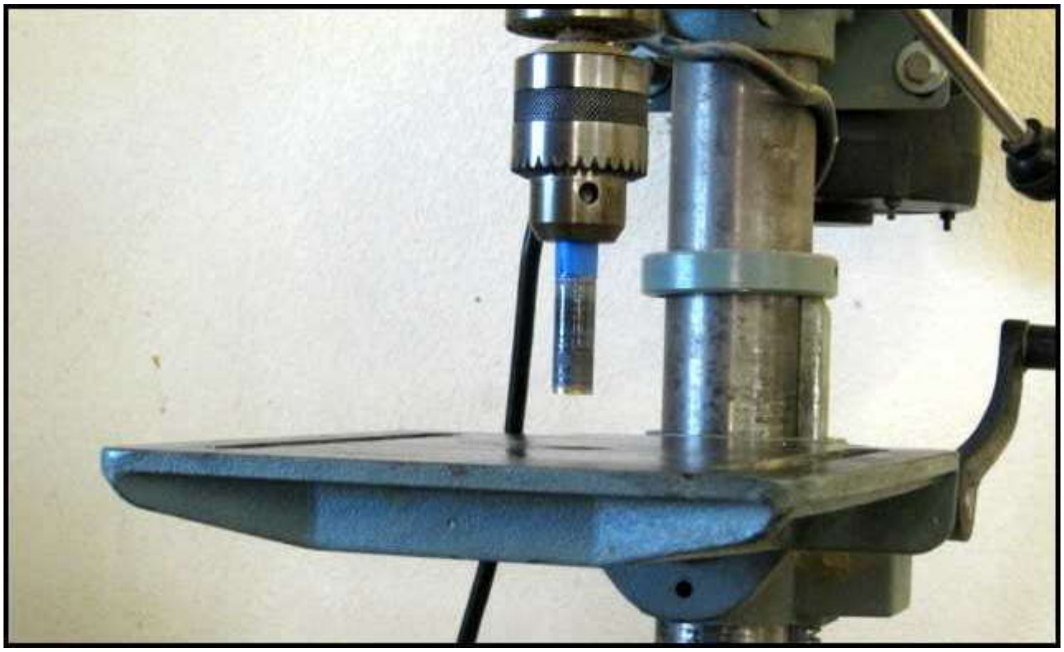


Now it is time to cut out the curved areas on the bottom edge of the frame. Do this with a technique called “chain drilling”. Chain drilling basically creates a perforation to remove the bulk of the material.

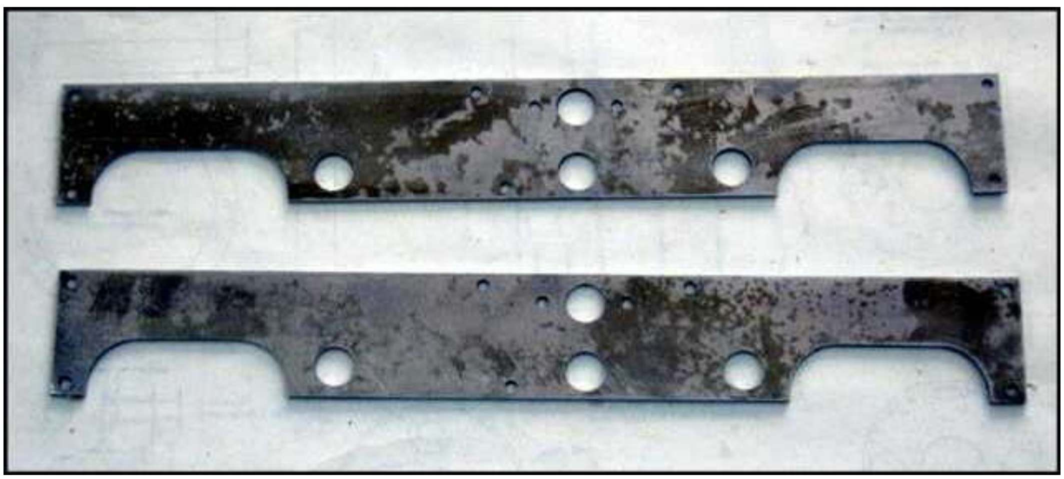


Evenly space a series of center punches. Drill them thru with a small bit. Drill each hole again with a slightly larger bit. Repeat until the holes are just touching each other. Saw thru the holes with a fine coping saw and remove the waste material.

Using the bench grinder and files, clean up the cut out area. As a final step, wrap a piece of 220 or 320 grit wet/dry sand paper on a rod and put it in the drill chuck. Oil up the paper and use it to clean up the scratch marks on the cut out areas.



Disassemble the frames. Clean off sharp edges with a fine file and deburr the holes. Rub the frames down with lacquer thinner or some other solvent to remove the Dykem blue. If the "Frame Gods" smile upon you, they will be identical and look great.



That's it for now. Next time we will do the spreaders and get the frame assembled.

Now it's time to do the frame spreaders and get the frame bolted together. Many Gauge 1 engines use square bar stock for the spreaders. The spreaders not only set the frame plates, but also secure the end beams and footplates. Here's a drawing of the spreaders (see end of this document **[Fig. 2]**):

Frame Spreader Shop Drawing

The spreaders need centered holes tapped on each end. To tap those holes we first need a "split collet" to secure the square stock in the lathe chuck. This is the split collet.

The split collet is a 3/4" length of 1/2" round steel bar with an 11/32” hole drilled thru. With a hacksaw, split lengthwise thru the tube.

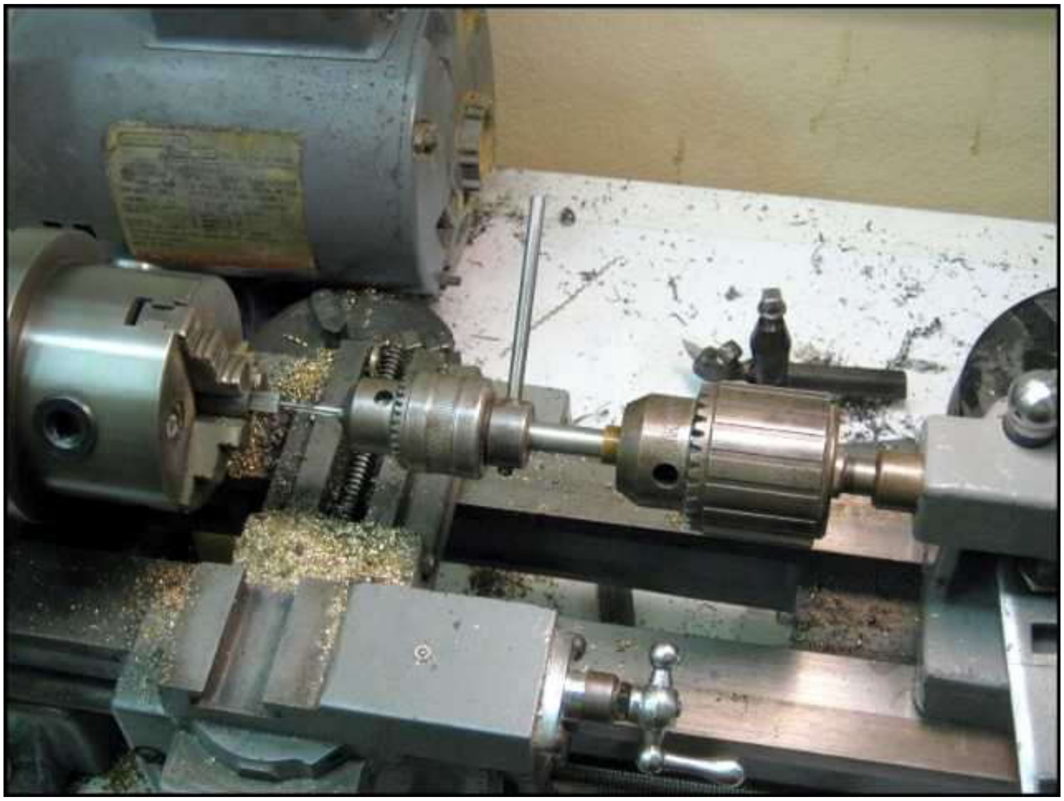
11/32” is the diagonal measure of a 1/4" square bar. Cut a piece slightly over sized length of 1/4" square bar. Slip one into the split collet. It should fit just fine.

Chuck the assembly in the 3-jaw, self-centering chuck. The split collet centers the square stock perfectly. Face off the end of the spreader blank.

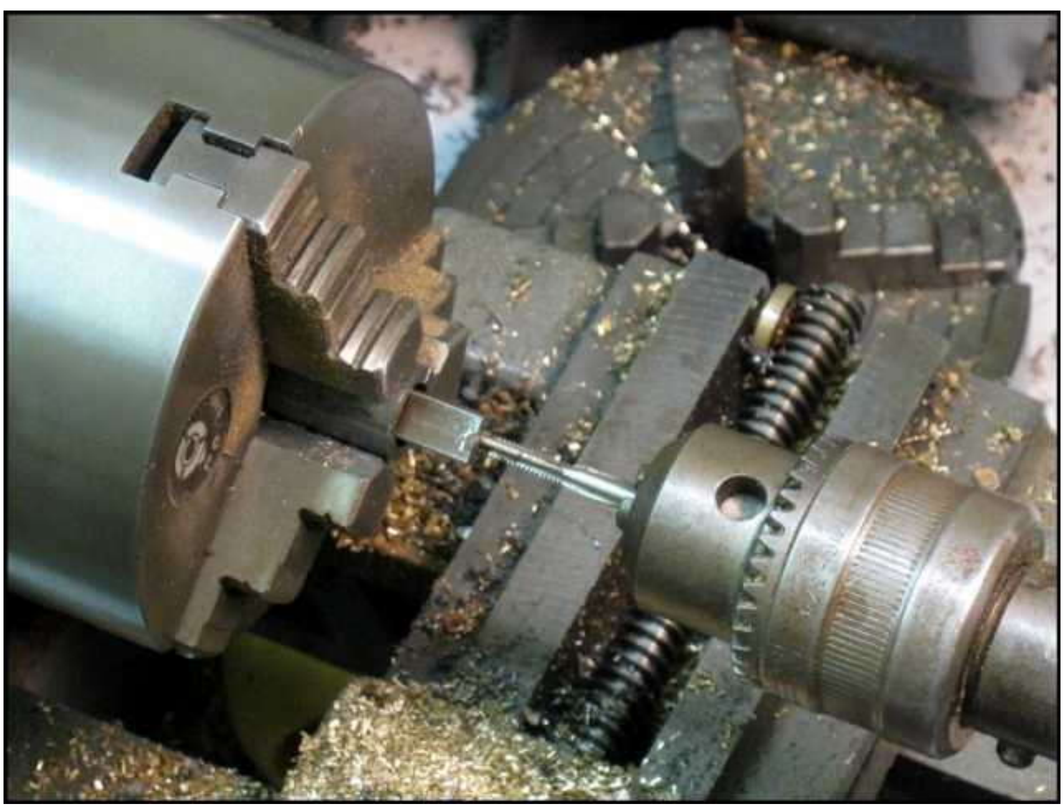
The spreaders require tapped holes, centered on the ends. Tap the holes while the square spreader stock is still in the lathe chuck. A special tap holding tool is needed to do this.

The special tap holder is essentially a drill chuck attached to a short piece of rod. I made this tap holder about 30 years ago from a chuck I got at Sears.

First center drill and drill a pilot hole for a #4-40 machine screw. Drill the pilot hole 3/8" deep. Chuck a #4-40 machine screw tap into the tool and insert it into the tail stock chuck on the lathe.



The tap holder and lathe tail stock ensure the tap is aligned and going squarely into the pilot hole. Grip the lathe chuck with your left and the tap holder with the right. With a drop of oil on the tap, turn the tap holder about 1/3 turn. Turn it back about half a turn to free chips from the tap.



It takes a little practice to do this process. The first hole you tap will probably take about an hour; then a minute each thereafter.

Reverse the spreader blank in the split collet and face it to the final length. Drill and tap as before.

The spreaders need several more tapped holes depending on their location. The top spreaders front & rear, secure the end beans and the footplate. The bottom spreader, just secure the end beam. To tap these holes, use the drill press with cross slide table to both drill the pilot hole and operate the tap holder. Here is the set-up.

With the spreaders all done, assemble the frame.

Next time we will make and install the bearings.

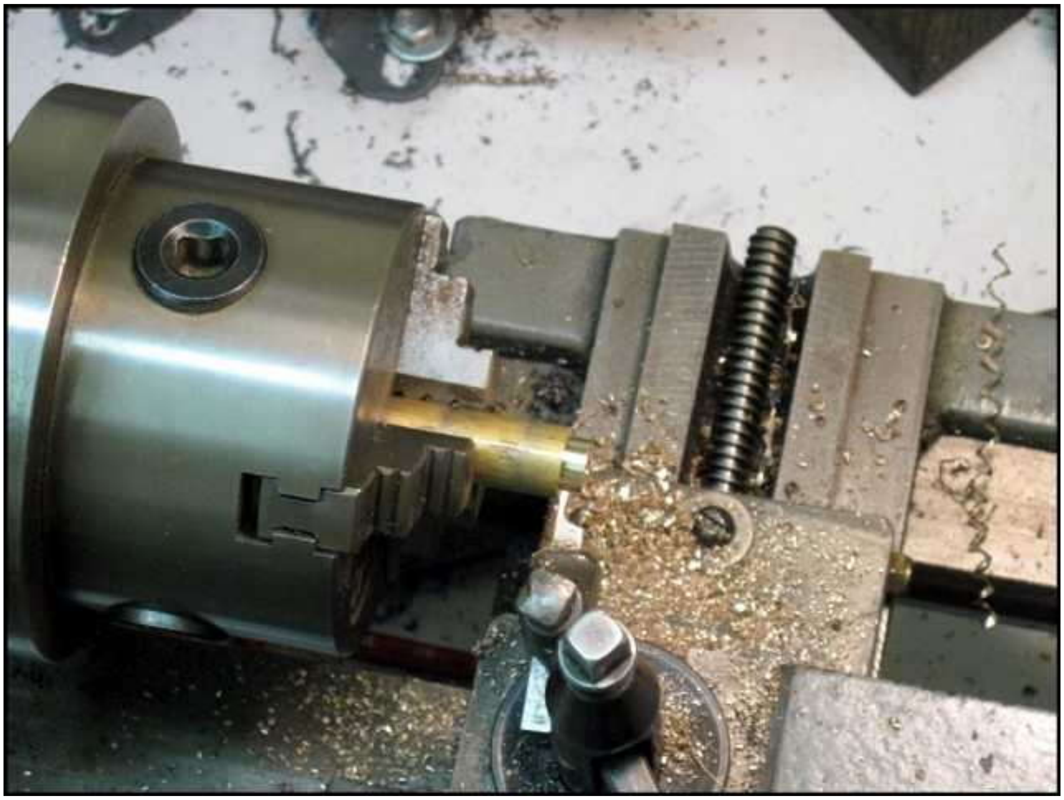
I agree Henner, there is nothing better than seeing one of your own creations come to life. Once you get one of your own running, there is no going back. “Nina” may be a simple little oscillator, but I would not trade it for any commercially made machine.

Next up are the bearings. There are eight bearings total in three sizes. Four are for the axles, 3 for the counter shaft and crankshaft and one crankshaft main bearing. Ordinary bearing bronze is the material to use. Alloy #932, also called SAE 660, is the stuff. Here are the drawings (see end of this document **[Fig. 3]** & **[Fig. 4]**).

Side Frame Bearings Shop Drawing 1

Side Frame Bearings Shop Drawing 2

The bearings are a straight turning job. It is easier to use a square tipped parting tool to turn the bearing shoulder and then part it off from the main stock. Chuck a piece of 1/2" bronze in the 3-jaw chuck. Center drill, drill and ream the bearing bore. Use the squared parting tool to turn the bearing shoulder.

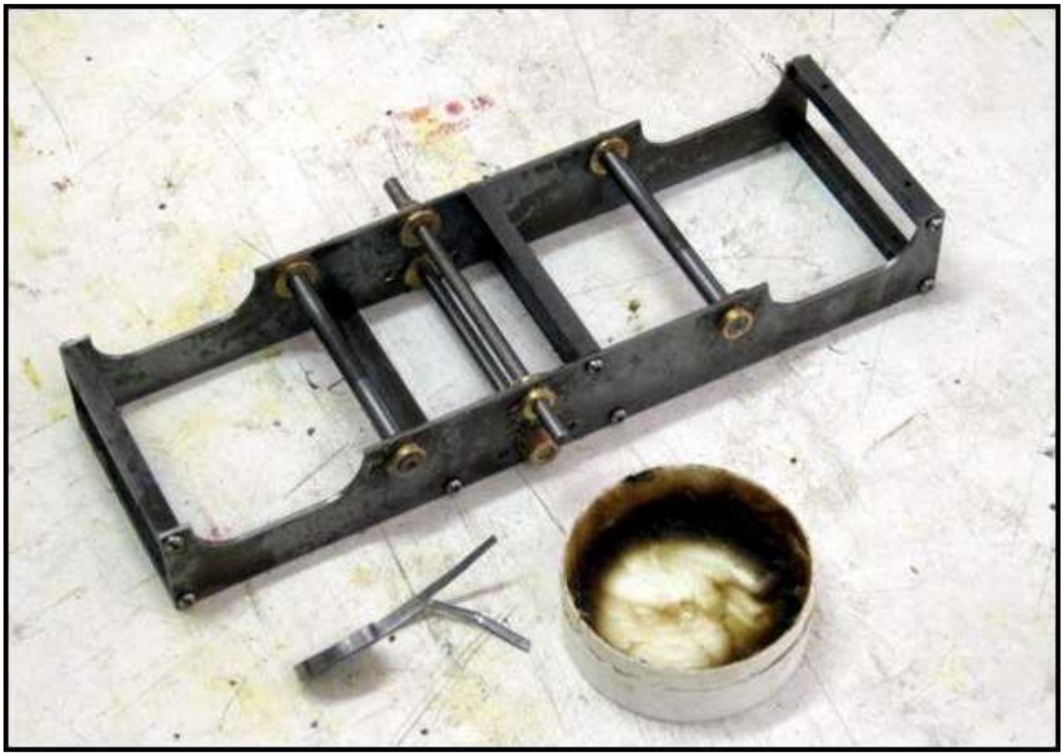


Use the parting tool in the same set-up to part off the bearing.

The bearings go into the frame with soft solder. 50-50 lead/tin solid wire is the best. It's soft and shapes for the job at hand, so you get the amount you need, where you need it.

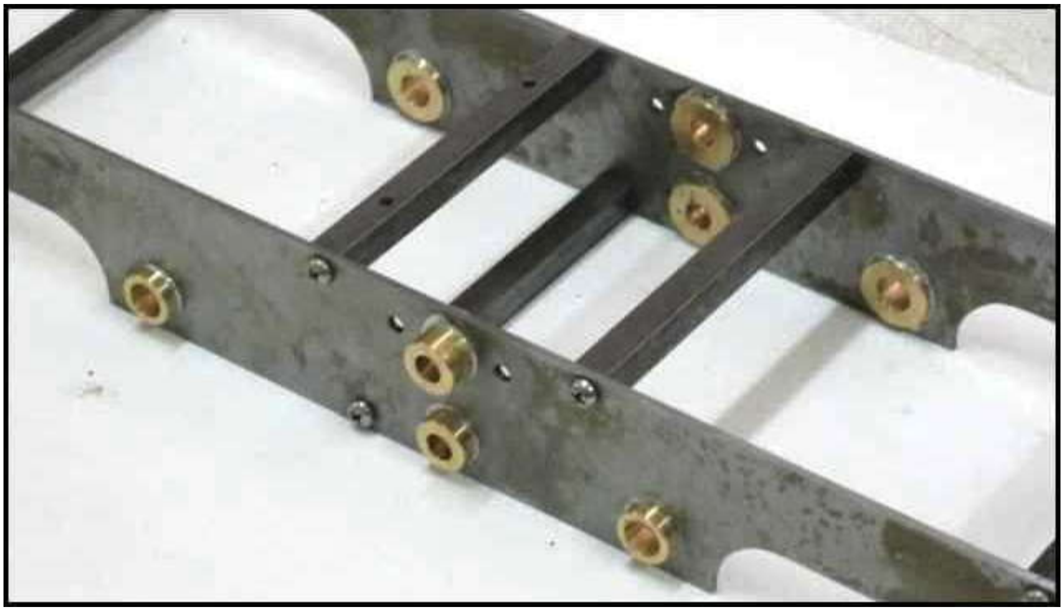
Clean the frame assembly and bearings in soapy water and dry. Cut some lengths (2) of 1/4" stainless steel rod 3-1/4" long and 3/16" (2) stainless steel rod 4-1/2" long. These rods will eventually become shafts and axles, but for now they will help get the bearings in place.

Apply solder flux to the frame and bearings. Slip the bearings into the frame and use the shafts to align them. When you are ready to solder it will look something like this:



Smash some solder into a thin sheet with a hammer and cut it into long strips. To solder the bearings in use a regular "Bernz-o-matic" torch. Use a very small flame, the inner bright blue cone about 3/8" long. Heat slowly from the outside of the frame. When the flux starts to bubble, rub in the solder on the inside of the frame, against the bearing shoulder. The heat will eventually transfer thru and melt the solder. Add just enough solder to get a nice fillet. Let it cool down a bit and move on to the next bearing. When you are done, clean up in soapy water. The rods will hold the bearings in alignment as you solder. They will turn smooth and freely.

Bearings are in place.



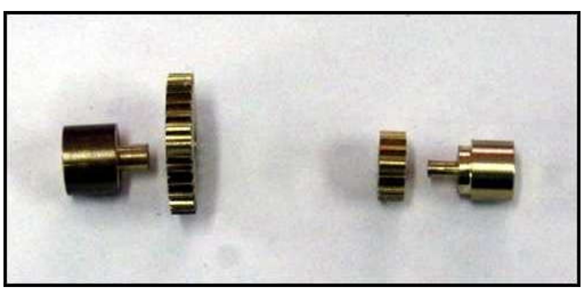
That's it for now. Next time we will work on some transmission parts and fix a major disaster.

Let's turn to the transmission components. Engine power is transmitted by gears to the counter shaft, then by ladder chain drive to the front axle. The total gear reduction is 4.8:1. The gears came from Stock Drive Products.

http://www.sdp-si.com/index.asp

The gear stock numbers I used are:
- Pinion (14 tooth):...........A 1B11-N32014
- Gear (30 tooth): ....A 1B11-N32030

These are hub-less brass gears. I do not know what possessed me to get hub-less gears, because you need the hubs and set screws. So I had to add hubs. First turn some hub blanks that fit closely to the gears: then silver soldering the hub to the gear.



Chuck the gears in the lathe, drill and ream to match their shafts. Tap the hub for a #6-32 setscrew.

The bottom line to this little mess is to get gears with hubs and setscrews.

I was eager to see how the gears worked, so I assembled the shafts with gears into the bearings. The gears were in so tight they would just barely turn. Way too tight to try to "run-in". In fact, you may as well just say they would not turn at all. What a disaster.

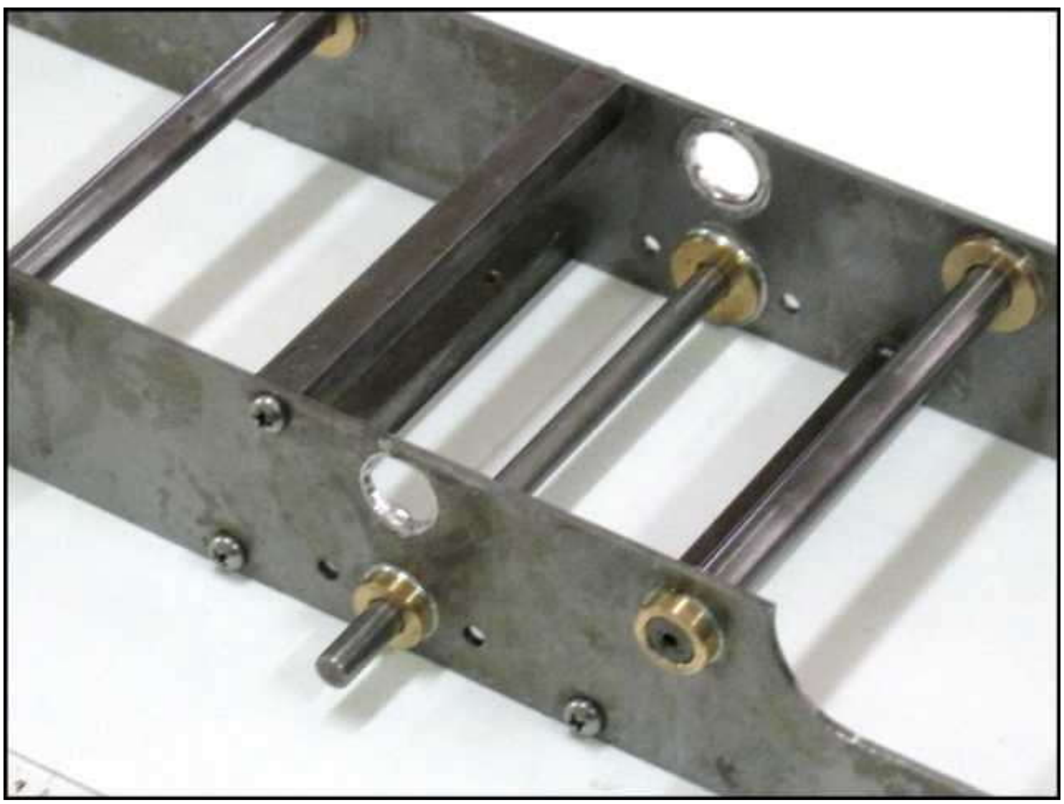
The fix, fortunately, is not that hard. It involves some new lower bearings for the countershaft and some brain surgery.

The new bearings are eccentric, rather than all turned in line. The inner bearing bore is off-centered from the outer diameter by about .020”. To make an eccentric bearing, chuck some 1/2" bronze in the 3-jaw chuck with some folded paper packing under one jaw. Drill and ream to 3/16”.

Remove the paper packing and re-tighten the chuck. Turn the outside of the new bearing as you did before and part off.

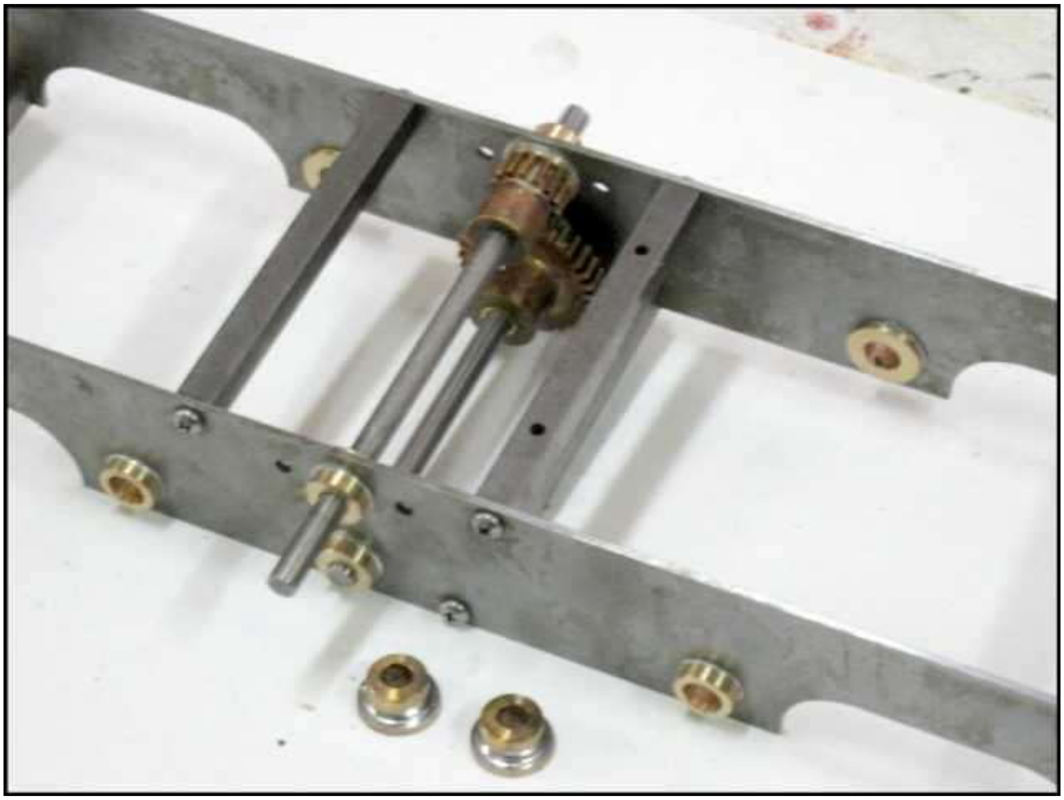
It is a little hard to see in the following photo, but the bearing bore is off centered from the outside diameter. The bore is slightly lower then center.

Now remove the lower counter shaft bearings from the frame. Put the axles and engine shaft back in their bearings. Heat the countershaft bearings until the solder melts. Gently tap them out.



Clean off excess solder blobs with a jack knife and get ready to solder in the new bearings. Flux up the new bearings and get them in place. Rotate the new bearings so the off centered hole is all the way down. This gives more distance between the shafts. Solder the new bearings in just as you did before.

The fix worked fine. The gears went in just right and turn free and smooth. The old bearings are off to the scrap bin.



Disasters like this happen all the time. When they do, stop and take a break. Think thru the problem and come up with a fix. If you understand what the problem is, the fix will work.

I was really sweating "brass tacks" on that gear fix. But everything turned out fine and the project continues smoothly. Hopefully that will be the only glitch. (See comments [C-1, C-2, & C-3])

The wheels for "Nina" are fixed to straight axles with setscrews tapped into hubs. The use of setscrews to fix wheels is fairly common with 16mm narrow gauge engines in the U.K. Setscrews allow for adjustment of the wheels to so the engine can operate on either Gauge 0 and Gauge 1 track.

There are a number of ways to make wheels. The method I used is purely based on material I had on hand. There are also a number of wheel profiles. I use the old "G1MRA" standard.

Here's the drawing for the wheel blanks (see end of this document [Fig. 5]):

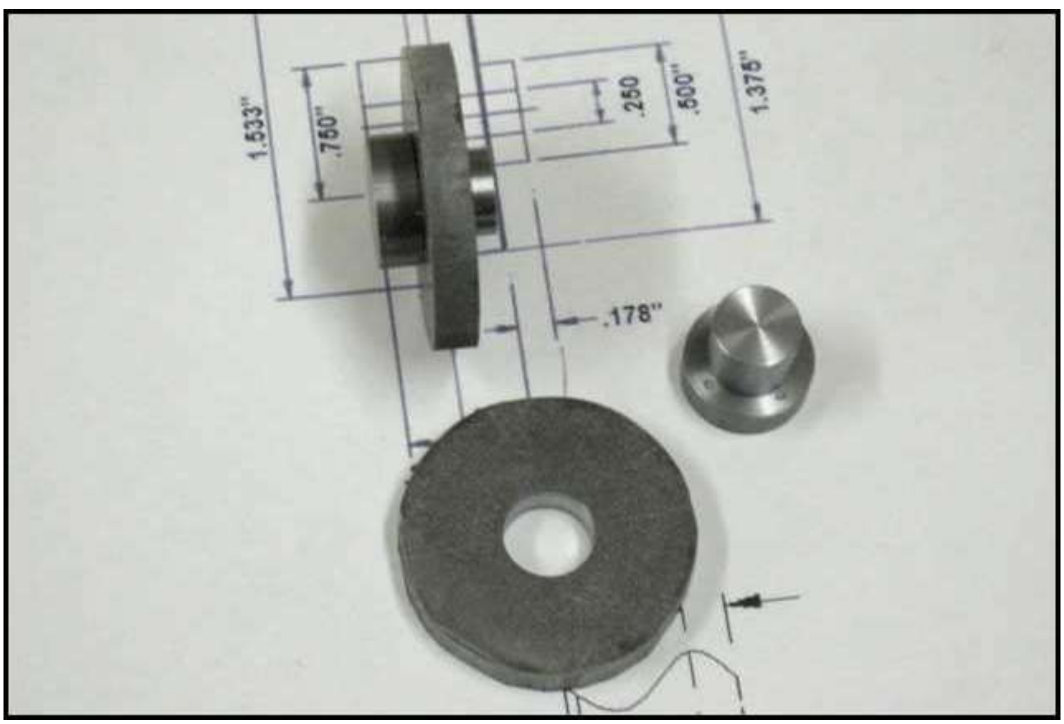
Driver Wheels Blanks Shop Drawing

And for the rim detail (see end of this document [Fig. 6]):

Driver Wheel Flange & Tread Detail Shop Drawing

The wheel blanks are built up with separate hubs and wheel disks. Turn the hubs from lengths of 5/8" diameter round steel bar. The wheel disks are roughed out from 1" steel bar stock. You can use brass for both as an alternative. Or you can turn the whole blank from 1" stock.

Carefully bore the wheel disks to fit the hubs. Don't try to drill the wheel disks. A 1/2" drill on a light lathe will probably chatter too much and leave a poor result.



Clean the parts and silver-solder the hubs in the wheel disks. The bright ring around the hub shows good penetration of the solder.

The large hub on the backside of the wheel allows all critical machining steps on the wheels to happen with one set-up in the lathe chuck. Grip the wheel blank by the backside hub in the 3-jaw chuck. Turn a step into the wheel, which produces the final tread diameter and flange thickness. Use a rather pointed HHS tool with a slightly rounded nose.

Rotate the compound slide on the lathe to 10 degrees and turn the front side of the flange. Skim very light cuts until the lathe tool just fits into the root radius between the wheel tread and flange.

Rotate the compound slide to 3 degrees and turn the tread on the wheel. Take light cuts, about .001” or .002” until the nose of the tool fits back in the root radius. Use a hand file to put a small chamfer on the sharp corner of the tread.

Reset to compound slide to zero and turn a decorative recess on the front of the wheel.

Center drill the hub and drill through to 15/64”. Use a ream with cutting oil to finish the hole out to 1/4".

Turn the wheel around and grip by the front side hub. Turn the flange to the final diameter. Taper cut the backside of the flange to 10 degrees, just as the front.

With the lathe running, round over the flange edge with a hand file and some oil.

Take the wheel to the drill press and drill and tap for a #6-32 setscrew. Do the other 3 wheel blanks in the same manner.

After posting the previous section on fabricating the wheels MLS member Havoc suggested an alternate method of turning wheels which is “more correct” than what I did. To checkout his method click the red superscript at the end of this sentence. [C-4]

Next take the rough 1/4" stainless steel rod axle blanks used when soldering the flange bearings into the side frames, and face them to an overall length of 3.187”

The wheels are not quite ready to go in between the frames. The hubs on the front side are over length and require some trimming based on the final frame dimension. Measure the inside width of the wheel bearings. Based on a 40mm back-to-back measure on the wheels, the thickness of the wheels and about .01” side-to-side play, figure out how much of the front side hub needs to come off. Do the measurements and math a few times to ensure you have the correct answer. Can’t put the metal back on once it comes off.

Put the chassis all together and give it a roll.

Let’s put in the rest of the transmission parts. Engine power from the counter shaft goes to the front axle by ladder chain drive. The rear axle is chained to the front axle to complete the drive. The ladder chain parts also come from Stock Drive Products. The chain is size #19 with a .185” pitch. The sprocket on the countershaft is 7-tooth and the front axle sprocket and coupling sprockets are 14-tooth.

The parts numbers are:

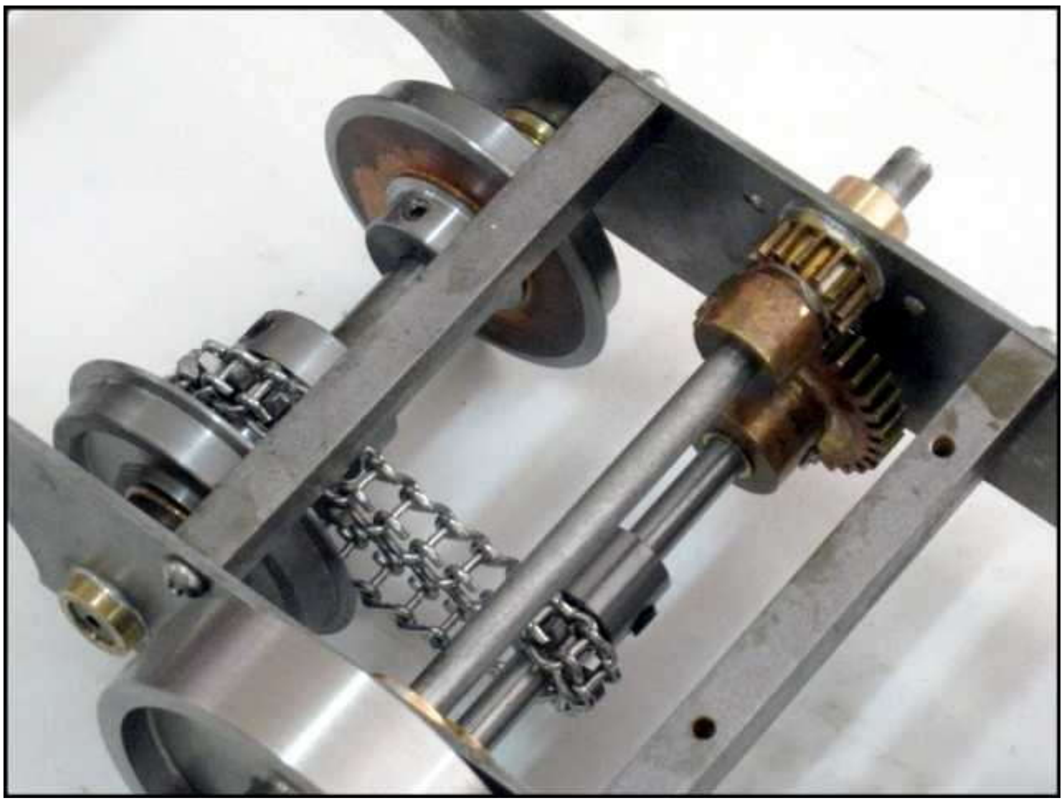
• Sprocket 7 tooth	A 6C 8-1907	(1 req.)
• Sprocket 14 tooth	A 6C 8-1914	(3 req.)
• Ladder chain	A 6Y 8-9	(2 feet)

The 7-tooth sprocket is ready to install on the counter shaft as is. The hubs on the 14-tooth sprockets are too long to allow two of them to be installed on the front axle and achieve the 40mm back-to-back measure between the wheels they need some trimming. Use another type of split collet to hold the sprocket in the 3-jaw chuck. This split collet is narrow and grips the hub of the sprocket, protecting the teeth from the lathe chuck.

Grip the collet in the lathe chuck. Skim off enough material so that two of these sprockets will fit on the front axle.

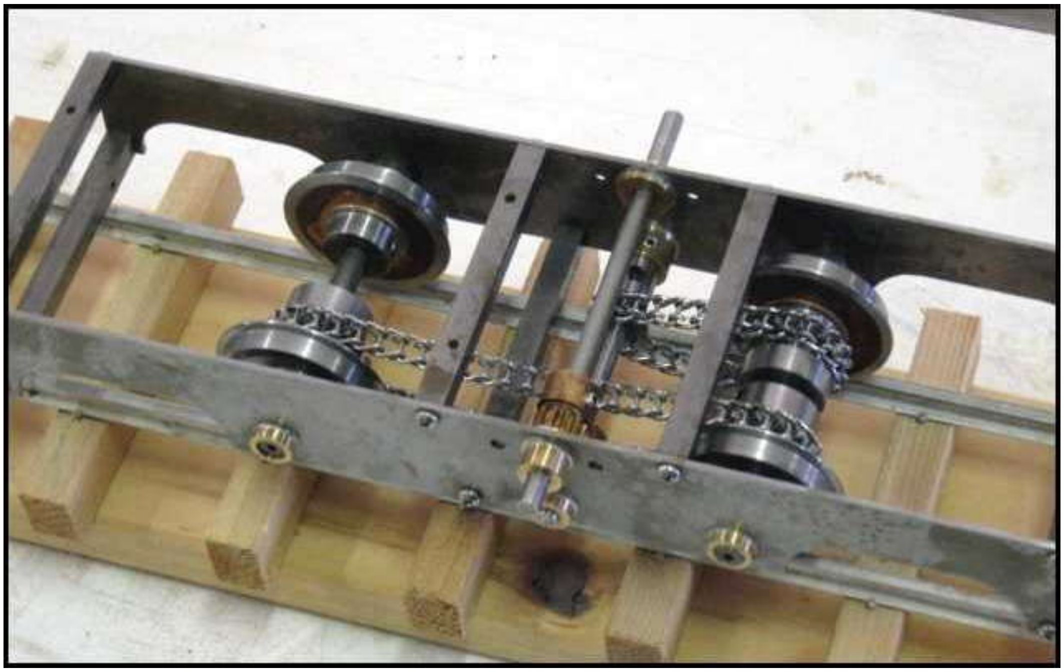
The last little part we need before putting in the chain drive is a stop collar. The stop collar goes on the counter shaft to keep it from sliding side-to-side. The collar is just a 1/4" length of 1/2" diameter brass rod. Drill a 3/16" hole thru and tap for a #6-32 setscrew.

Assemble the chain drive to the front axle, along with the gear drive.



When that piece of the transmission works smoothly, put in the drive sprockets from the front axle to the back.

After using setscrews to lock the various components (sprockets, wheels, & gears) to their respective shafts, MLS member Havoc put forth another good suggestion of milling flats on the respective shafts where the setscrews will bite. Thus over time avoiding the hassle of having to remove components from burred shafts. To review his comments click the red superscript at the end of this sentence. [C-5]



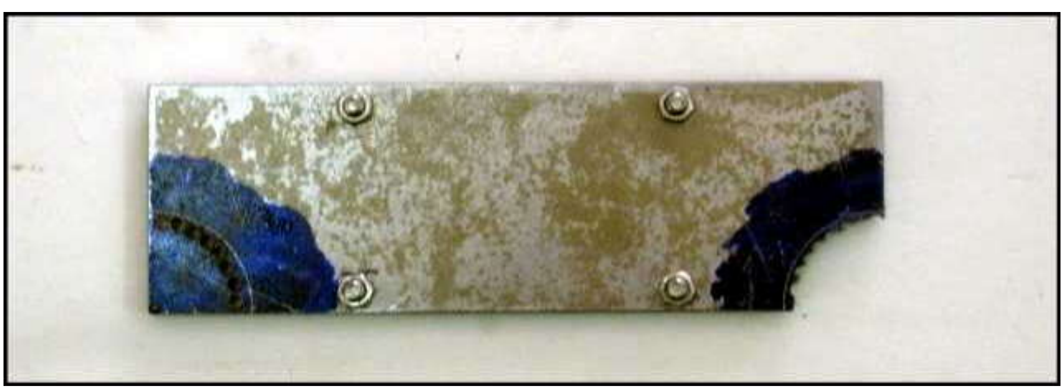
The whole transmission turned out good. It turns smoothly and with almost no effort. The single cylinder oscillator should turn this with no problem. The rolling chassis is almost done.

Next we will get caught up on some leftovers to finish the rolling chassis. So far we have not had to make any real decisions on the appearance of the engine. The end beam arrangements and couplers need a decision right about now.

First are the end beams. The final profile is up to you. Here is the generic drawing (see the end of this document **[Fig. 7]**).

Front & Rear End Beam Shop Drawings

There are two end beams. Their method of fabrication is the same as the side frames. Square up two blanks, clamp them together and drill the holes. I decided to add concave rounds to the lower corners using the chain drill method.



I am partial to the U.K. profile. So the front-end beam of my "Nina" will have a single buffer. The rear coupler is link and pin to use with some existing rolling stock. Here is a picture of the parts.

U.K. style buffers are straight turning jobs. Here is the plan (see the end of this document **[Fig. 8]**).

U.K. Style Buffer Shop Drawing

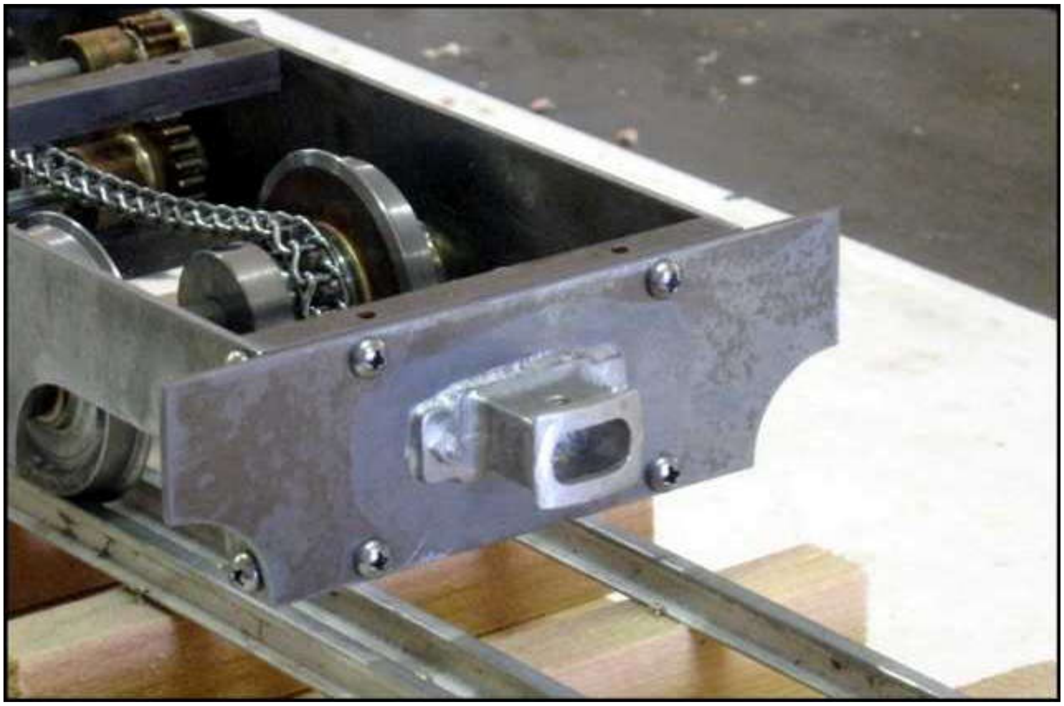
The buffer pad is best turned from a slightly longer piece of stock, then cut off and finished. Grip the stock and turn the backside of the buffer pad:

Cut off the pad from the stock, grip by the shoulder and turn the front. The front gets a round over using a file.

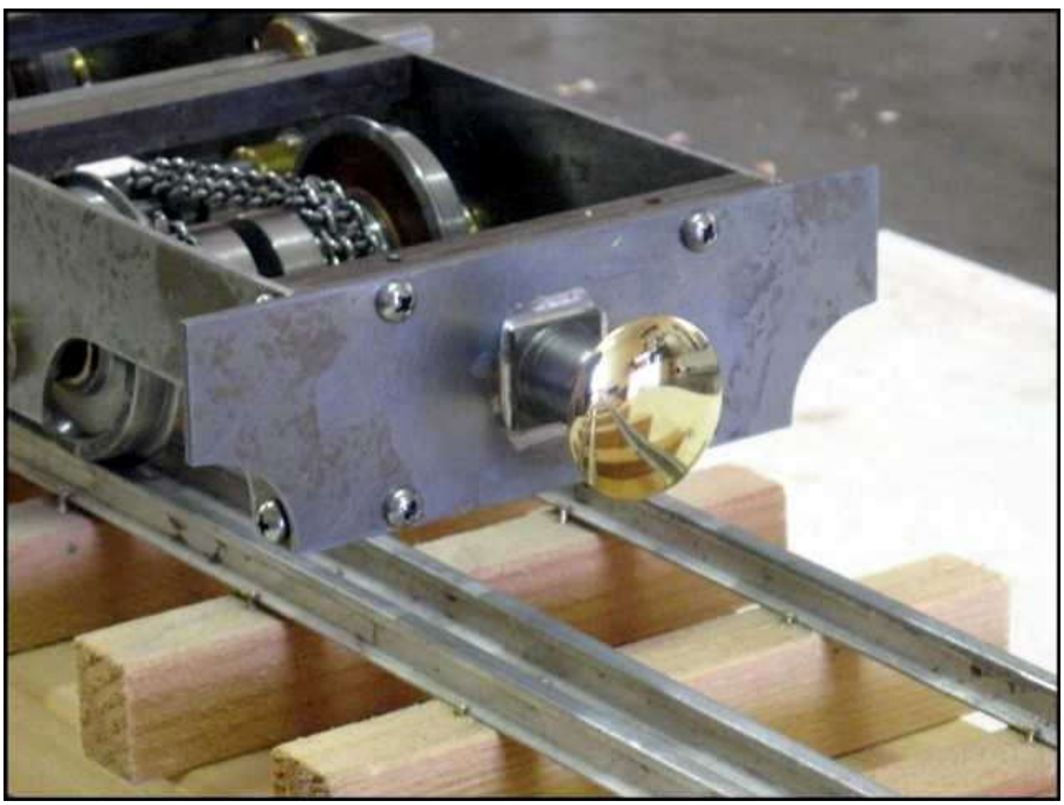
The buffer box is square bar stock. You can either make a split collet as with the spreaders or just center the stock in the 4-jawed chuck.

The coupler came from Ozark Miniatures. It is their 7/8" link and pin coupler cast in white metal. The coupler has a single #4-40 machine screw cast in place. I worried that a single screw holding the coupler could loosen and cause the couple to turn. So I soft solder the coupler to the end beam.

White metal soft solders just fine. Just use a very small flame and heat from the backside.



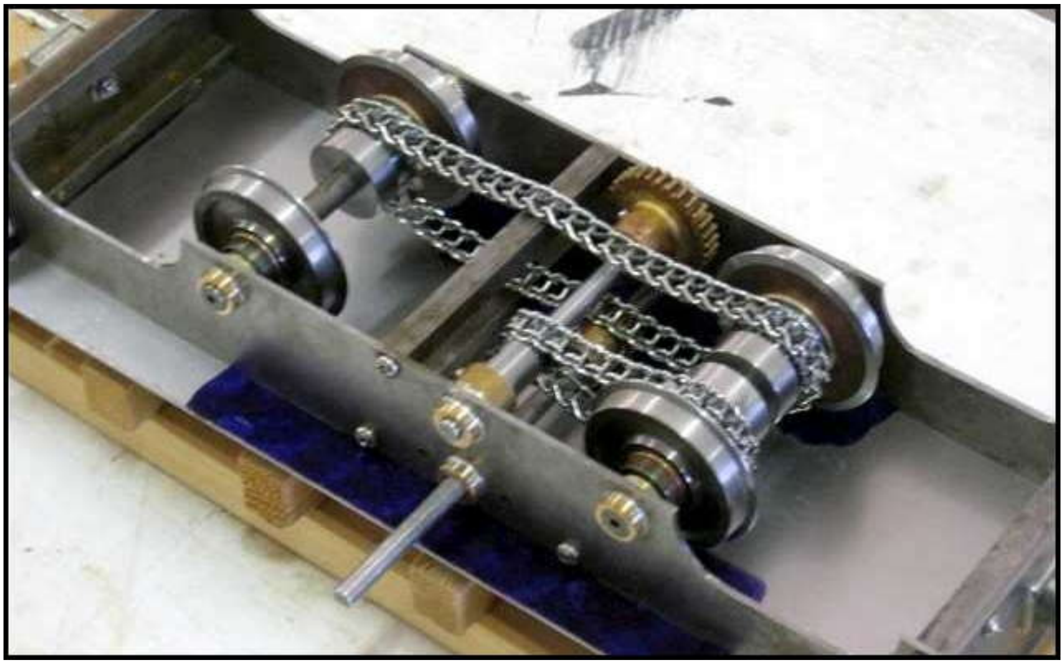
If you go with a U.K. style buffer on the front, polish that baby so it's radio-active.



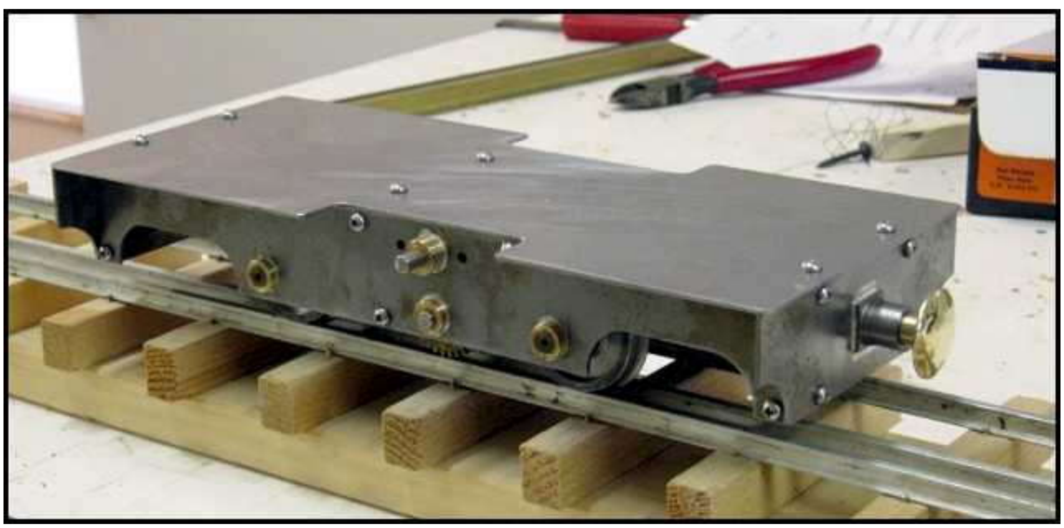
Next up is the footplate it is made from 16-gauge CRS plate. Here is the plan: (see end of this document **[Fig. 9]**)

[Footplate Shop Drawing]

By now, you are an expert at working 16 gauge CRS plate. The only thing different about doing the footplate is to use the chassis as a pattern to accurately layout the side indents. Measure the screw holes from the spreaders, just make sure no little errors crept in and the footplate lines up.



Put everything together and have a look. Looking nice.



This is the end of a major phase. The rolling chassis is all done.

Next is the motor unit. It will go much quicker than the chassis. The motor follows Mr. Glaser's Cracker plan with a scale of 1mm = 1/16". The only difference is that Nina's main crankshaft bearing is part of the frame rather that the engine standard.

First up is the engine standard. The standard is a brass fabrication, which includes the stand and the manifold. Here is the drawing (see end of this document [Fig. 10]):

[Engine Standard & Manifold Shop Drawing]

Start by squaring up a rectangular brass block. Layout and drill all holes.

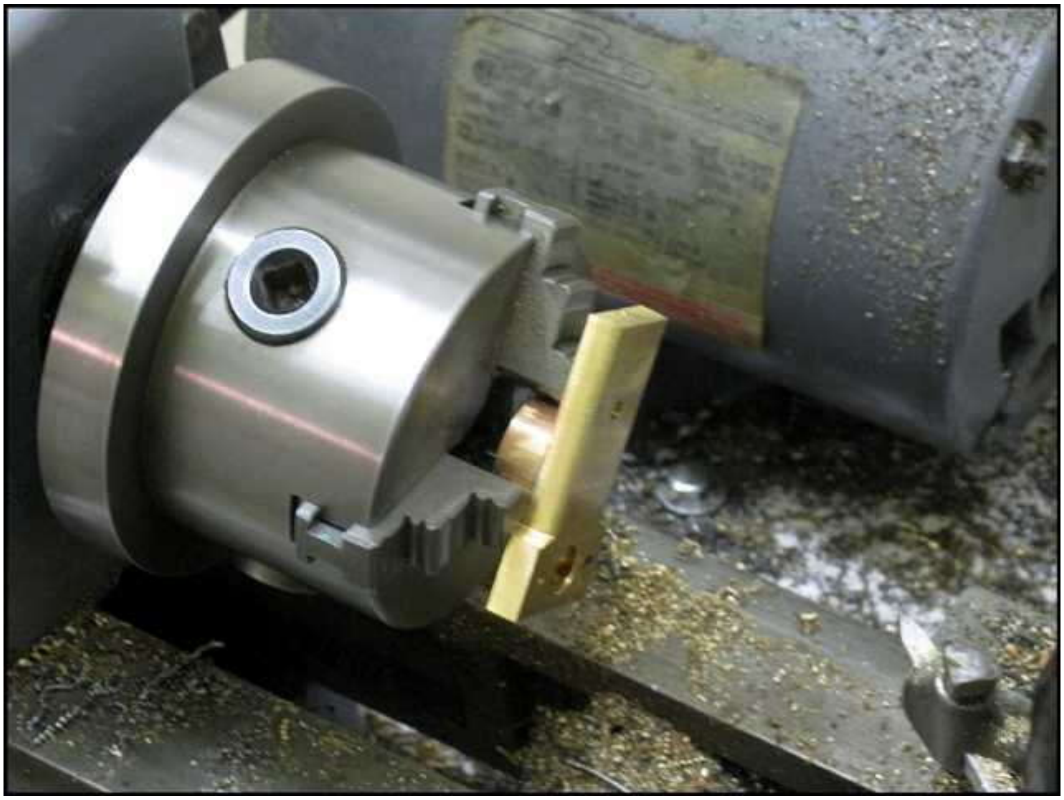
As an editorial comment, a small milling machine is essential in the hobby shop. Not that you will do a lot of milling, if any, but the graduated XY table is so helpful for drilling. As an alternative, use a compound sliding table on a drill press. Something like this:

Grizzly has three compound sliding tables. Check page 647 of their online catalog. It would be well worth the investment. (See comment [C-6])

Next, profile the upper portion of the standard. Do this by either sawing/filing or turning on the lathe. Turning on the lathe will chatter a bit. Just take light cuts.

The plan for the standard calls for 3/16" thick brass. All I have is 1/4". In order to thin it down, soft solder on a temporary chucking spigot.

Chuck up the standard and face down to proper thickness



Now turn the manifold. The manifold is a one-inch length of 3/8” brass rod. Drill both ends 7/16” deep with a #2 drill and tap with 1/4"-40 TPI

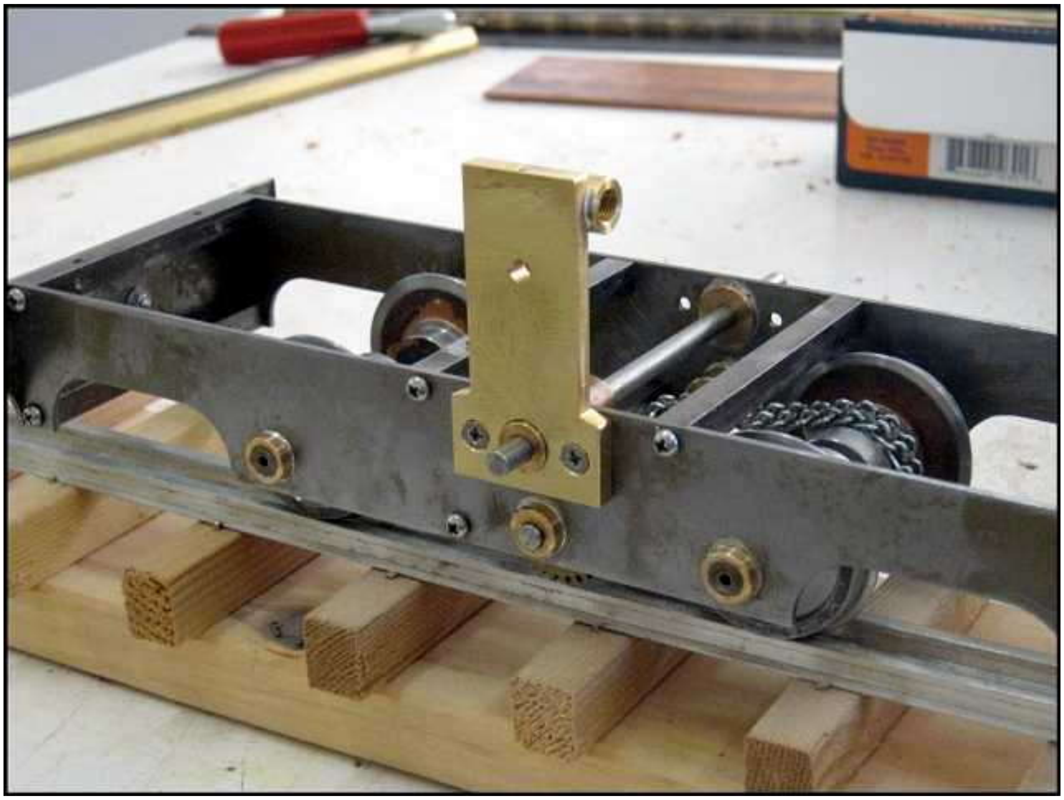
Taps and dies above about 3/16” diameter used in live steam construction tend to be the same “threads per inch” (TPI), either 32 or 40 TPI. They are loosely referred to as Model Engineering (ME) taps and dies. ME is an “old school” U.K. practice that has stuck over the years. Many commercially available boiler and plumbing fittings are ME. 32 and 40 TPI taps and dies are available from industrial suppliers such as Traver's Tool, MSC Industrial Supply and Victor Machinery Exchange. I use all 40 TPI.

Below 3/16" most builders use standard SAE machine screw thread. For Nina, most small threads are #6-32, #4-40 or #2-56

Many builders also use metric thread. Instead of 1/4"-40, you could use M6 x .5mm. When deciding which thread to use, check into commercial availability of boiler and plumbing fittings. Otherwise be ready to make all that stuff yourself.

The next step on the standard is to notch the back to accept the manifold. Do this on the mill or with a round file.

The last step for the standard is to silver-solder the manifold to the stand. After cleaning up, bolt the standard on the to frame.



Next we are going to build up the lower rotating assembly for the motor. The flywheel and crank shaft, first the flywheel.

There are two options for the flywheel: one with a larger diameter and thinner rim and another smaller diameter and more stocky. Either will work or you can customize your own. Just make sure it fits the notch on the footplate. Here are the two plans (see end of this document **[Fig. 11]** & **[Fig. 12]**):

Flywheel Option 'A' Shop Drawing

Flywheel Option 'B' Shop Drawing

For an unusual and professional touch, turn the flywheel from stainless steel. Highly polished stainless steel has "karma". And while everyone else's stuff is rusting out, yours will still look cool. A lot of builders worry about stainless steel, that it is too hard to turn. Actually it is not that bad. Use a "free machining" alloy of stainless steel, such as #303 or #416. Turn stainless at a slower speed and use a lot of oil. The oil will smoke and stink-up the shop, but the result is worth the effort. High Speed Steel (HSS) tools will get dull. When you get to the last .005" or so, re-sharpen the tool and take the last cut with oil. Polish the rim with oiled sandpaper to a high luster.

An alternative to stainless is cast iron. Polished cast iron "makes a statement" too. Cast iron is easy to turn. Turn it dry at very low speed.

Turn the front side of the flywheel from a longer section of 2" stock. Drill and ream for the 3/16" crankshaft. Turn a decorative recess as desired.

Cut off the flywheel from the stock. Chuck from the front side and turn the reverse. Chamfer the sharp edges with a file. Tap the hub with #6-32 for a setscrew. You will be very relieved when the flywheel is done. And sore. Sawing a 2” bar is no fun.

Next is the crankshaft. The crank is assembled from three parts using Loctite. Here is the plan (see end of this document **[Fig. 13]**):

Crankshaft Shop Drawing

Use one of 3/16” x 4-1/2” stainless steel shaft blanks created when soldering the flange bearings into the side frames for the crankshaft. The plan says 4”, but depending on flywheel option used wait till assembled to determine finished length.

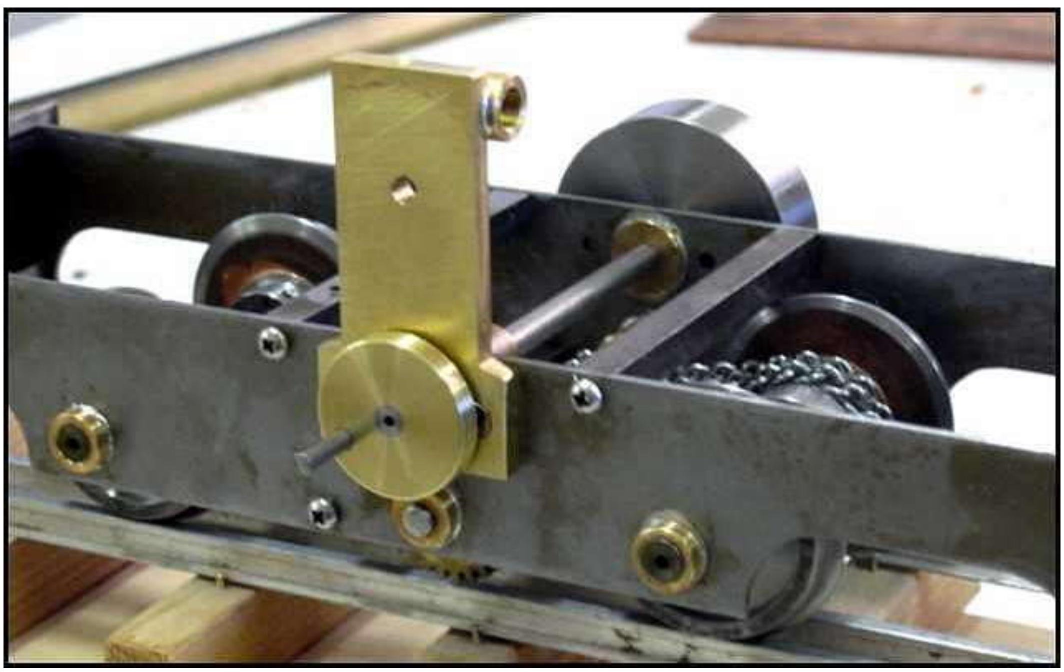
From a longer piece of 1” brass stock turn disc to size and form the backside of the crank disc. Drill and ream a 3/16” hole somewhat deep for the shaft.

Clean the shaft and hole in the crank disc with solvent. Apply Loctite Compound #680 to the crank disc hole and the shaft. Insert the shaft into the disc. Use the lathe tailstock to align the shaft to the disc.

Leave it set for about 30 minutes, then clean of the excess Loctite with solvent. If the excess Loctite hardens, it is nearly impossible to remove. Leave the assembly sit in the lathe overnight to fully cure.

Cut off the crank disc from the main stock and machine it clean on the lathe. Drill the crank disc for a 1/8" wrist pin. Use Loctite to set the wrist pin. The crankshaft is done.

Assemble the rotating parts (remember to check and mark for finished length, then trim and face). The flywheel will give quite a bit of momentum to the chassis. Rotate the crank by the wrist pin. It will be effortless. It's looking very good.



Next up is the cylinder. It's been a while since the last update. The reason for that is because I was having some trouble getting the cylinder done right. The original plan was to drill and ream the 1/2" bore in a bronze cylinder blank. Reaming that size turned out to be difficult for my little lathe. There was too much chatter and the resultant bore not very clean. I decided to abandon the ream and use a traditional boring bar instead. (See comment [C-8, & C-9])

In preparation for turning the cylinder, my old Atlas 6" lathe got an upgrade this past week. I ordered a quick-change tool post set from Littlemachineshop.com

A quick-change tool post allows you to set the tool in its holder just once and then quickly change the holder as needed. This post is much faster than the original rocker style post and light years ahead of those 4 position turret things that come with most lathes.

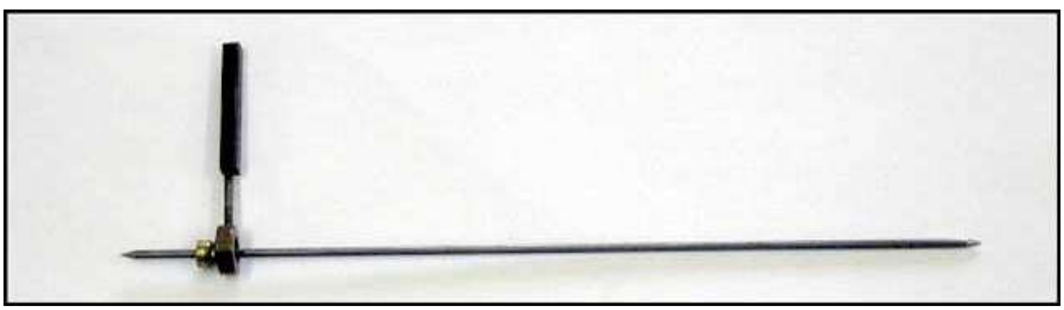
Before getting started on the cylinder, we need to fabricate a special little measuring tool called a center test indicator. They are also known as a wiggler, or wobbler. The wiggler helps get an odd shaped piece centered in the 4-jawed chuck. Here is an article I found on how to make one. (See end of this document **[Fig. 14]**)

Wobbler Article

Modify this idea to suit you lathe. And here is an illustration of how to use it. (See end of this document **[Fig. 15]**)

How to Use a Wobbler

My homemade wiggler is a 2-piece contraption using a ball for the pivot point.



With that done, let's get started on the cylinder. Here is the drawing: (See end of this document **[Fig. 16]**)

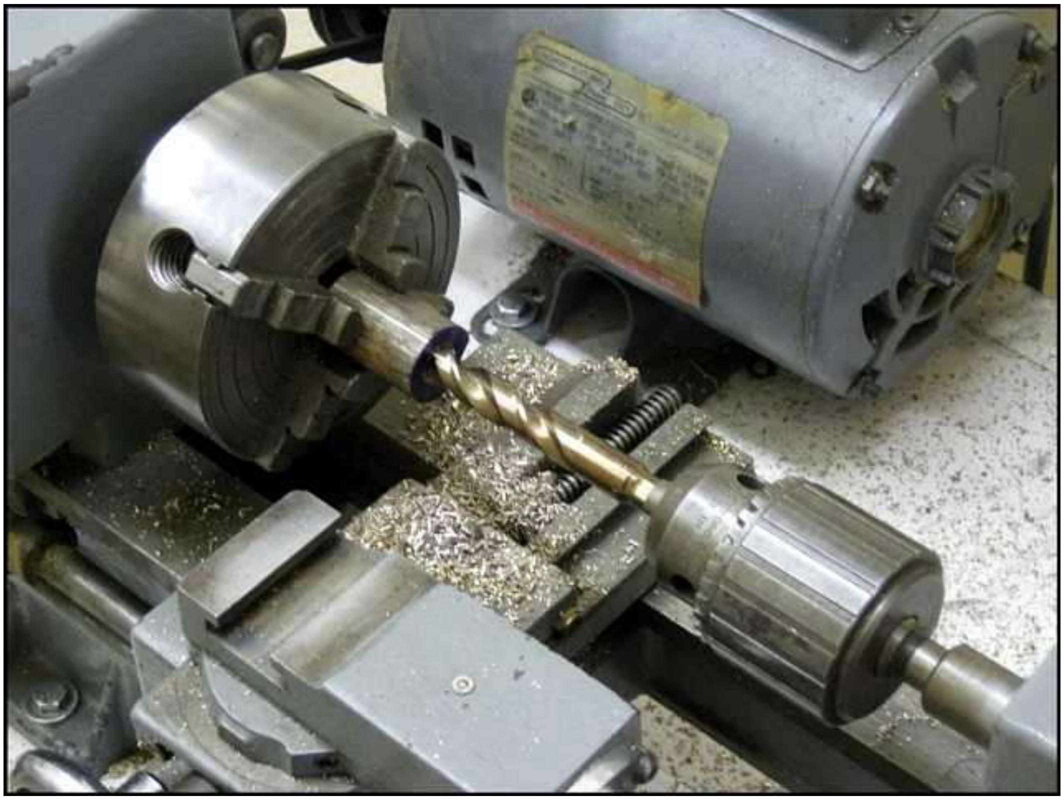
Cylinder Body Shop Drawing

The cylinder body is bronze, alloy 932. Bronze only comes in round bar and our cylinder is more or less rectangle. So we will have to start with an oversized bar and work it down. First, face and part off a length of 7/8" diameter bar to 1-3/8" long. Grip the bar sideways in the 4-jawed chuck and turn it flat to a width of 5/8"

This face spot will eventually be the port face.

Locate and lightly center punch the cylinder bore center. Grip the cylinder in the 4-jawed chuck and center it up with the wiggler.

Drill a 1/8” pilot hole thru the cylinder. With the lathe set at the slowest speed, preferably in “backgear” if your lathe has one, drill thru with 7/16”.



Set up the boring bar in the lathe. Since there is 1/16” of material yet to remove from the bore, you have plenty of time to set-up, practice and make adjustments before taking the final cuts.

Take very light cuts. Even the most rigid boring bars find a way to spring. So take a cut occasionally without any adjustment. Let the bar relax out. Test the bore with a short length of 1/2" stainless steel piston material. The piston material will eventually go in very tight.

Don’t force it. Take another super light cut, and test the piston again. When the piston just goes in, it’s time to stop the boring bar operation and finish the bore.

Be patient boring out he cylinder. Expect 18 to 20 passes with the boring bar to get it right.

High quality cylinder bores are finished with a process called “lapping”. Lapping uses a fine abrasive powder mixed in oil on a lapping mandrel to polish the bore. Since our cylinder is bronze, a hard wood mandrel will work fine. Turn a 4”, or so length of maple or oak to exactly .500”. Wipe on some abrasive powder mix. Slide the cylinder over the mandrel and turn it by hand. It will be tight at first, but the wood will smoothen down and the cylinder will turn freely.

When the cylinder is turning freely, hold it buy hand and turn on the lathe. Work the cylinder over the entire length of the mandrel. It will only take about 30 to 45 seconds for the lap to polish the bore. The bore comes out free of scratches and with a lightly frosted surface. The piston material should slide smoothly with no air blow-by.

In the lapping process, the mandrel must be a softer material than the cylinder material. The abrasive lapping compound embeds itself in the softer mandrel and polishes the cylinder walls. For brass and bronze cylinders, wood mandrels work fine. For steel or cast iron cylinders, use a brass or copper mandrel. Lapping only removes micro scratches and burrs left from the boring bar. The initial bore has to be straight, round and reasonably smooth. If the bore is bad to start with, lapping will not fix it.

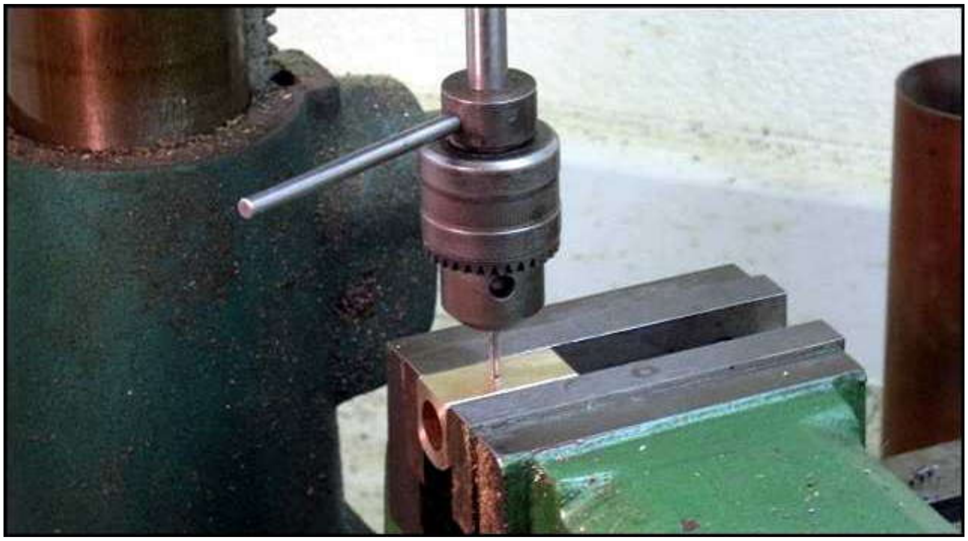
That’s it for now. Next time we will shape the cylinder, put on a top cover and hang it on the standard.

Last time we got the cylinder bore finished; today we will get the rest of the cylinder done. When the cylinder came off the lapping mandrel, it looked like this:

There is a lot of excess material to remove. Chuck the cylinder sideways in the 4 jawed chuck and face down the sides. At this point start using strips of paper as packing to prevent the chuck jaws from marring finished surfaces.

With the sides faced down, draw file the rounded surface of the cylinder to get the mill marks cleaned off.

Set up the cylinder in the drill press vice to drill and tap for the #4-40 trunnion pin.

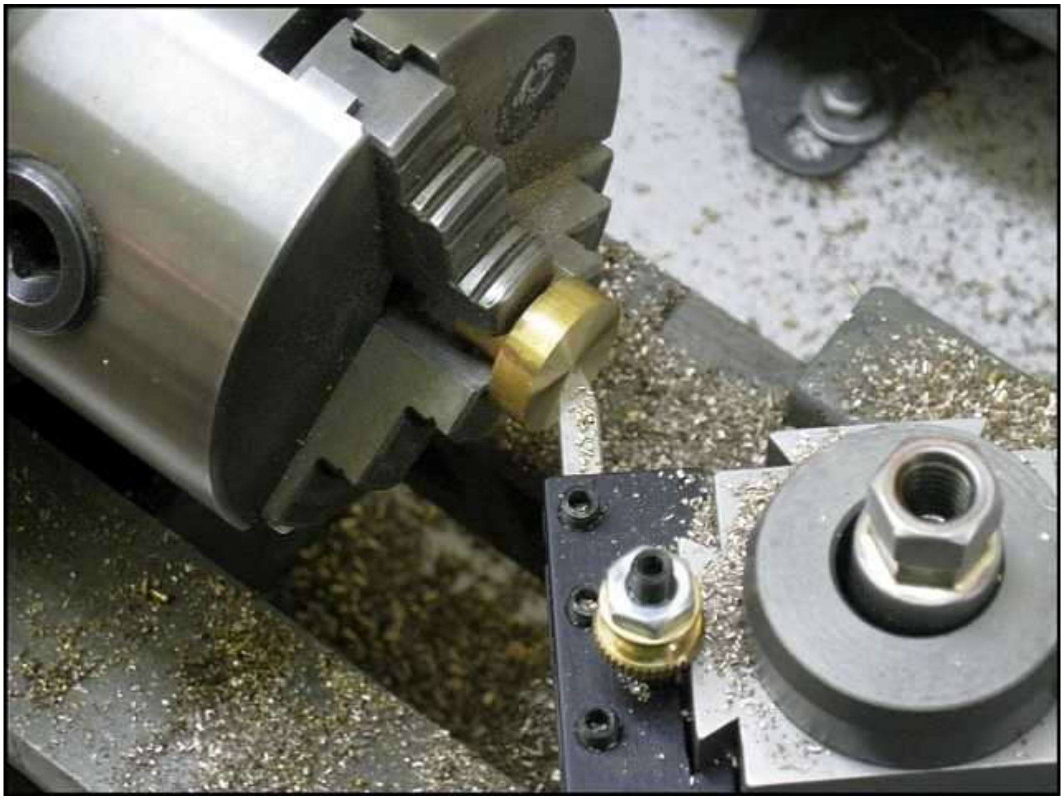


The cylinder block is essentially finished. The next parts are the cylinder top cover and trunnion pin. First the top cover. Here's the drawing (See end of this document **[Fig. 17]**):

Steam Cylinder Top Cover Shop Drawing

The top cover is brass and is soft soldered to the cylinder. Start by cutting a 1/4" length of 3/4" round bar. Soft solder on a chucking spigot, just like we did for the engine standard.

Chuck up the top cover and face down to clean metal. Don't worry about getting the cover centered in the chuck. We are just cleaning this face off. This faced surface is the top of the cover.



Melt the chucking spigot off and re-solder it to the faced off side. Chuck it up in the lathe and turn the outside diameter to 5/8”

Face the top cover to length and turn the shoulder that fits inside the cylinder.

Melt off the chucking spigot. Use a file and sandpaper to clean of the excess solder.

Now soft solder the top cover to the cylinder. Use just a “TT” of solder to put the cover on. Don’t run the risk of a solder blob running down the inside of the cylinder.

The last part for the cylinder is the trunnion pin. The trunnion is the pivot point of the oscillating cylinder. Here’s the drawing (See end of this document **[Fig. 18]**):

Steam Cylinder Trunnion Pin Shop Drawing

The usual method to make this pin is to turn a shoulder on the bar stock and cutting the threads with a die. That is nearly impossible to do with threads this small. Instead make the pin with a length of stainless steel rod and two #4-40 machine screws.

Cut a 7/16” length of 5/32” stainless steel rod. Drill and tap both ends for #4-40.

Use Loctite #242 to lock the machine screws into their holes. When the Loctite cures, trim the machine screws to length.

With the trunnion pin installed, the cylinder is pretty much done.

Next time we will drill the port holes and lap the faces. Maybe even get on the piston. The air test is right around the corner.

We still have some work to do on the cylinder. One of the things to do is drill for the steam, exhaust and cylinder ports. According to Mr. Glaser's original Cracker design, the ports are 1mm. Using the scale of 1mm = 1/16" our ports should be 1/16". This just seems too small to me, so I am going to try 0.0785" (#47 drill) first and see how that works. If it's too small, I will open them up some more. But for now, we will try that.

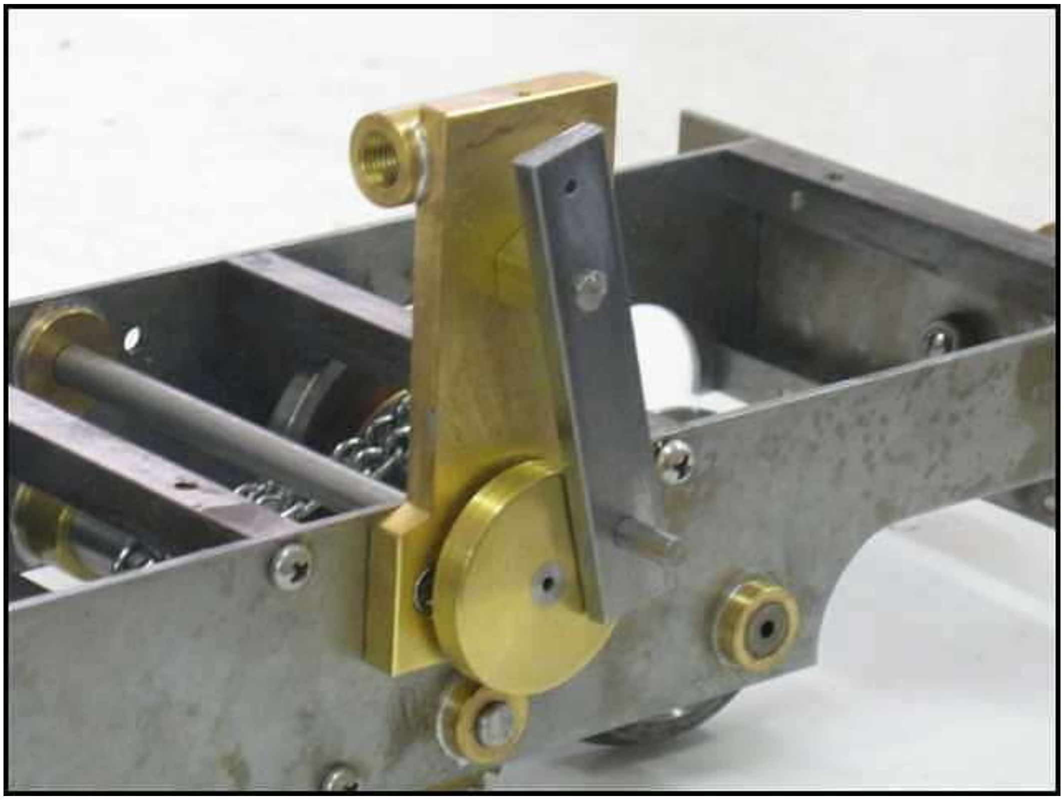
First drill the port in the cylinder. I should have done this last time when it was set-up for the trunnion pin.

Now drill the ports in the engine standard for the steam and exhaust. The best way to do this is with a drilling jig. It would probably be impossible to lay these holes out any other way. Here is the jig plan (See end of this document **[Fig. 19]**):

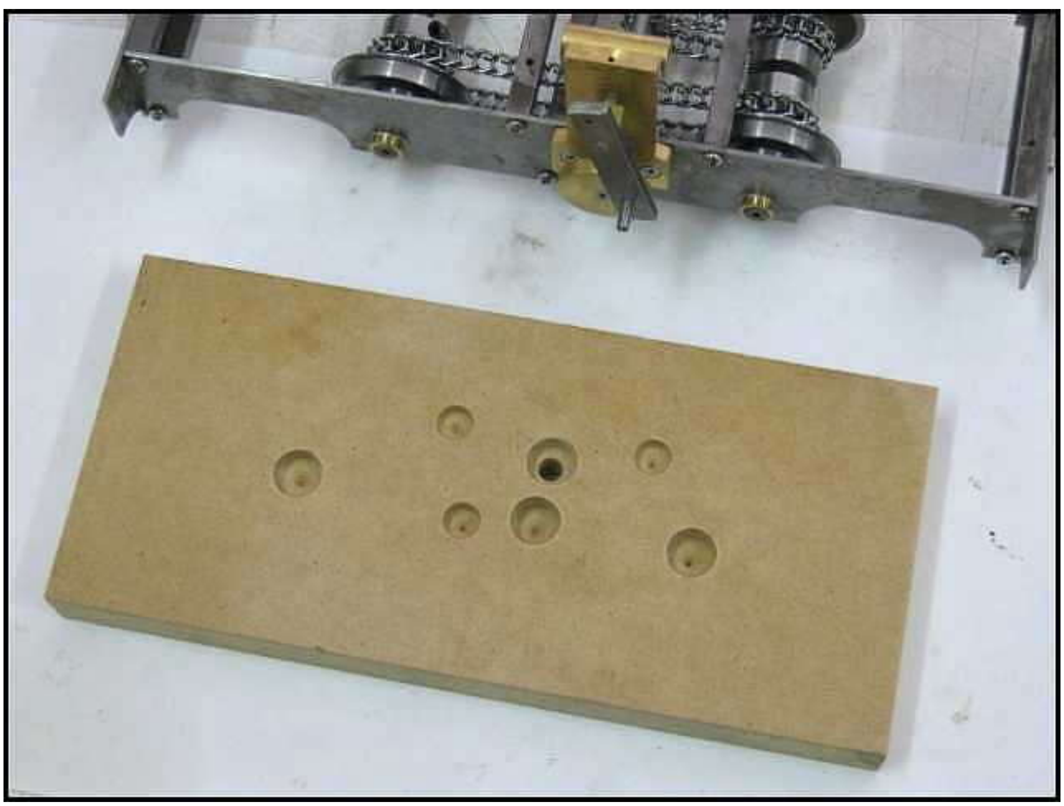
Steam and Exhaust Port Drilling Jig Shop Drawing

Here is the jig and a little spacer piece.

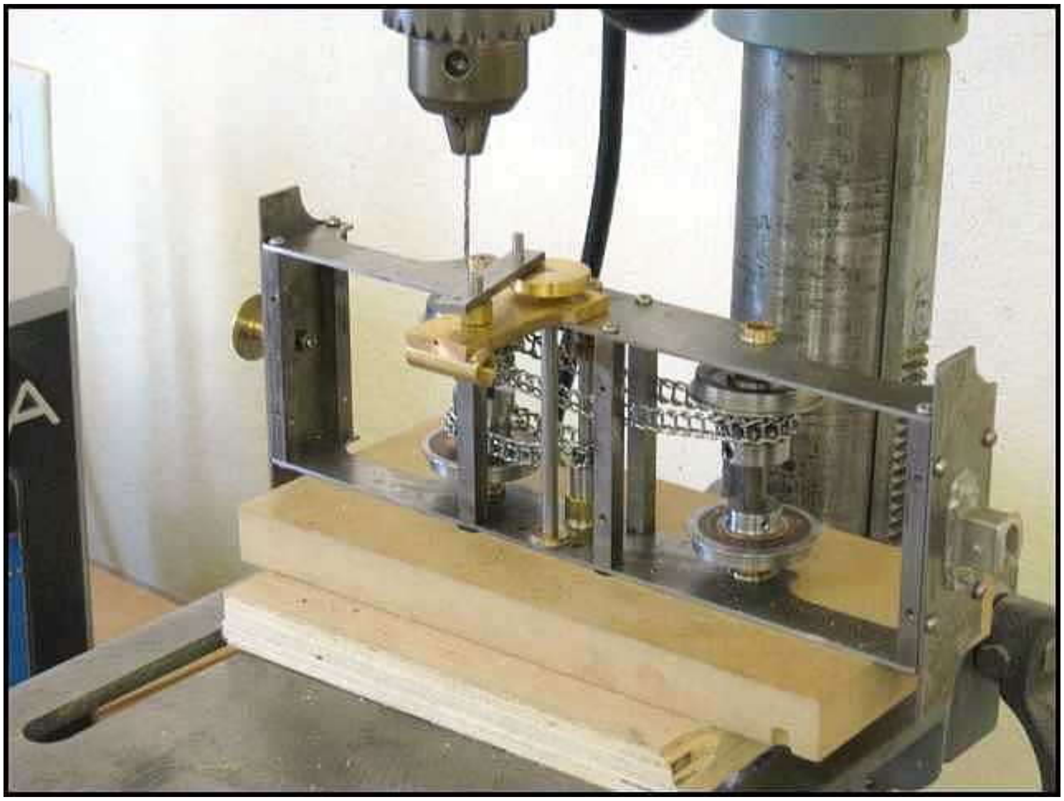
The jig simulates a rigid piston/cylinder. It puts the port holes in the right spot. Set up the jig with the engine standard and crankshaft.



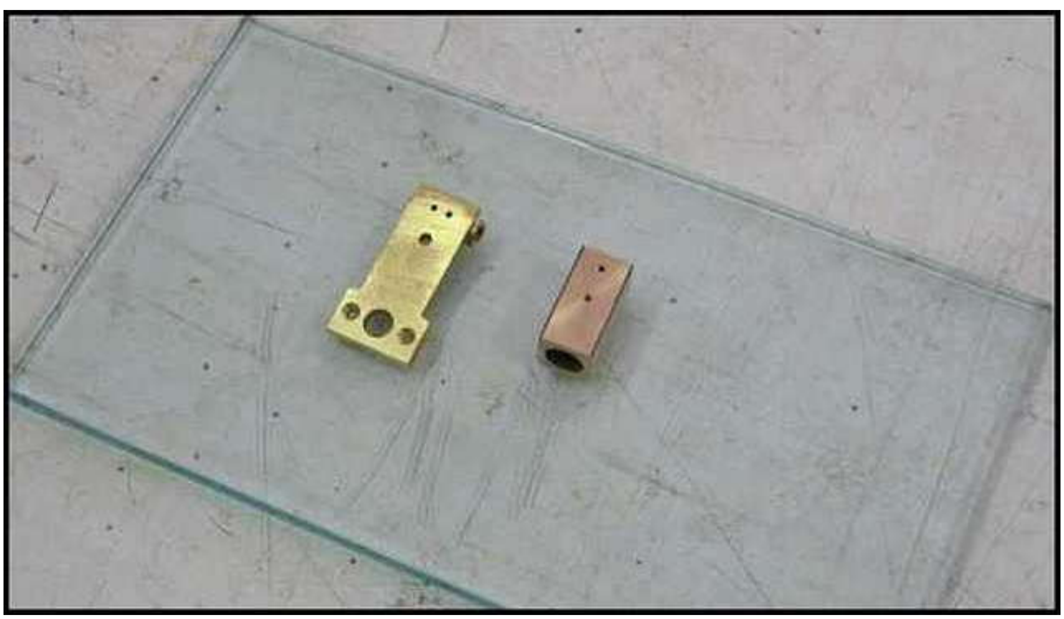
Before trying to drill this, build up a cradle from a piece of plywood or MDF. Drill recesses to clear the bearings and screw heads and the engines firmly on the side frame.



Use the drill press to drill ports. Prop up the engine standard your thumb under the manifold to keep everything level. Drill deep enough to break into the manifold center. Reverse the jig to drill the other side.

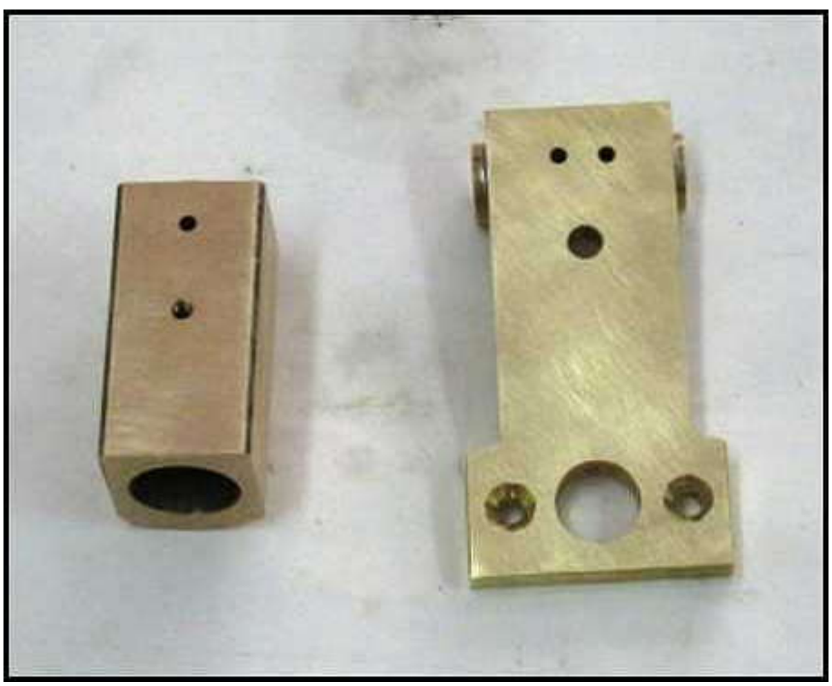


The next step is to lap the port faces on the engine standard and cylinder. The port faces need to be perfectly flat and smooth. To lap the faces we need a surface plate. For hobby purposes a small slab of thick plate glass is flat and true enough. Go to a good glass shop and have them cut a piece of 3/8” or 1/2" thick plate glass to about 8” x 10” and round the edges. They will mostly likely have a scrap piece ready to go in the junk bin.



The lapping material is a sheet of good quality wet/dry sandpaper in about 320 grit. Wet the paper with water and lay it on the glass. The paper will lay done tight against the glass. Rub the port faces of the cylinder and engine standard on the paper in a circular motion.

Continue to work the port faces until all scratches are gone. The faces will have a slight frosted appearance.



The frost is a good thing. My mentor taught me that the frost is microscopic scratches that help hold oil in place and lubricate the surfaces. Highly polished surfaces will squeegee the oil away and cause wear or binding. I have had that happen, I believe my mentor.

That’s it for now. Next time is the piston. Maybe the air tests too. I am getting nervous.

Today we are going to get this motor unit finished and Nina running on air. The piston is the last part to do. By now you have enough machining expertise that the piston is easy to knock out.

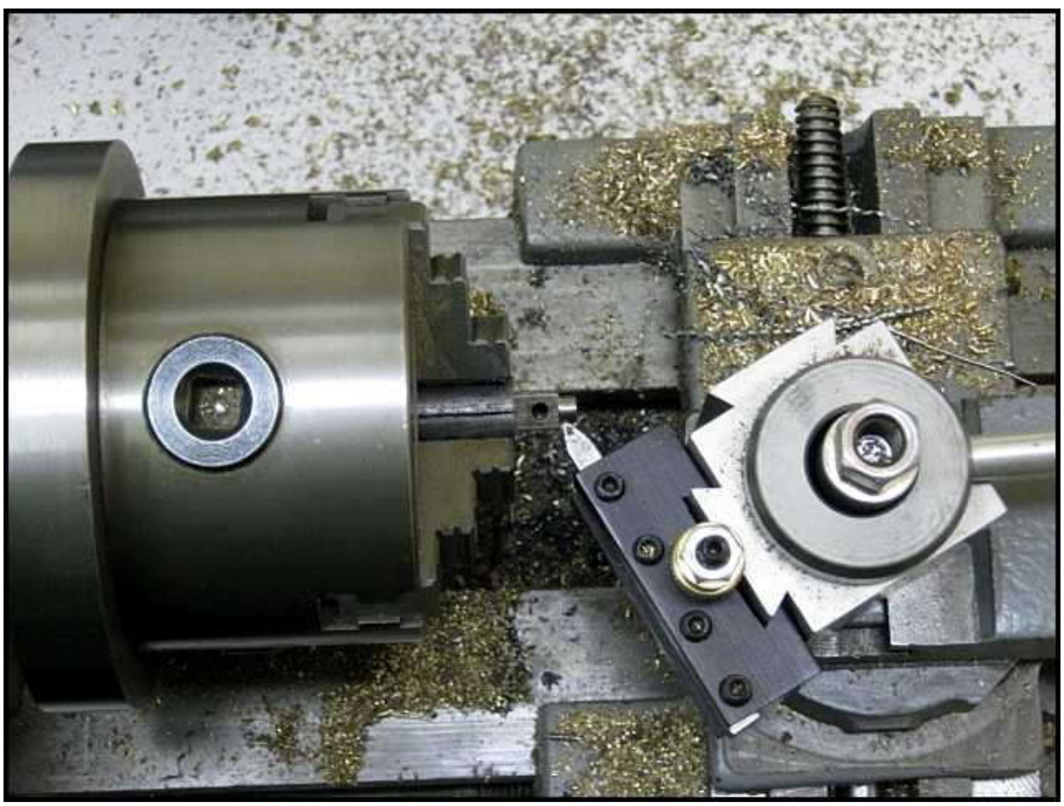
The piston is in 3 parts and just screws together. Start with the bottom end, known as the "big end". The piston big end is a drilling and turning job from 1/4" square CRS. Here is the drawing (See end of this document **[Fig. 20]**):

[Steam Piston Big End Shop Drawing]

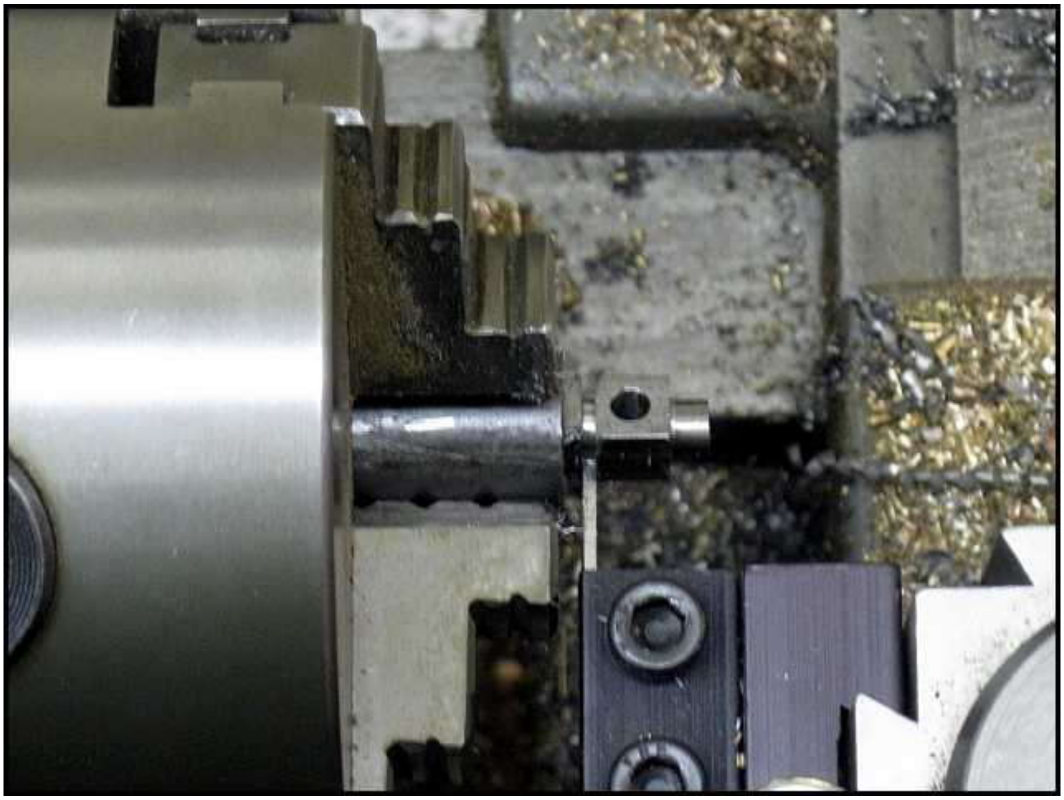
Start by facing off the stock and drilling and reaming the 1/8" hole for the crankshaft wrist pin.

We are going to do something different. We are going to completely machine the big end with just one set-up in the lathe. The finished part will be ready to install. Chuck the square stock in the 3-jawed chuck using that collet you made for the spreaders. Hope you did not throw it away. Drill and tap for the #4-40 threaded piston rod end.

Now turn a little shoulder.



It’s time to try a new gadget that came with the quick-change tool post set. It is a parting tool. A parting tool is basically a knife tool that plunges into the stock to cut the finished part off. This particular parting blade is only 0.040” wide, which is about the thinnest available.



Run the parting tool at a somewhat lower speed then regular turning and use oil.

Next is the piston rod. Make it exactly as you did for the trunnion pin. Drill and tap both ends of a 5/8" length of 5/32" stainless steel rod for #4-40. Loctite in some #4-40 machines screws and trim to length. Too easy, here's the drawing (See end of this document **[Fig. 21]**):

Piston Rod Shop Drawing

The piston is straightforward too. Chuck some 1/2" round stainless steel stock. Face, drill and tap for #4-40 to accept the piston rod. With the lathe running, polish the rod with #320 grit wet/dry sandpaper and oil. For an extra smooth surface, repeat with #440 grit. Cut off the polished piston and face to a length of 9/16". Here is the drawing (See end of this document **[Fig. 22]**):

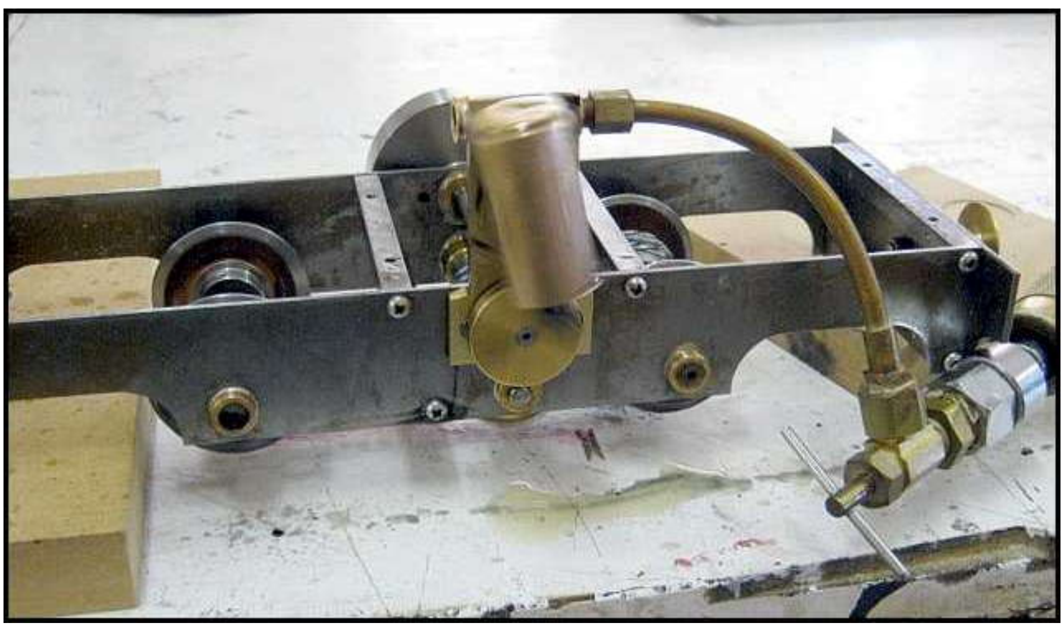
Steam Piston Shop Drawing

Here are the piston parts ready to assemble.

Put it together with some Loctite #242 and it's ready to go.

Time for the air test. Put the engine together including the drive train. Everything needs to run. Oil all the moving parts. Secure the chassis to the bench and attach an air source. Turn on the air, give the flywheel a spin and see what happens.

And there it goes.



It started up, ran jerky for about 15 seconds, and then smoothened out. I stopped it after about 2 minutes, disassembled and cleaned it. The oil was blackened a lot. I suppose it cleaned out the last of the "gook". I ran the engine for about 2 hours, stopping every 15 or 20 minutes to clean and add oil. The speed was about 250 RPM.

Some observations:

- The spring used to retain the cylinder was way too light. It is 1/4" wide and 1/2" long, 0.015" diameter wire and about 8 turns. The slightest air pressure lifted the cylinder off the port face. After clamping down nearly all the way, it ran normally. I will need to order a slightly stiffer spring.
- The motor runs with a lot of power. I was surprised. If the "torque-o-meter" (finger on the wheels) is any measure, it was difficult to stall.

- It took very little air to turn the drive rain. Seemed like just a trickle. I need to find a low pressure gauge and see what it is really running at.
- Almost no friction between the cylinder and port face. The oil seems to form a film so there is no real metal-to-metal contact. The piston is airtight and no friction.
- After 2 hours of running there are no signs of wear.

We are calling this air test a success. Next time we will start on the boiler.

All the spring clean up chores are done, so we are back on the Nina project.

The boiler is a single flue, gas fired, "T" shape. The "T" shape allows for large water capacity in the vertical barrel and extra heating surface on the flue in the horizontal barrel. The vertical barrel is from 2 1/2" nominal copper pipe. The horizontal barrel is from 1 1/2" copper pipe. The flue is a length of 3/4" copper coupling pipe. Coupling pipe is used for plumbing repairs and is larger in diameter then the nominal pipe. 3/4" couple pipe is almost 1" diameter.

The end plates and flue sheet are from 1/8" flat copper plate. In small, low-pressure boilers for Gauge 1, there is no need to flange the end plates. The plates just get turned on the lathe to fit their barrels.

Before getting started we have to make some decisions. Mr. Glaser's original "Cracker" design is very basic. His boiler has neither a throttle, nor a safety valve. His design is satisfactory that way. There is an unobstructed path from the boiler to the engine. The engine runs when boiler builds enough pressure. If there is too much pressure, the oscillating engine acts as a safety valve, just as we saw during the Nina air test.

I want to put a throttle on Nina. With a throttle, we need a safety valve. We will do a lubricator, which Mr. Glaser left off of the Cracker. I also want a site glass and a water fill plug. So basically, all the boiler fittings.

Here are the drawings for the boiler (See end of this document **[Fig. 23]**, **[Fig. 24]**, **[Fig. 25]**, & **[Fig. 26]**):

Boiler Page 1

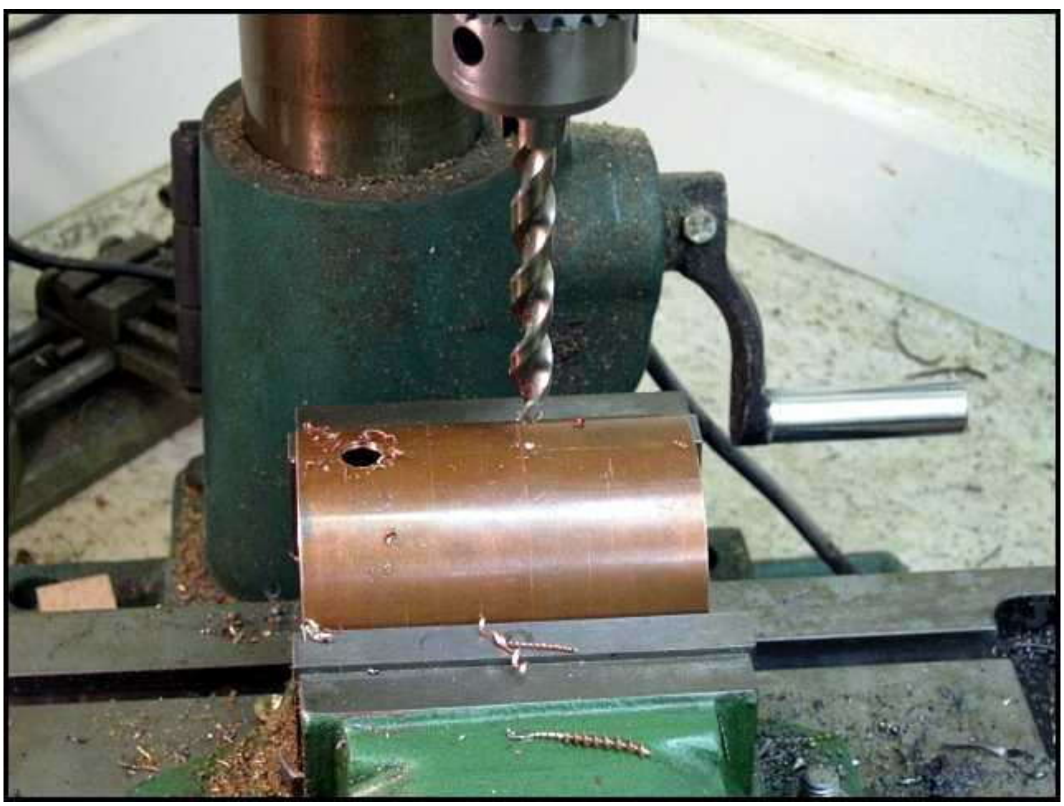
Boiler Page 2

Boiler Page 3

Boiler Page 4

Start off the boiler by cutting the barrel sections and flue slightly over length. Square the sections by clamping a block of wood at a right angle on the disk sander. Turn the barrel as you sand. It squares up in no time.

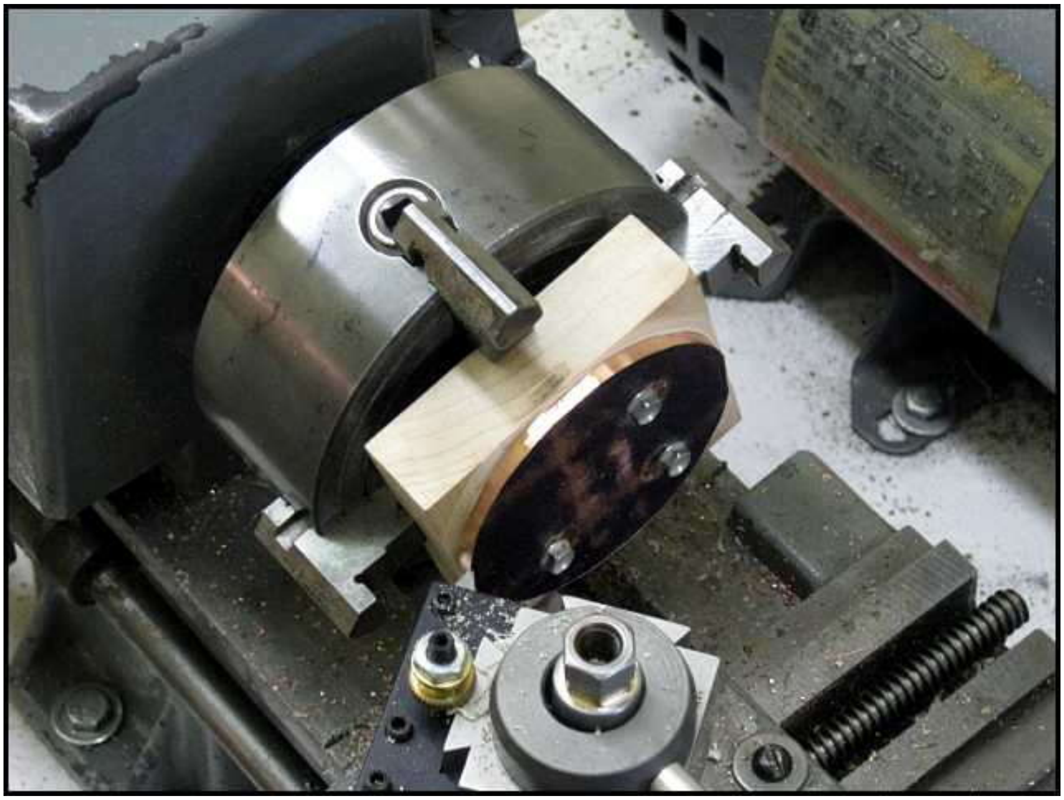
Next, drill the 3/8” holes in the vertical barrel for the site glass bushings. Securely clamp the barrel and set the drill to very slow speed.



Rough saw the top and bottom boiler sheets from 1/8” copper plate and drill for their bushings. The top plate gets 3 bushings: throttle, safety valve and water fill. The bottom plate gets 2; both are blind mounting bushes.

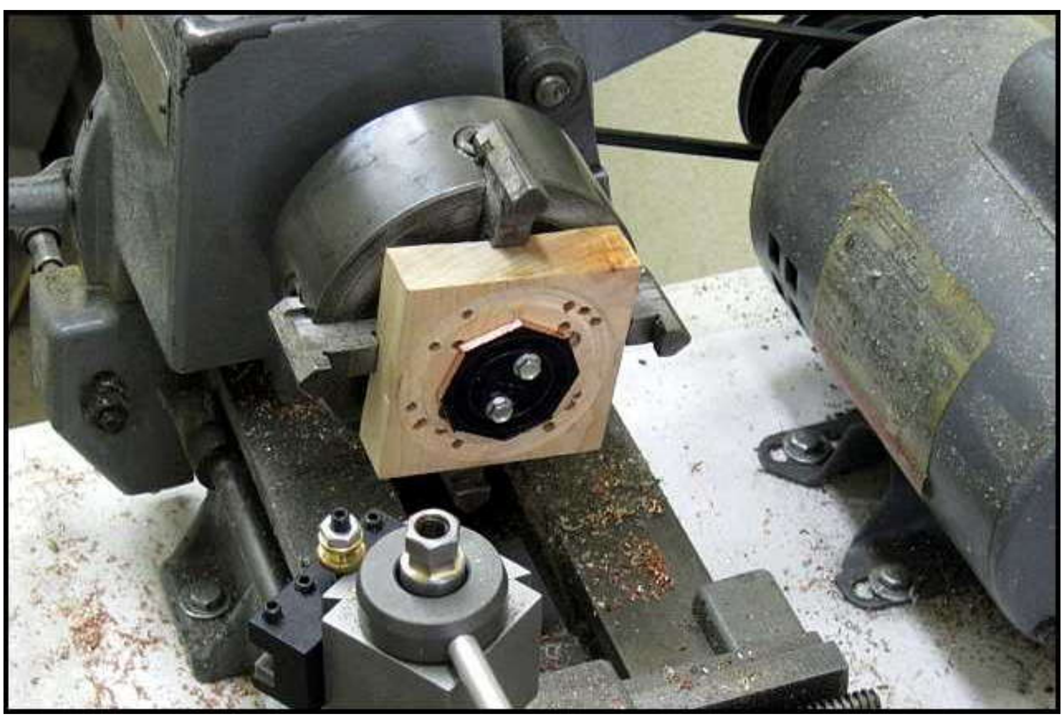
The boilerplates get turned on the lathe to fit the vertical barrel. Use a square block of hard wood, oak or maple, as a sacrificial faceplate to turn the plates. Fix the plate blanks to the wooden faceplate with #8 sheet metal screws.

Use your center test indicator (wiggler) to center the plate in the lathe. Turn the plate down so it just fits inside the boiler barrel. Not too loose, not too tight, just right.

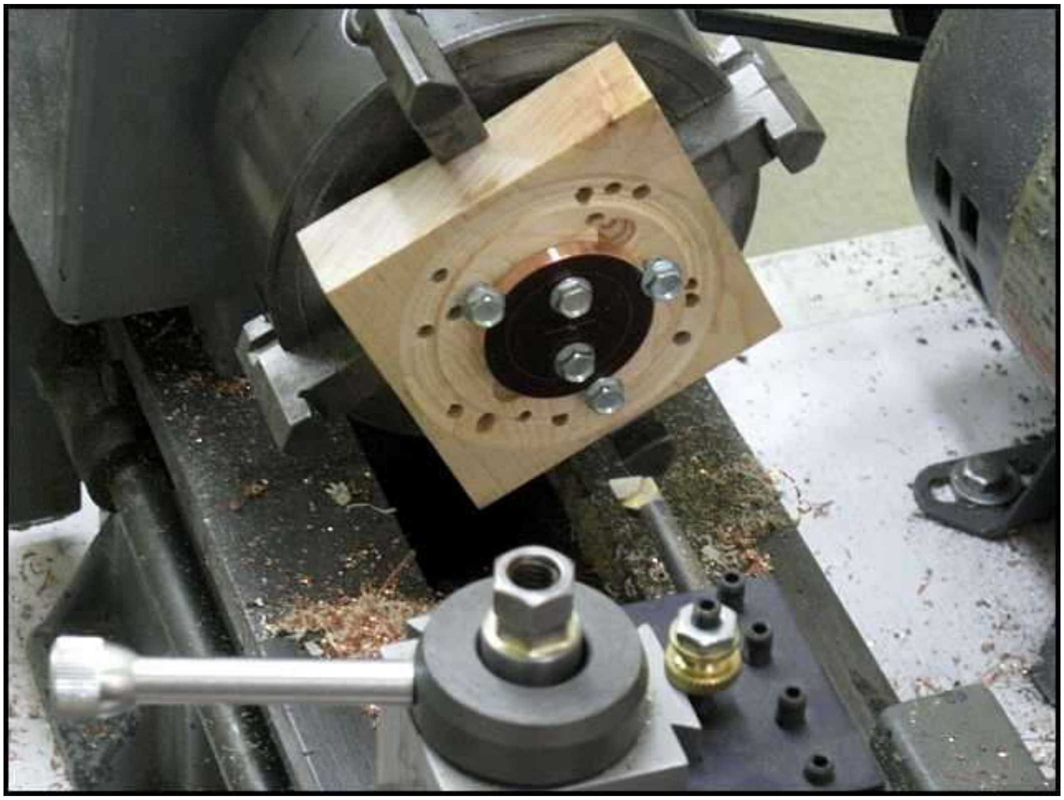


Run the lathe tool well into the wooden faceplate to ensure the cut is complete. Do the top and bottom plates the same way.

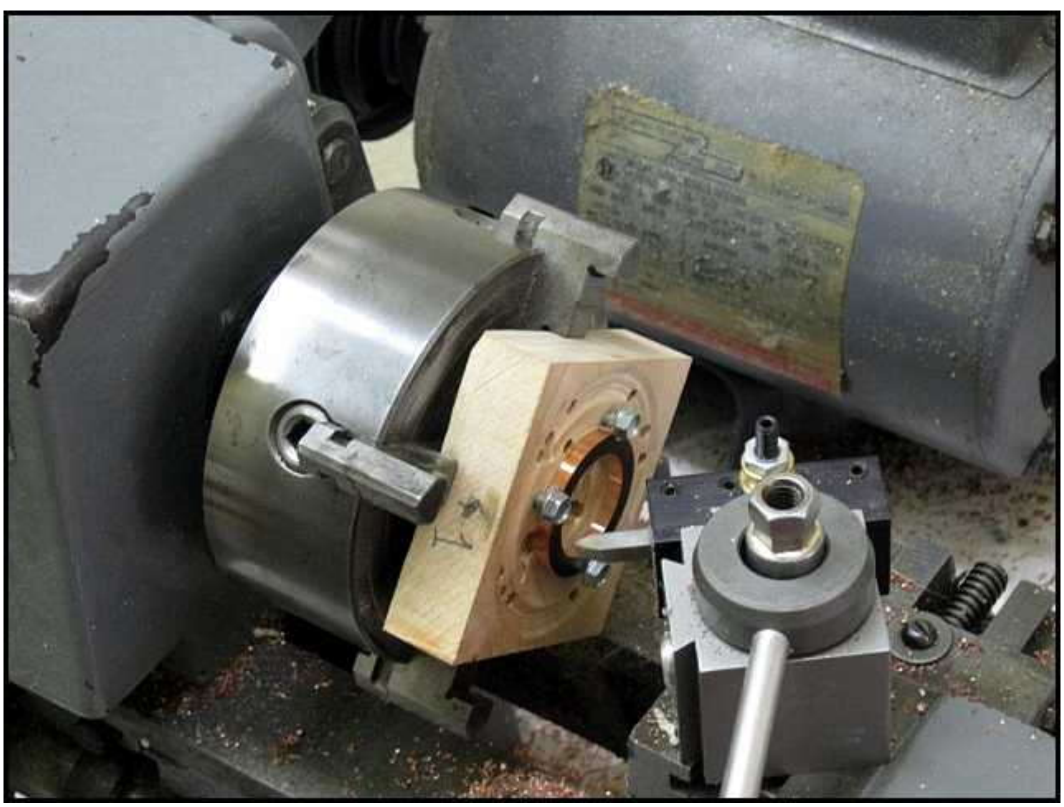
The front flue plate has 2 turning operations, a hole for the flue and the outside to fit the horizontal barrel. Drill 2 holes for #8 sheet metal screws in the center, wasted out area of the flue sheet. Mount the flue sheet to the faceplate and center in the lathe.



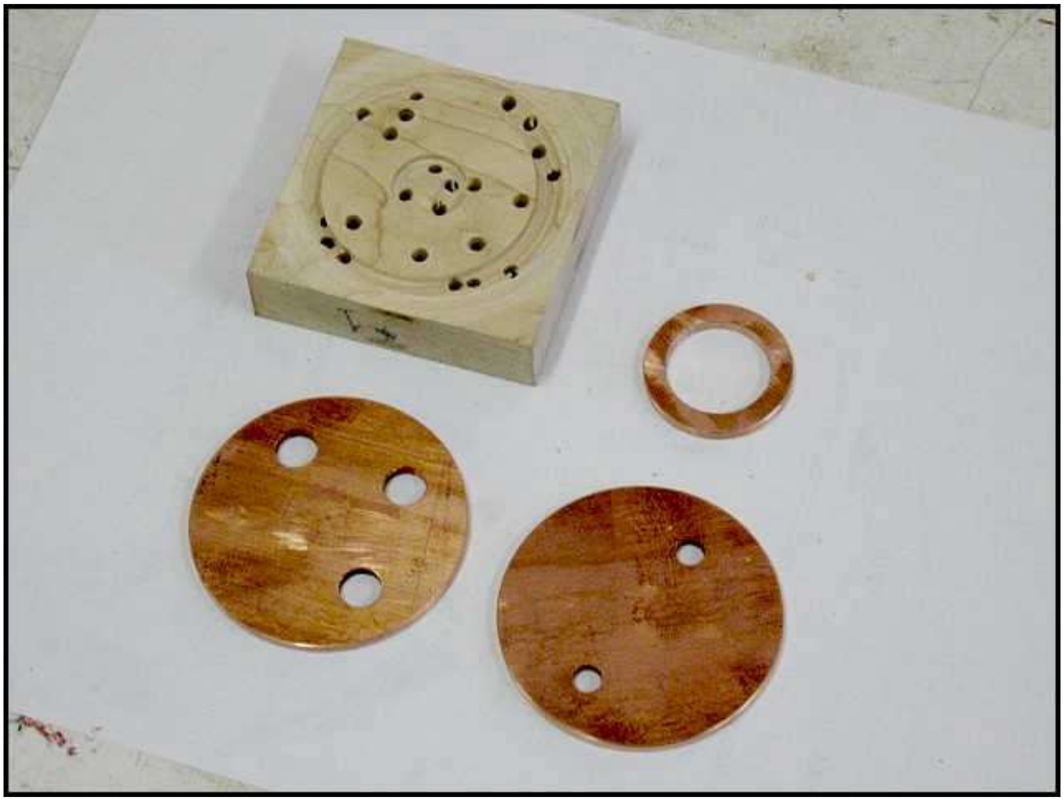
Turn the outside to fit the horizontal barrel. With the flue sheet still in the lathe, drive in 3 sheet metal screws around the perimeter.



Pull the center sheet metal screws out and turn the center of the flue sheet to accept the flue.



Here are the plates all cleaned up and ready to silver solder.



That's enough for now. Next time we will work on the boiler barrels to get the outer shell fitted up.

Plenty of metal cutting and fabrication work to do on the boiler before silver soldering everything together. First up are the bushings. There are 2 boiler mounting bushings and 5 for the plumbing. When planning the boiler it is a good idea to add extra bushings for the plumbing even if you don't plan use them. For example, you may not want a sight glass on this boiler, but in the future you might. So add the sight glass bushings now and just cap them off. Another thing to consider is the boiler fittings you want to install. You can purchase commercially made fittings, if so, tap the bushings to suit. We will fabricate our own fittings for Nina.

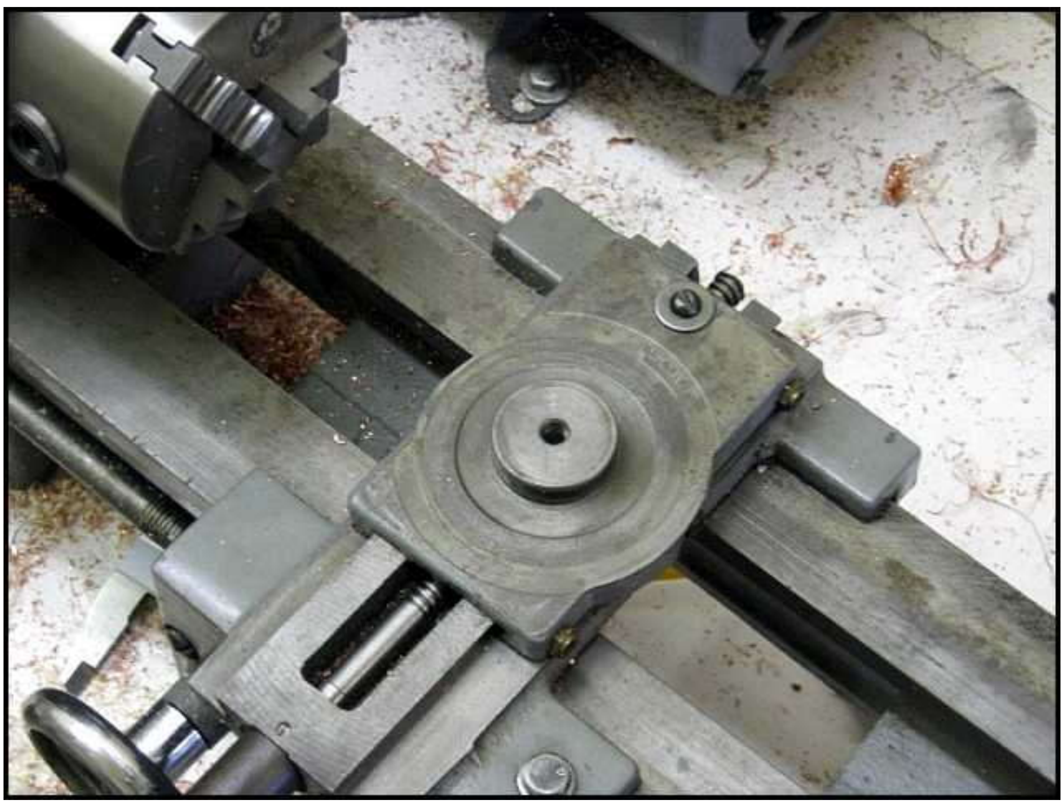
The bushings turn up the same way as the wheel and countershaft bearings. Not much more to add, you are a pro at this by now. Here are the drawings (See end of this document **[Fig. 27]** & **[Fig. 28]**):

Boiler Bushing 1

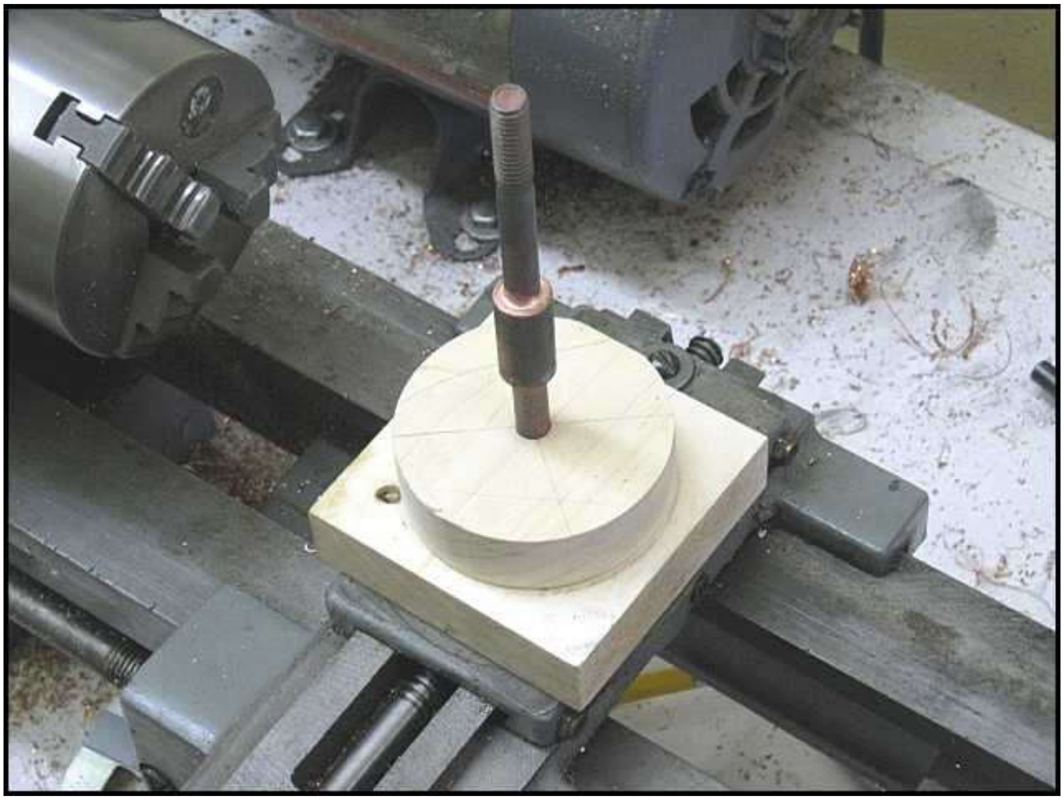
Boiler Bushing 2

The next task is to cut 2 large holes in the vertical barrel to accept the horizontal barrel in the front and the flue in the back. The usual way would be to rough cut the holes, then finish with files. Instead of that, we are going to set up the lathe to bore these holes out. First, chain drill and saw out the hole.

Now take the compound slide off the lathe and see what's under that we can use to mount a barrel holding fixture.



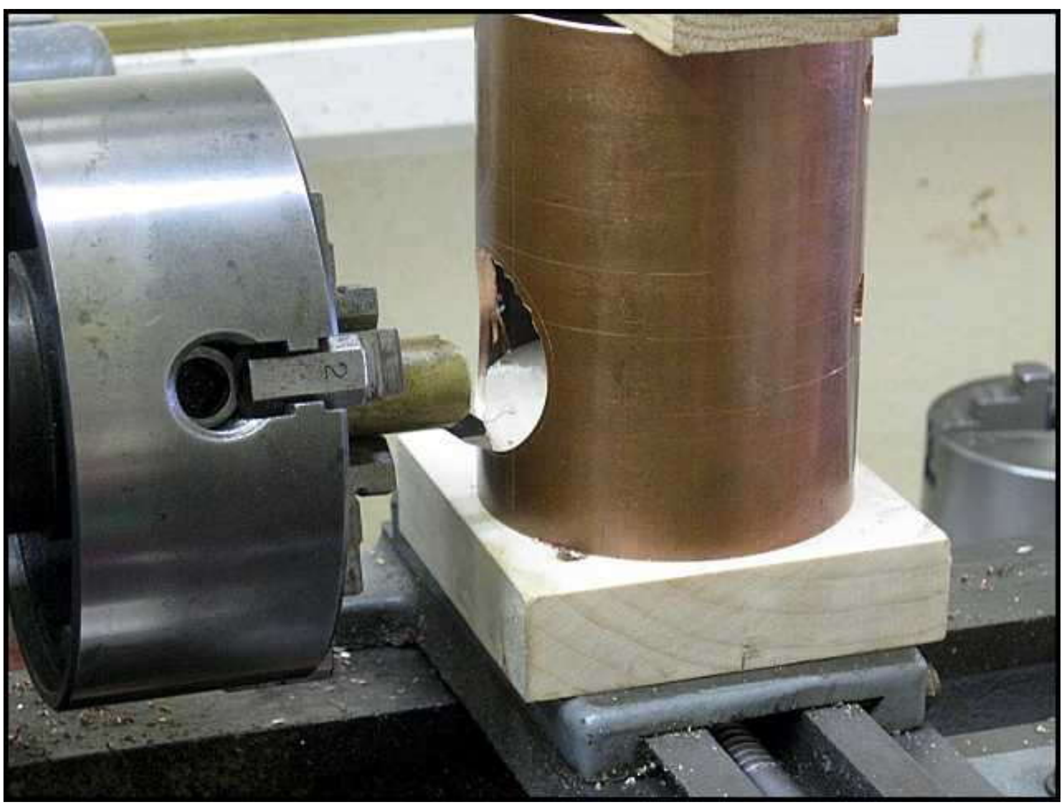
Fabricate a fixture from hardwood to secure the boiler barrel to the lathe carriage. Years ago I tapped a 5/16" x 24 hole in the cross slide so I could screw in a long bolt if I ever needed too. Some of the import lathes have "T" slot tables for cross slide. Those would be ideal for this job.



Secure the boiler barrel to the fixture and align so the center access of the lathe passes thru the centerline of the barrel.

Chuck up a little home made fly cutter in the 4-jawed chuck. This “hurry up” fly cutter has a small setscrew to hold a short length of lathe tool ground for this particular job.

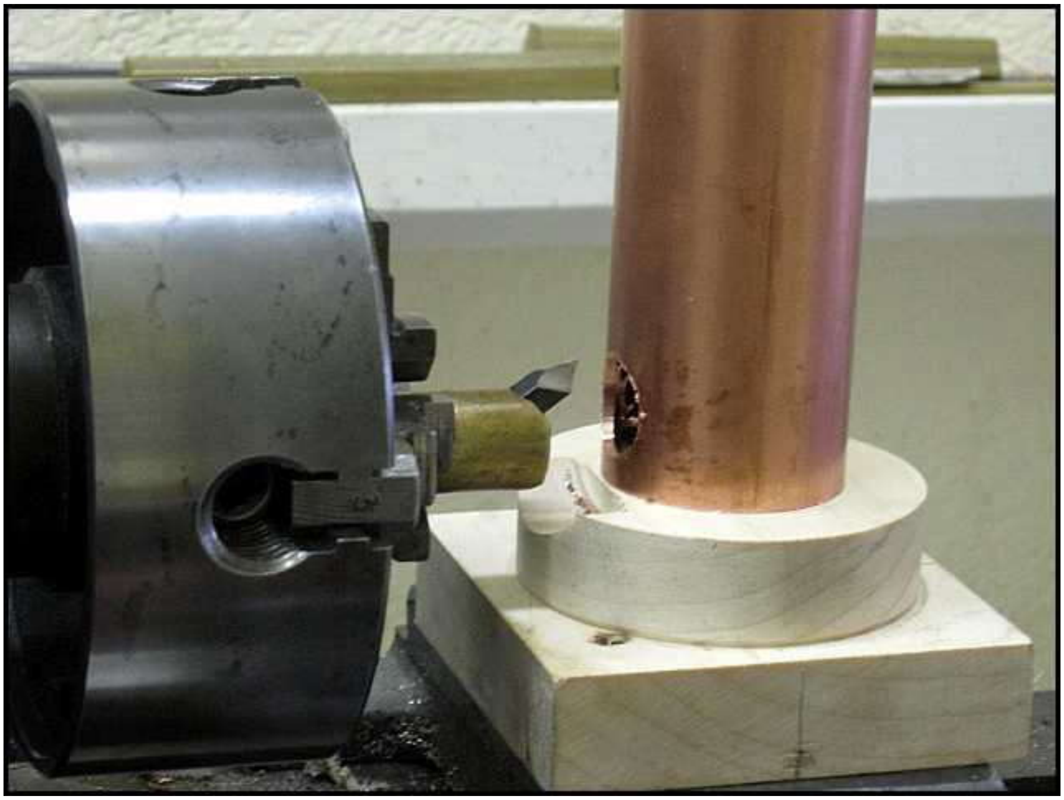
Set the lathe to run at a slow speed and engage the carriage. Take light cuts by making small adjustments to the fly cutter in the 4-jawed chuck.



A real machine shop would have a special attachment called a boring head for this task. A boring head can be set to take a very precise, known cut. Our fly cutter is not as precise, but does the job very well. Very small adjustments to the chuck make for even smaller cuts. It took a lot of passes and time, but the result was right on.

Turn he barrel around in the fixture and machine the flue hole the same way. All the copper parts are cut out and almost ready for soldering.

Sorry, there is one more thing to do. Re-cycle the fixture to machine a hole in the horizontal barrel to accept the smokestack.

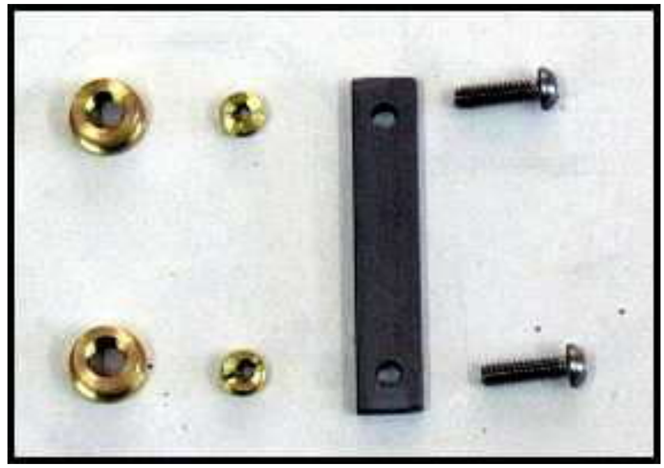


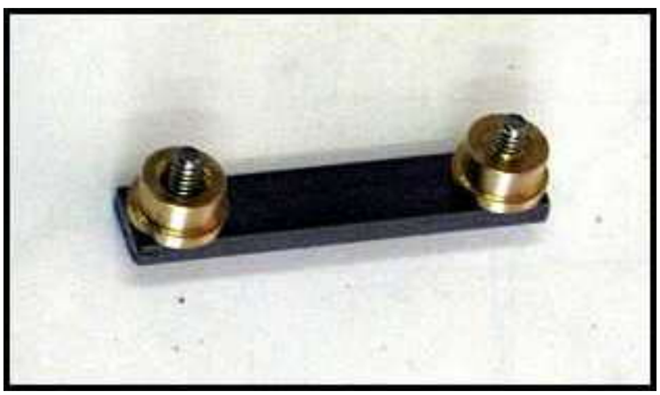
You can certainly cut these big holes by chain drilling and filing. But part of the whole process is to find different ways to use our limited shop equipment to do complex tasks. Now we know how to set-up a lathe as a horizontal boring machine.

Next time we will do some little house keeping tasks and get ready to solder this thing together. (See comment [C-10])

There are 2 little tasks we need to pick up before soldering the boiler. The first is to solve a problem I know is going to happen with the top and bottom plates. The plates fit just fine, but will become unstable as the torch warms the boiler and will fall out of place. I know it will happen. To solve that, drill 3 small holes around the edge of the vertical barrel and drive in some copper pins. The pins will act as a shelf for the plate to rest on during soldering. This is what we want:

The second thing is to make a fixture jig to help install the site glass bushings. The site glass bushings must be flat to each other or the site glass will not line up correctly. Here are the parts for the jig and the bushings.





Assemble the jig with the bushings. The bushings are flat against the jig and will line up, as we need them.

Put the assembly in the vertical barrel. These bushings are ready for solder.

There are a number of silver soldering techniques and methods. They all work as long as the resultant boiler passes all its tests and operates the engine in a safe manner. The best method is the one you grow up with or are the most comfortable with. The techniques I use comes from Kozo Hiraoka and his construction of 3.5" gauge live steam geared locomotives. Wolverine Joining Technologies has some very good online instructional documents at their website (www.silvaloy.com/home.php)

The solder is a medium-low temperature alloy consisting of 45% silver, 15% copper, 16% zinc and 24% cadmium.

The common trade names are: Easy-flo 45, Silvaloy 45 or Safety-silv 45. It has a melting temperature of 1125F and flows almost immediately. As a word of caution, cadmium is poisonous. It vaporizes during the soldering process. Do your silver soldering outdoors or in a well-ventilated shop.

Silver solder requires a flux to chemically clean the metal as it heats. The flux is a white, water-based paste specifically matched to the solder. There is also a black colored flux used for stainless steel. The white flux is intended for non-ferrous and regular steel. All manufacturers and suppliers of silver solder have the flux as well.

I believe the 2 most important things in good silver soldering are the torch and understanding the flux. The torch must produce a large volume flame of low temperature. The solder melts at only 1125° F, so there is not much need for higher heat. A propane-air torch with interchangeable tips is commonly used. This is the torch I use:

This torch comes from Sievert. It consists of a regulator that connects to the tank, 10-foot hose, a valve handle, neck tube and interchangeable tips. The gas tank is a standard, refillable 5-gallon bar-b-que tank. The tips I have are the #2942, #2943 and #2944. The #2942 is the small tip on the bench. It has a max output of 26Kw or 89,000 BTU. The #2943 is on the torch. This tip did all the work on the Nina boiler running at about 2/3-throttle max. It has a max output of 44Kw or 148,000 BTU. The big #2944 is a real volcano. I only fired it once and it scared the snot out of me. Its max output is 86Kw or 300,000 BTU.

The second critical thing after the torch is reading the stages the flux goes thru during soldering. Out of the jar the flux looks like toothpaste. As it first heats, the water boils off and leaves a white cake. The top of the white cake turns brown as it begins to melt. The flux continues to melt and turn brown. As the heat increases the flux starts to bubble and turn more transparent. Each time a bubble pops you see very bright shiny metal underneath. The flux reaches it's final stage when it is almost completely clear. At that point, just a pinch more heat, the solder melts and runs like crazy. The flux has a maximum temperature of 1400° F. After that it chemically breaks down and is useless. No amount of heat will make the solder work if the flux burns.

The silver soldering process is not too unlike regular soft soldering. The parts have to be clean and close fitting. The book says that parts must fit between 0.002" and 0.005", but 45% silver solder is fairly forgiving stuff. It will gap more than that, but try to the utmost to get within tolerance. There are no tricky joints on the Nina boiler. If you are careful, everything will fit fine.

When the soldering is done, let the part cool to room temperature. There is still a lot of flux left on the parts that needs to come off. Leftover, melted flux is chemically removed in a process called "pickling". Pickling is an acid bath that dissolves the leftover flux with eroding copper. The pickle bath is 10 parts water and 1 part sulfuric acid (ordinary battery acid). I have not tried it, but citric acid works too. I understand that plain vinegar works too, although very slowly.

The first parts to solder in are all the bushings. They go in easily. Apply flux and solder them in. Here's what the top plate looked like immediately after the torch shut down.

The shiny area is the leftover flux. The blackened area is un-fluxed. After about 15 minutes in the pickle tank, the plates are ready for the next step.

Solder the site glass bushings to the vertical barrel using the jig to align them. After pickle, remove the jig.

I used the site glass jig for each soldering step. Just as a precaution in case the solder re-melted for some reason. You don't want those bushings coming out of alignment. Remove and clean the jig after each soldering step. It gets crusty from the heating/pickle bath and you don't want the risk of it freezing in.

That's enough work for now. Next time we will get into the heavy solder work. (See comment [C-11])

Today we are going to get the boiler weldment finished and ready for a pressure test. The first job is to solder the vertical and horizontal barrels together. This is the most difficult joint on the boiler, because it is the intersection of 2 curved surfaces. It is extremely difficult, if not impossible to solder this joint with the boiler remaining in one position. You will either have to solder it part way, let it cool down, clean it up and reheat the next part of the joint. Or reposition the whole assembly while it is hot and continue to solder the joint.

If you choose to reposition the boiler to continue work, keep an eye on the flux. Flux is good for an initial heat and usually 2 re-heats. By then its pretty much worked away. You will have to stop, let it cool down, pickle and start over. The solder can re-melt many times without affect.

Here is the initial set-up for this step.

Not only do you have to worry about the technical aspect of soldering, but also the position of the barrels. They have to be square, plumb, level, flat and all that too.

One thing you learn quickly on this joint is torch control. The vertical barrel is more massive than the horizontal barrel. Apply more heat to the vertical barrel. Other wise the horizontal barrel heats up first, melts the solder and sucks it all away, while the vertical barrel is too cold to work. The hardest part of silver soldering is deal with odd joints and dissimilar sized parts. Just have to practice.

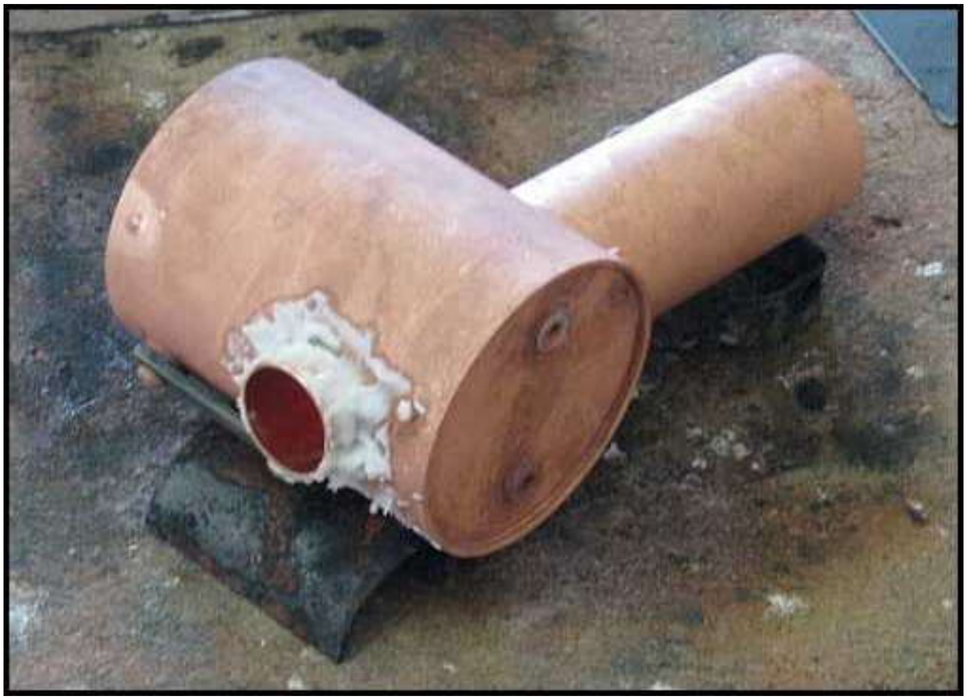
When the joint is done, remove from the pickle and clean under running water with a brass wire brush. Closely inspect the joint from both sides to ensure good solder penetration and a smooth overall fillet. This is the last joint you can visually inspect from the inside. If you get this one right, you can be confident that the others will turn out fine.

For me, I positioned this assembly on the top; both sides and the bottom to ensure the solder flowed all around. During inspection, the inside looked good, but there appeared to be a pinhole on the side. So it got fluxed up, positioned and that side re-soldered.

Next is the soldering on the top and bottom plates. Here is the setup prior to the torch.

The site glass jig is back in for this job. Notice the short lengths of solder buried in the flux around the edge. The plates solder in with much trouble because flat surfaces are easier to work. The small pieces of copper rod that the plates rest on need solder too. Some of them may solder on the own with the plates, but some won't. Let the assembly cool and then setup again to do these. Reposition the boiler while it's hot and get them one at a time.

Now it's time to solder in the flue. Put the flue in with the front flue sheet in the horizontal barrel. It is basically the same task as soldering the barrels together. Do the backhead end first.



Reposition and reheat as needed to solder the flue in.

The front end got a little more difficult. Heat radiates thru the barrel just fine but only melts the solder against the inside of the barrel. The flue stays too cold to solder. To fix that, we used a second torch (regular Bernz-o-matic propane) operated by Andy (my son) to run extra heat up the flue from the inside out. That got the flue hot enough to solder just fine. If that did not work, I was ready to simply cut off the smoke box and get at it directly. Unfortunately, I did not get a picture of that step.

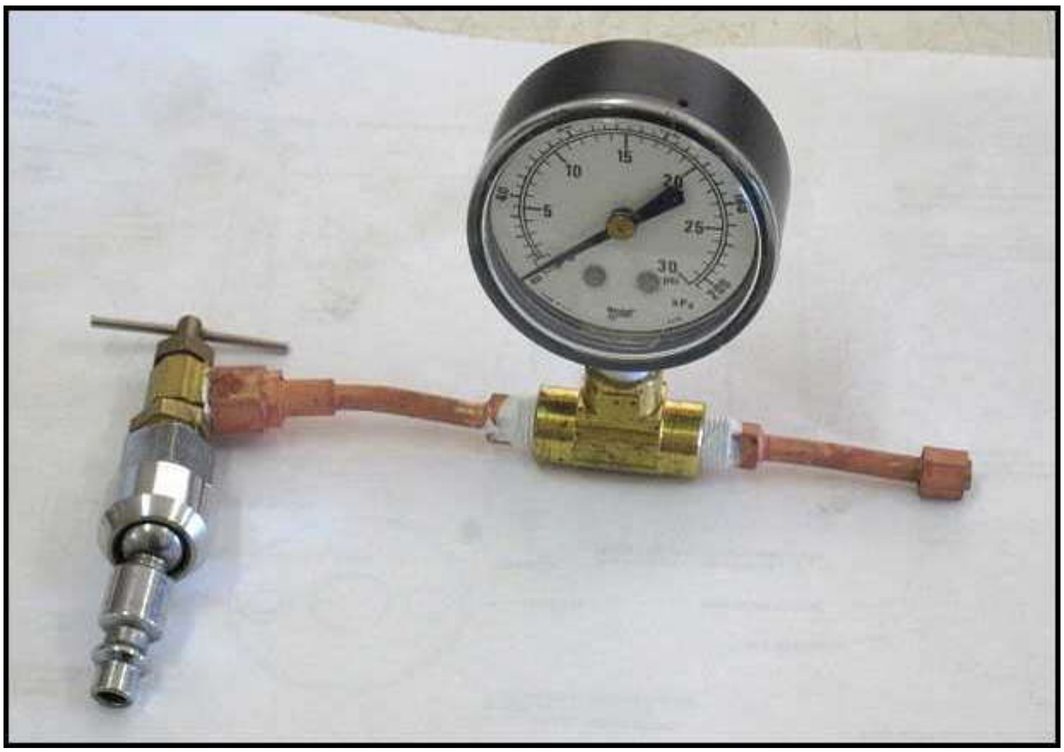
With everything soldered up, clean with a brass brush and have a good look.

All of the joints on the Nina boiler are exterior. You can get to all of them for repair if you need to.

It was an all day job soldering to get the boiler together, mostly waiting for it to cool down and pickle. Next time we will do another air test on the motor and a pressure test on the boiler.

The first air test on the motor was on an unregulated air source. It was just to test the motor and give it a good break-in. There was no way to tell what pressure it was running at. This time we will use a pressure gauge to find an actual operating pressure. Last time, we discovered that the spring holding the cylinder to the port face was way too weak. The air pressure lifted the cylinder off the port face. This time there is a stiffer spring.

For this test, cobble together a manifold with a pressure gauge close to the motor. Add in a stop valve, which is a modified refrigerator water valve and a swivel connection to the air hose.

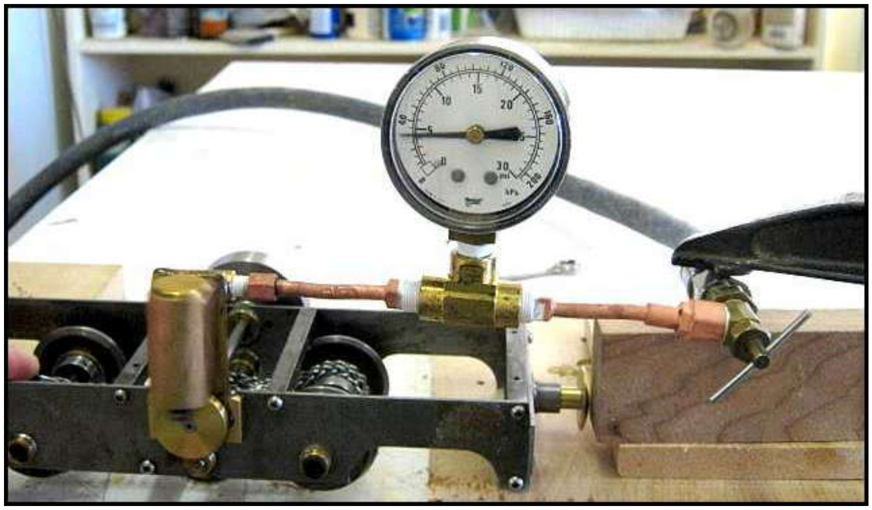


This is clearly not an ideal solution. A good quality air compressor with a secondary pressure gauge is the way to go. I am too cheap to get a good air compressor.

Hook everything up and give the motor another test.

The reason this manifold is not ideal is because as the motor rotates between power stroke and exhaust, the pressure gauge oscillates wildly. The pressure drops during the power stroke so the gauge is low. During exhaust the air pressure is cut off and gauge is up.

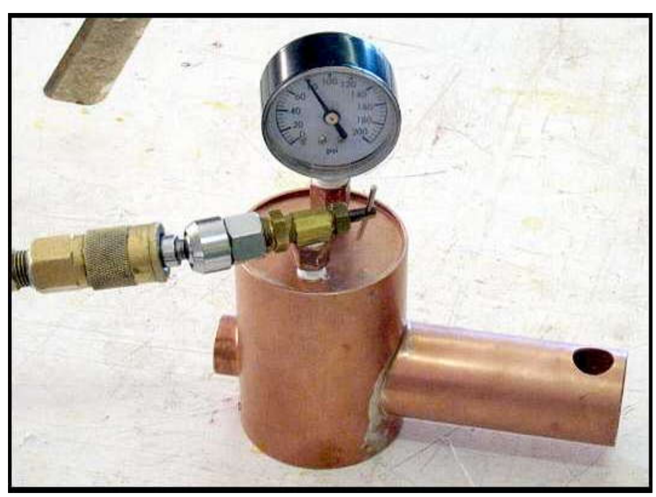
After a lot of experimentation, I determined that the motor operates best at 25 PSI. With no load on the wheels, the motor flies at about 2000 RPM. With a finger applying a load to the wheels, the motor speed drops to about 600 RPM and thru the gear reduction the wheels turn at about 140 RPM. At that speed, it's powerful. The nasty gouge on my finger still hurts.



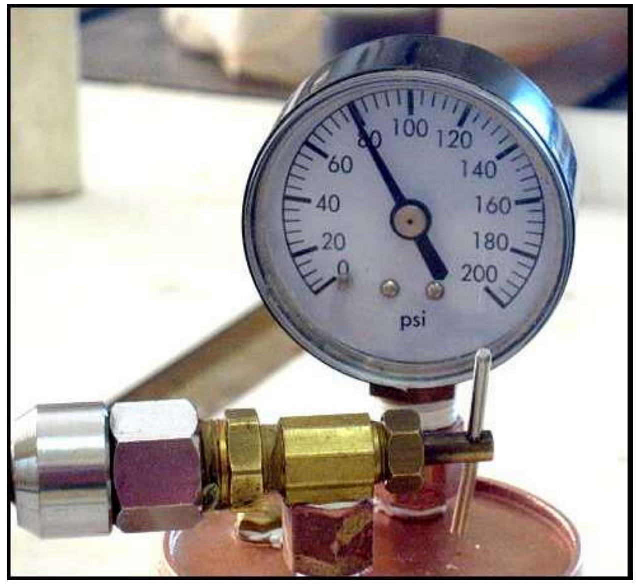
Knowing an operating pressure, it is now time to pressure test the boiler. The normal test doctrine is to plug all the holes, fill the boiler with water, and attach a hand water pump and pressure gauge. Pump the boiler to two times the operating pressure and hold that pressure for 30 minutes. Rather than use a hand water pump, I used the air compressor. I also tested the boiler to 80 PSI, instead of 50. In the unlikely event this boiler ends up on a different engine, I want it to handle a more usual Gauge 1 operating pressure of 40 PSI.

Using the same parts from the air test manifold, get the boiler ready to hook up to the air line. The boiler is full to the top with water.

Attach the air line and build pressure. Look for water leaks.



I stopped the test twice because the plumbing junk insisted on leaking. After all that got fixed, the pressure was held at 80 PSI for 30 minutes. No leaks in the boiler. My son, Andy, who is equally knowledgeable in Gauge 1 live steam operations, witnessed the test. And to stake my reputation in a public forum, here is the gauge reading just before shut down.



So what happens if there is a problem? The two problems I had on past boilers were an insufficient joint and a pinhole on a bushing. The insufficient joint prevented pressure from building up at all and shot a stream water all over the shop. The pinhole leak made it difficult to maintain pressure and sprayed a mist all over. If there are any problems, you will know it right away. The problem will be obvious and the test a failure. Disassembly the test and re-solder the bad spot.

Out of curiosity, I did some theoretical performance calculations.

How fast (or slow) will it go? The wheels are 1.375" diameter. Each turn of the wheels moves the engine 4.32". At 140 RPM on the wheels, the engine moves 605" per minute. That works out to .84 feet/sec. The main line at our club track is 305 feet, so it's about 6 minutes per lap. That's good. Nina will certainly upset the high-speed mainline guys.

Does the boiler have enough steam producing capability? The motor has a .500" bore and .688" stroke. That is a volume of .135 cu in. Each revolution of the single acting, single cylinder engine will consume .135 cu in of steam. At 600 RPM the motor uses 81.05 cu in of steam per minute. At 25 PSI, 1 cu in water produces 640 cu in of steam. To produce 81.05 cu in of steam at 25 PSI, the Nina boiler will have to boil off .127 cu in water per minute. About 12.7 square inches of heating surface (water in contact with a surface heated by the fire) is required to do that. This boiler has about 15.3 sq in heating surface. It should have enough capability to produce all the steam we need.

How long will it run on a single fill of water? Leaving about .500" open space at the top for steam accumulation, the vertical leg of the boiler holds 1.25" of water before the top of the flue is exposed. With an inside boiler diameter of 2.5", that is 6.136 cu in of water capacity available for steam. Based on the consumption calculation, the Nina boiler should produce 3927 cu in of steam at 25 PSI. That will give 29089 revs on the motor. At 600 RPM, that should give us 48.5 minutes of run time. If that ends up true, then we may need a separate fuel car.

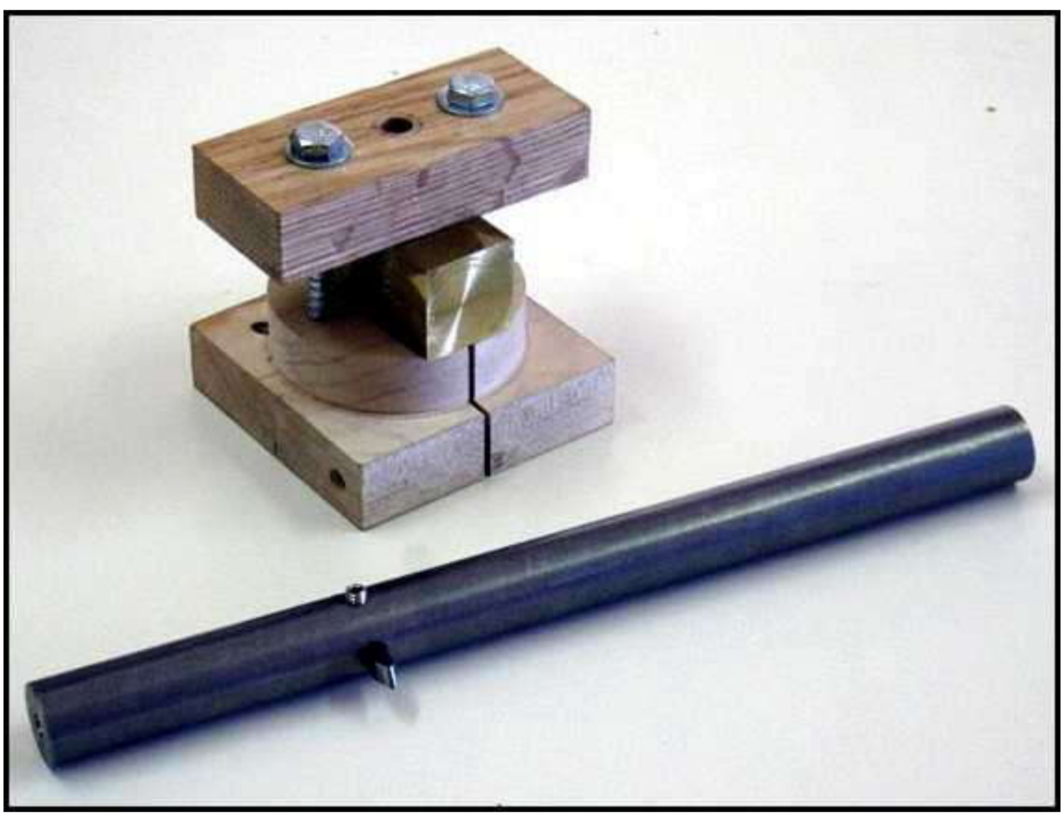
Next time we will get on the smoke box front, stack and maybe the smoke box saddle.

With the table saw project done, it’s time to get back on Nina. The next phase is the front end of the boiler, starting with the smokestack. There are no drawings for the stack or other front end parts. Since they are mostly decorative, you may choose another style. Here is a shot of the stack cleaned up and ready to install:

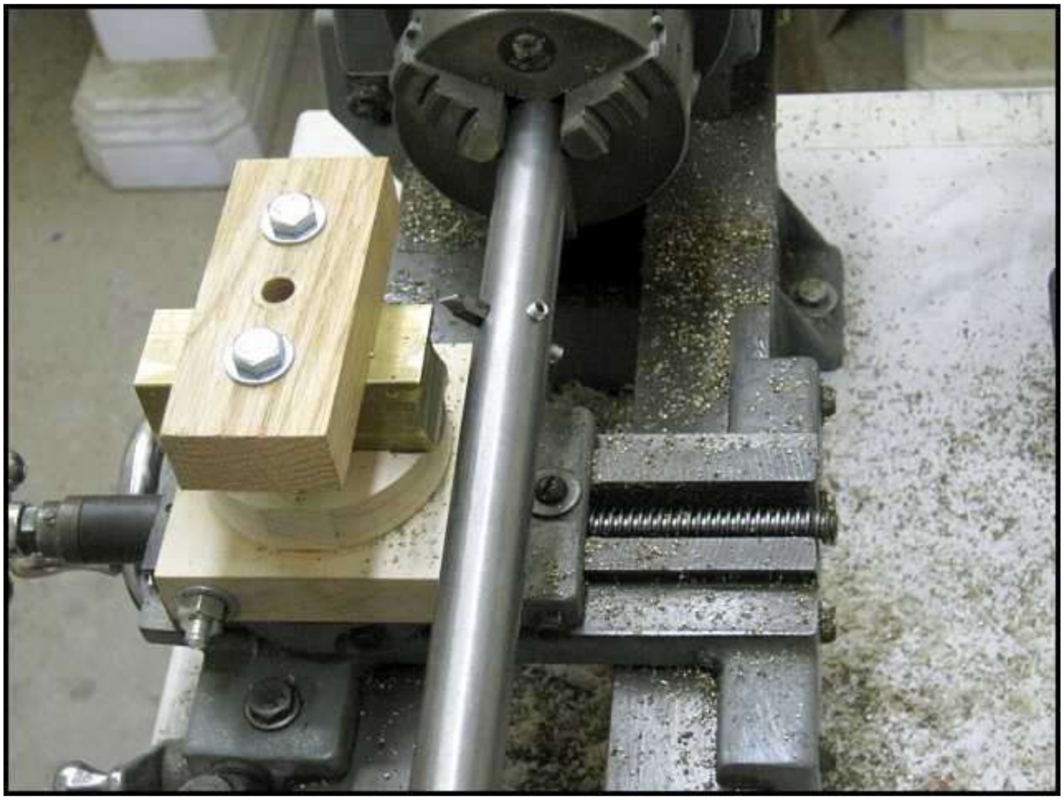
The stack consists of 4 parts; the top cap, the stack tube, a base, and a base flange. The stack tube is a length of half-inch copper plumbing pipe, which is actually 5/8" diameter. Cut a piece to desired length and square both ends.

The base has an unusual shape. There is a rounded portion on the bottom end that allows for a smooth fit with base flange and the boiler smoke box. The rounded portion is the most difficult to do, so let’s do that first. Everything else after that is straight turning.

The base starts out from 1" square brass. Cut a 2" or so length. We are going to cut the rounded bottom using a modified horizontal boring technique. Modify the wooden jig used early to cut the large holes in the boiler barrels. We will need to fabricate an in-line boring bar. An 8 to 12" length of 3/4" steel rod will do fine. Face both ends and center drill. Drill a hole for the cutting tool and tap a setscrew to secure the cutting tool. Here is the holding jig and boring bar ready to go.



Secure the jig with brass stock to the lathe cross slide. Set the cutter in the boring bar to swing the exact radius needed for the base flange. In my case, the base flange came from a copper coupling pipe 1 5/8" diameter. So set the radius on the boring bar to 13/16". Mount up the boring bar in the 3-jaw chuck and stabilize the other end with the tailstock.



Engage the half nut on the lathe carriage, taking about .020" depth cut on each pass. Continue taking .020” deep cuts until there is a clean cut across the entire bar. Cut both ends of the brass stock. We will need the other side later on for the smoke box saddle. Before you know it, it’s done.

I was very surprised how well the wooden jig worked out. It was rock solid on the cross slide, no chatter at all and the cut turned out glass smooth.

Now center up the square stock in the 4-jaw chuck and turn a decorative profile.

Next, drill and bore a 5/8" hole to accept the stack pipe.

Part off the stack base from the square stock. Turn it around in the 3-jaw chuck and finish the parted end. A soft round over with a file is all I did.

For the base flange, bore a 5/8" hole in a length of copper coupling pipe. The coupling pipe has an inside diameter the same as the outside diameter of the horizontal barrel on the boiler. Bore the hole the same way as you did on the boiler.

Cut out a section of the coupler pipe and round over the corners with a file. Drill #51 sized holes in the corners to accept 0 x 80 machine screws for mounting the stack to the smoke box. Here's the stack base and flange ready to silver solder to the stack tube.

The top cap is a straight decorative turning. Turn the outside to profile, bore for the stack tube, everything just like for the base.

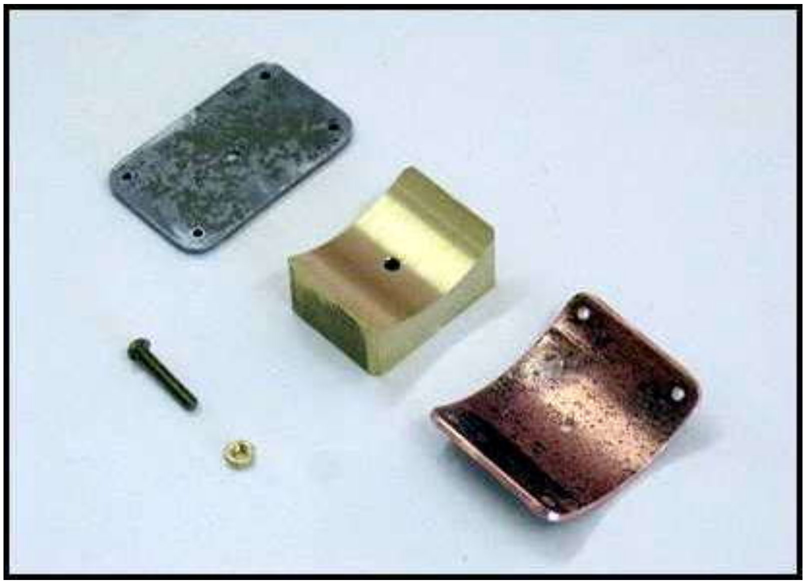
Finally, all the stack parts are done.

Silver-solder the stack, pickle and clean up. Hang it on the boiler for a look-see.

I think it turned out very nice. The stack is not hard to make, but it is very time consuming. It involves a lot of tool set-up and chuck changing on the lathe. Next time we will do the smoke box saddle and the smoke box front. (See comment [C-13])

Today we will continue with the front end of the boiler and get the boiler mounted on the engine frame. The smoke box saddle uses many of the same construction techniques as the smokestack. Fortunately, the saddle is not as complicated as the stack, and we already have the most difficult part done. Start by setting the boiler on a flat surface and measure the distance from the bottom of the smoke box to the table. The overall height of the saddle must be such that the boiler sits squarely on the engine frame without binds or distortion.

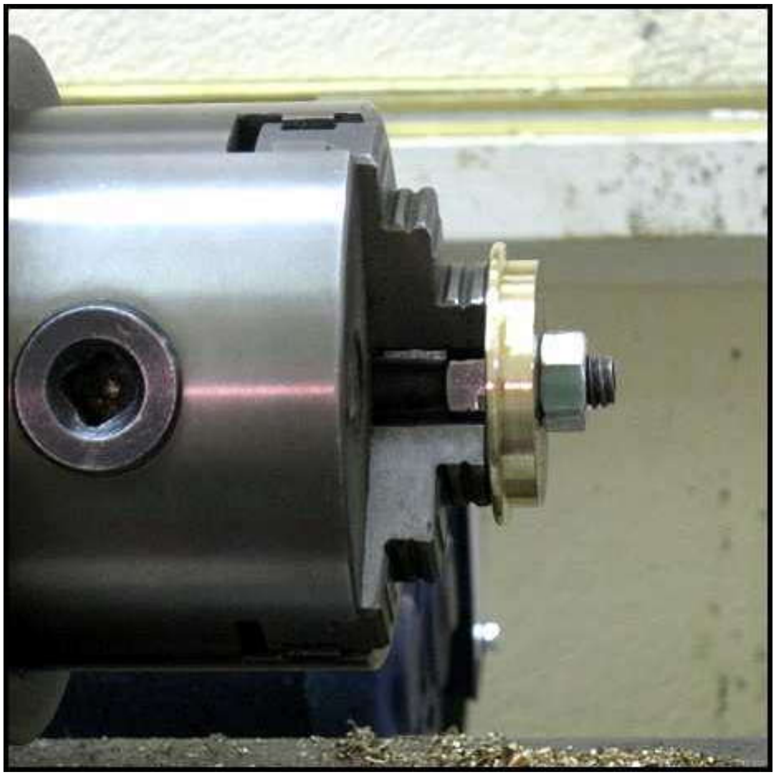
Cut out the saddle parts as you did for the stack. Drill a hole for a #2 machine screw in the center of all the parts:



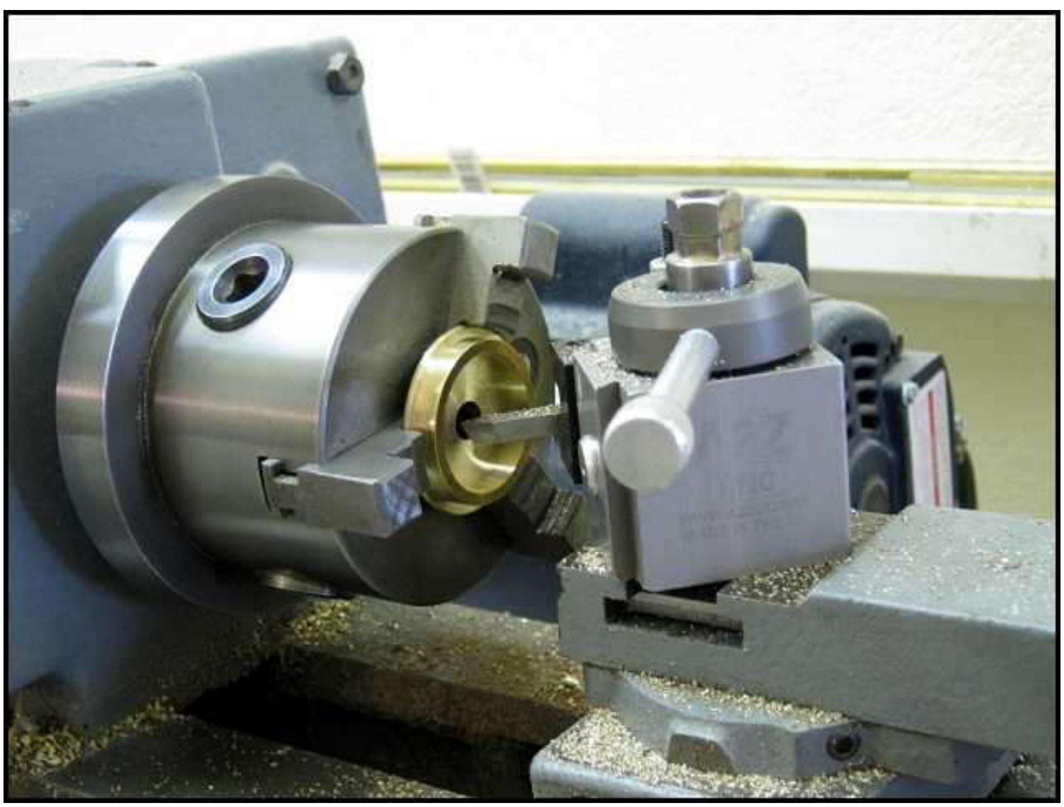
The machine screw holds everything together while soldering. Silver solder the saddle together and remove the holding screw.

It is better to use 2 or more screws to hold parts together for silver soldering. Assemblies have a bad habit of loosening up just about the time the solder wants to flow. The saddle base decided to squirrel around on me right after the solder melted. Fortunately I was able to keep it hot and tap it back in place.

Next is the smoke box front. It is basically a turned ring from 1/4" thick brass plate with a hinged door. Rough saw a slab of brass and drill a 5/16" hole in the center. Sandwich the brass stock between two hex nuts on a bolt. Chuck the assembly in the 3-jaw and turn the outside to the desired shape. About 3/16" of the smoke box front fits inside the smoke box. Turn this portion to a good smooth fit.

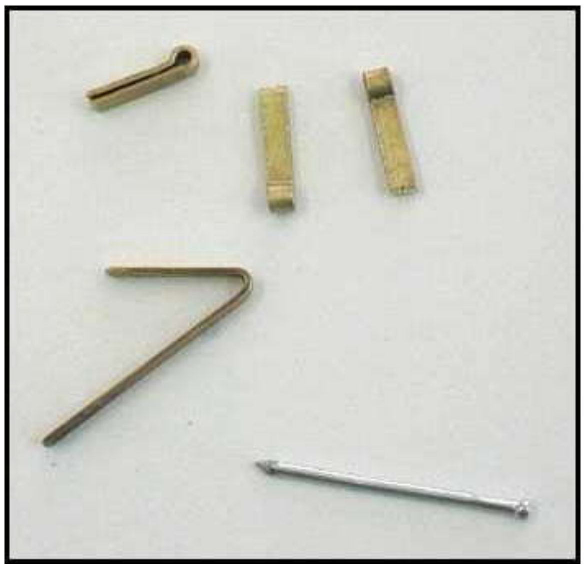


Put the reverse jaws in the 3-jaw chuck and turn out the bulk of the inside of the smoke box front. Leave about 1/16" thickness on the front and 1/8" on the walls.



Now chain drill and file an opening in the smoke box front for the door. If you go with a round door, turn it out on the lathe. Cut out and shape a door. The door should be about 1/16" larger all around then the opening.

The door is functional, so we have to make up some hinges. They are simple strap hinges made up from 1/8" x 1/32" brass strip. Bend the strip over a 16-gauge (1/16" diameter) nail.



Then finish the hinge by squeezing in the vice. You have to practice this a few times, but soon they come out nice.

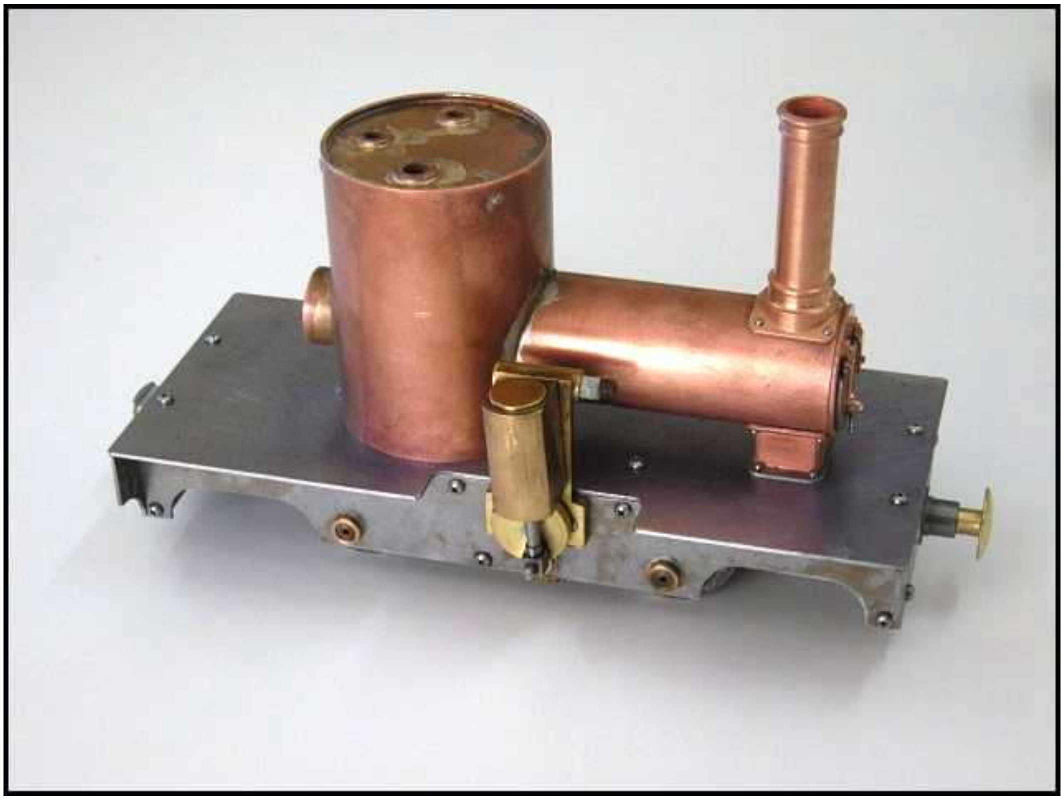
Trim the hinges to final size. Drill the hinges, door and smoke box front for either a 0 x 80 or 00 x 90 machine screw. I happen to have some scale #00-90 model hex bolts left over from another project.

Silver-solder the hinges to the door and smoke box front. The little #00-90's probably won't hold to well on their own. Fashion up a cutesy handle. This handle is fabricated from a #2-56 screw, a small turned hub and a 16 gauge nail for a knob.

Attach the smokestack and saddle to the smoke box. The machine screws on the back go thru the smoke box and are fixed with nuts on the inside. The screws on the front go into tapped holes on the rim of the smoke box front.

I think it looks very nice, if I do say so myself.

Mounting the boiler to the engine frame is an exercise in locating and drilling. Center the boiler on the frame. The front to back position is not too critical; just don't interfere with the manifold on the engine. The boiler is secured with two #6-32 screws going into the bind bushings on the bottom of the boiler. The smoke box saddle has four #0-80 screws and bolts.



It’s really starting to look like a steam locie now. I guess it’s time to start thinking about the style of the engine. I have absolutely no artistic talent so I don’t know. Nina is going to have an open top wooden cab, that’s all I know. After that, I will have to plagiarize ideas. Paint color, trim, I have no idea. Suggestions are very welcomed.

The last 2 mechanical phases are the plumbing and burner. The plumbing is straightforward. The burner has some options. A torch type burner like Mr. Glaser used on "Cracker" or a conventional poker type. I am thinking about trying a bottom feed fuel tank with a pre heat loop. Maybe adding a secondary control valve. That would be different.

Anyway, next time we’ll either get started on the plumbing or play with fire. (See comments [C-15] & [C-16])

It’s time to get started on the plumbing. Engine plumbing consists of the safety valve, throttle valve, site glass, pressure gauge, pressure gauge syphon, lubricator, steam dry pipe, and exhaust. Plumbing is a lot of work. Fortunately, many plumbing parts are commercially available, which cuts down on the work. For this engine, we are going to scratch build all of it. At first, I thought about skipping the pressure gauge, but now I am thinking about adding one. There is an extra bush on top of the boiler we could use. We’ll think about it.

For now, let’s get started with the lubricator. The combination gear and chain drive transmission used on Nina requires that the steam inlet be on the front side of the engine and exhaust on the back. The steam and exhaust pipes cross each other. I did not think about that mess. It made a difficult placement of the lubricator. Normally the lubricator goes inside the cab, sort of out of sight. Our lubricator is going directly on top of the horizontal boiler barrel. It will be different.

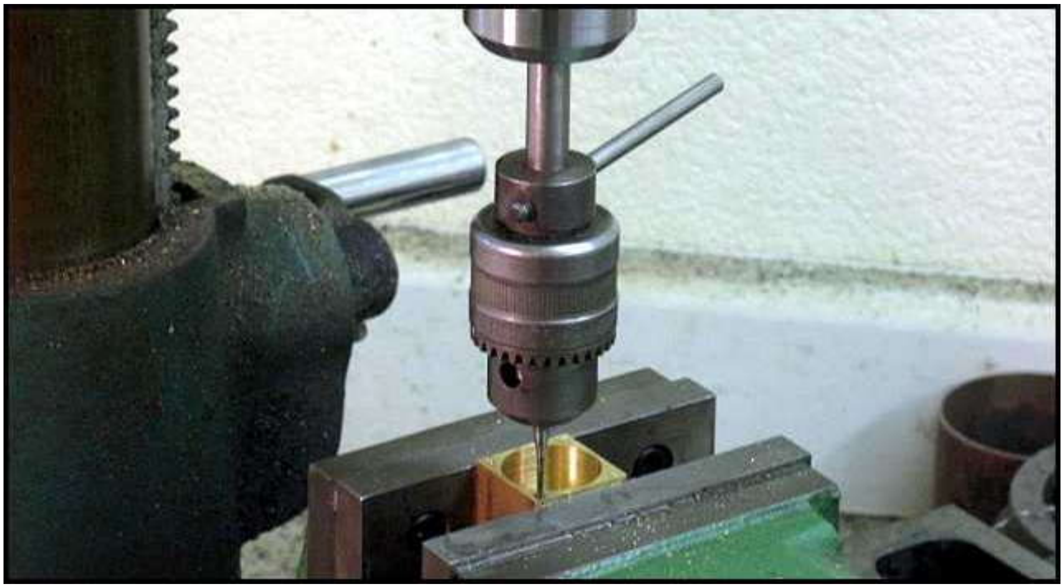
Here’s the finished lubricator, ready to go on its stand. There is no drawing for the lubricator. As my old college professors always said, "it is left to the student as an exercise"

The large plug is the fill/drain. The small plug is directly over the small hole in the top of the steam pipe. In the unlikely event the small hole happens to get plugged, we need a way to get to it to clean it out.

Start on the lubricator by turning the tank from a piece of 1" square brass stock. Bore a flat bottom hole 11/16" deep and as wide as possible without poking thru the sidewalls.

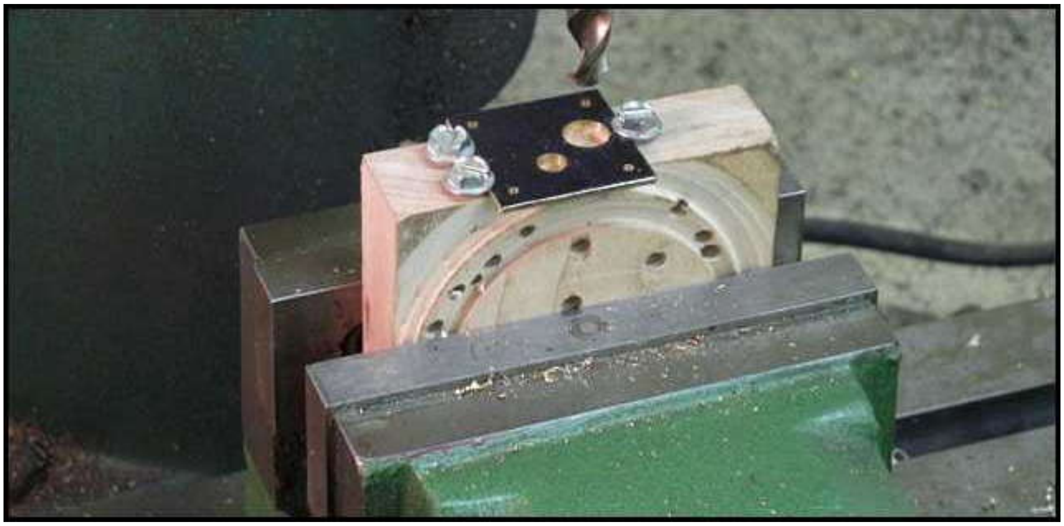
A flat bottom hole can be hard to do with a regular boring bar. Instead use a regular end mill bit instead of a boring bar. The end mill does just fine.

Cut off the tank from the bar stock and face the bottom smooth. Next, drill and tap #0-80 holes in each corner on the top and the bottom of the tank. The tapped holes on the top are for the lid and the holes on the bottom are for mounting on the stand.

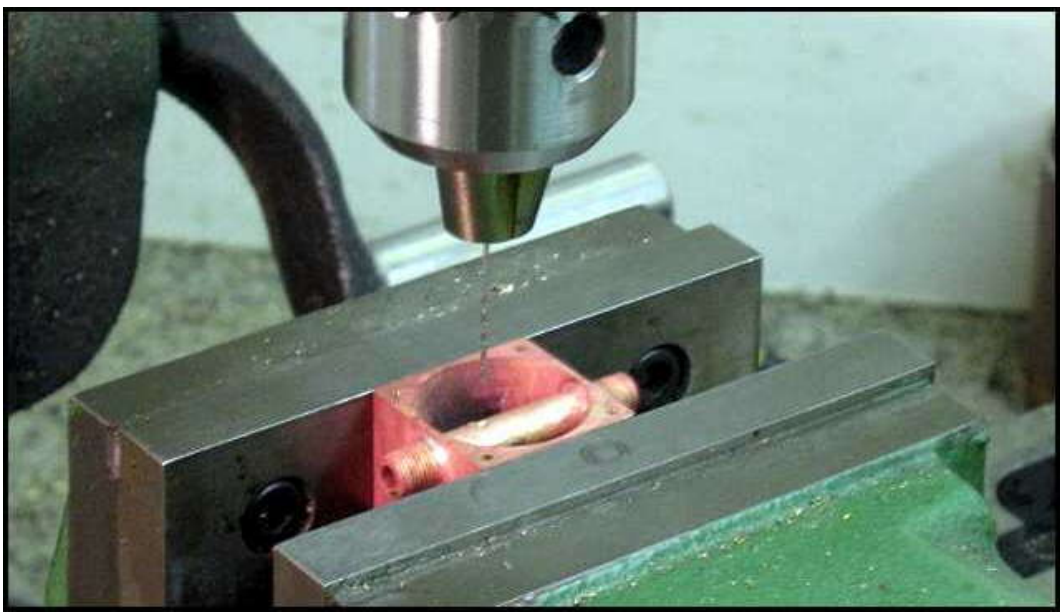


You have seen the picture of the tap handle several times. I can't emphasis enough how important a good tap handle is in the shop. You can't tap a #0-80 hole by hand, no way.
Now make the steam pipe. Cut and face a 1 1/2" length of 1/4" brass rod. Drill clear thru with a #30 drill. Run a die over both ends for a length of about 3/16". Drill a 1/4" hole in the tank 7/16" from one edge and 3/16" down from the top. We want the steam pipe slightly off set so it clears the fill plug. Silver-solder the pipe into the tank.

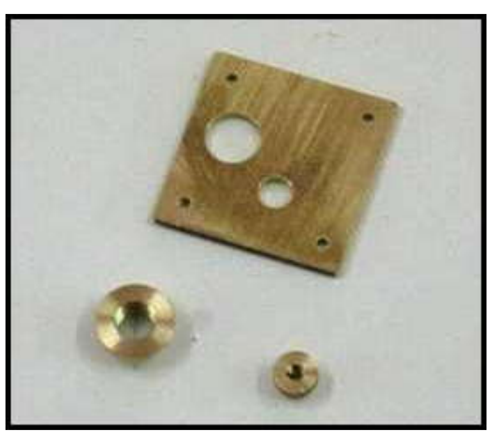
The top lid is from 1/16" brass plate. Cut a 1 1/8" square piece so it overhangs the tank just a bit. Using a block of hardwood with some #8 sheet metal screws to secure the top lid, drill #51 holes in the corners to match the #0-80 holes in the tank. Drill a 3/16" and 5/16" hole for the plug bushings.



It is really handy to have an X-Y table on the drill press or a milling machine. The graduated table knocks these parts out super accurate and so quickly. Using the top lid as a guide, drill a #60 hole in the steam pipe, top side only.



Turn bushings out of brass for the plugs. The fill plug is 1/4"-40, just like the boiler bushings. The clean out plug is #4-40 or #6-32, whatever is handy.

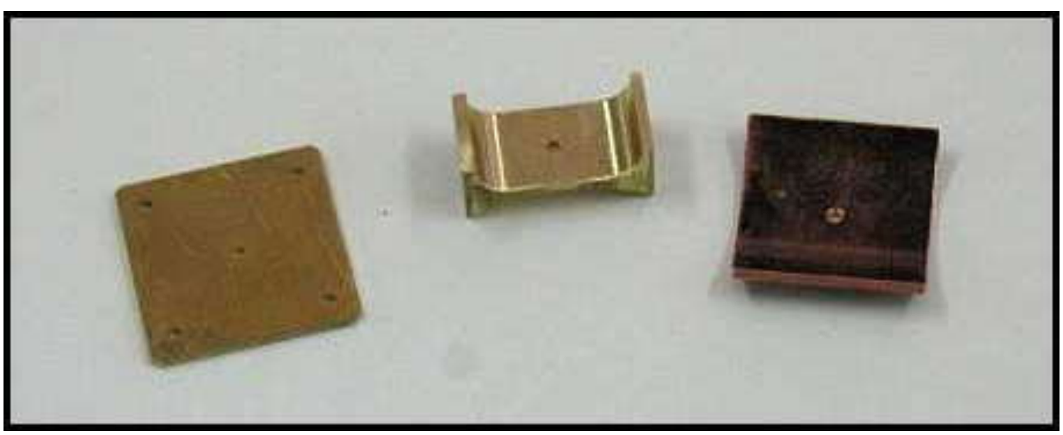


Secure the top lid to the tanks with #0-80 screws in the corners. Silver-solder the lid to the tank.

Finally, silver-solder the bushings into the top lid. Make some plugs with washers and the lubricator is done.

Next time we will get on the lubricator stand and get everything mounted. I don't know when the next update will be. I have to report for jury duty on Monday. Federal District Court, must be a biggy. May last 4 to 6 weeks they say. (See comment [C-18])

Today is the second half of the lubricator. We are going to fabricate the lubricator stand and get it mounted on the boiler. The stand for the lubricator is basically the same process as with the smoke box saddle. The stand consists of a top and bottom plate and a curved spacer in between. All the parts fabricate the same way as the saddle. You will have to set up the between centers boring bar to carve out the round portion just as before.

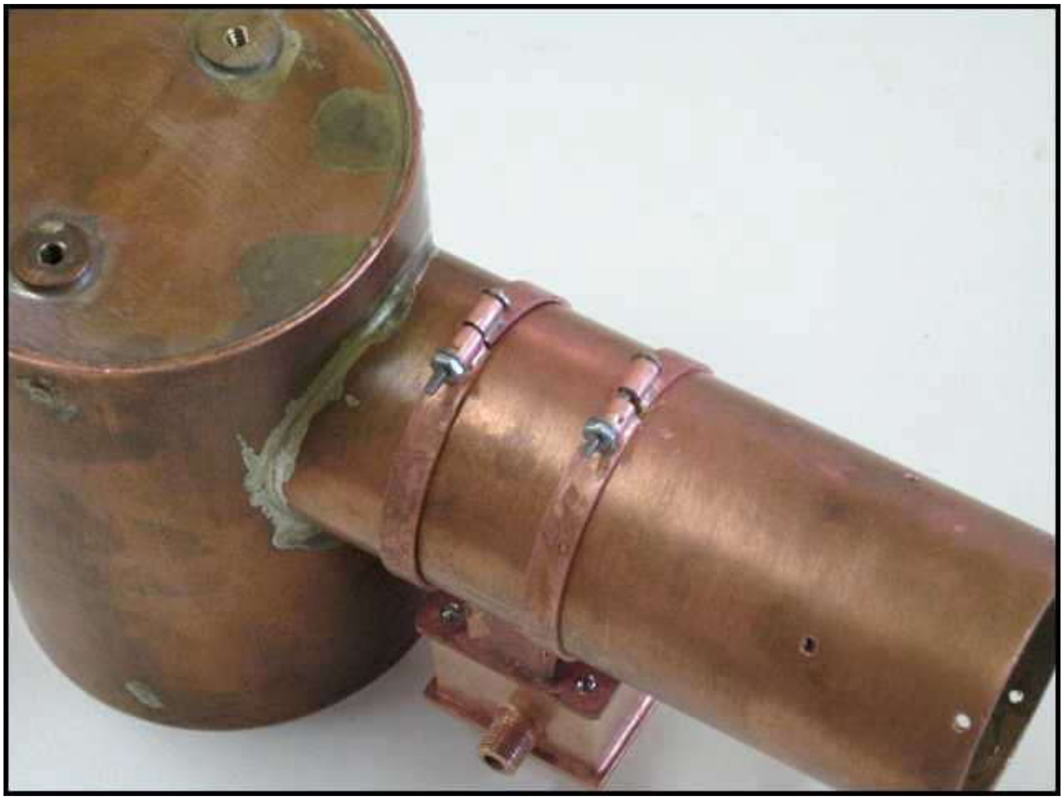


The only difference from the smoke box saddle is the spacer for the lubricator stand has the bulk of the interior material removed. Just for looks.

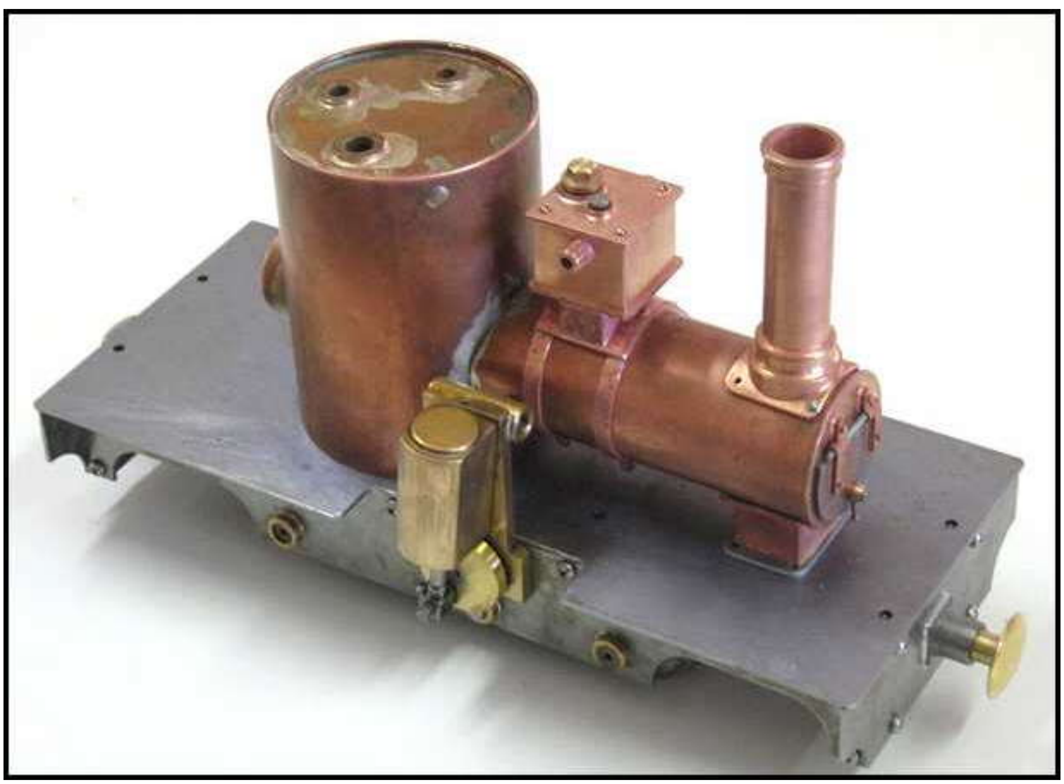
The lubricator assembly gets strapped to the top of the boiler. To make the straps, coax lengths of brass strip around a piece of pipe to the exact diameter of the boiler barrel. Cut the ends of the straps so they meet exactly. The brass straps can be from 1/32" thick strip, either 3/16" or 1/8" wide. If the brass strips get too springy and uncooperative, heat them to dull red and quench in water. That will soften them up.

Silver-solder the stand assembly together. Do it in stages. First solder the base plates and spacer. Then solder on the straps. Finally, solder on a 3/8" length of 1/8" OD, 3/32" ID brass tube directly over the ends of the strap. This is the stand assembly, upside down. Now with a fine saw, cut thru the brass tube and strap.

Attach the lubricator to its stand with some #0-80 screws. Disassemble the boiler and slip the lubricator assembly over the boiler barrel. Size #0-80 machine screws fit nicely inside a 1/8" brass tube. Cinch up the screws just enough to hold the lubricator in place.



Re-assemble the boiler to the engine frame. With the lubricator in place we can mock up the steam and exhaust piping.



That looks cool. At least the horizontal boiler barrel has something useful to do. Brightly polished brass straps against a black boiler should look good. Next time we will do a safety valve and maybe start on the site glass.

In researching miniature safety valves, I looked at work by K.N. Harris, Martin Evans, LBSC, Tubal Cain and Kozo Hiraoka. The Nina boiler is so small in terms of steam production that it is off the low end of all the charts, graphs and formulas. I came to the conclusion that the only real design criterion is that it must release steam faster then the boiler can produce it. After looking at Kozo's work some more, I think this one will do that.

This valve is the usual stainless steel ball type. Our valve will use a 1/8" diameter ball against a 15-degree beveled seat. It is not a true safety valve in terms of a "pop" valve; it's more of a pressure release valve. Real pop valves close quickly when the pressure drops to the safe level. This type closes sometimes, sometimes they don't.

Here is the exploded view of all the parts.

Here are the drawings for the safety valve (see end of this document **[Fig. 29]** & **[Fig. 30]**):

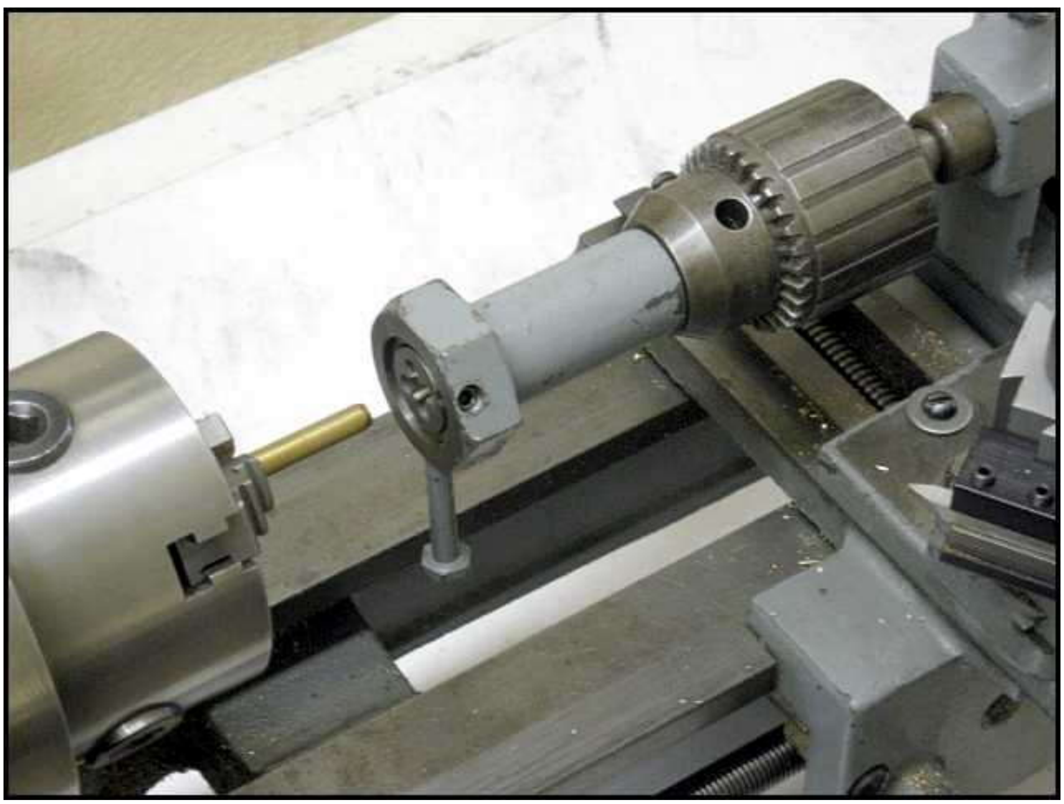
Safety Valve 1 Shop Drawing

Safety Valve 2 Shop Drawing

Start with the valve body. Normally the valve body is turned from a single piece of hex brass stock. A specially sharpened "D" bit cuts the 15-degree for the ball seat. I am going to try an experiment with the valve body and make it in 3 parts. I want to do away with the special "D" bit and make all the parts with standard lathe tooling.

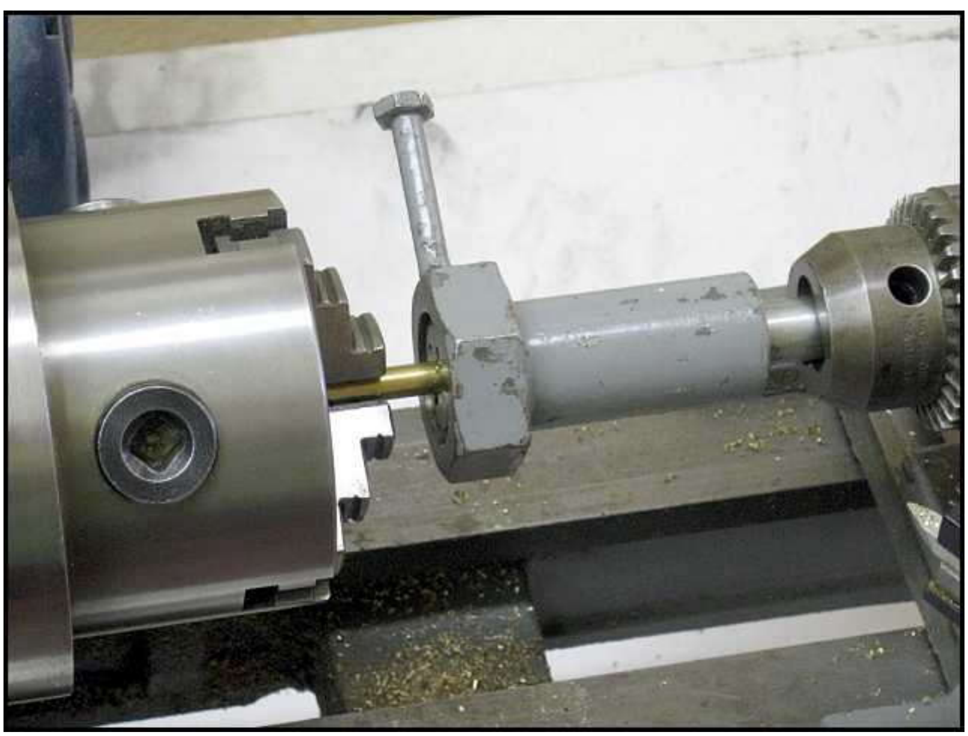
Before starting on the valve body, there is an important accessory you need for your lathe. We have used a tap holder for threaded holes, now we need a die holder to cut threads on a rod. While dies holders are commercially available, you can make your own. Here is the "temporary" one I made 30 years ago.

My die holder is an old 1" bolt, cut off, with a 1/2" hole drilled thru it and a recess for a 1" diameter die. Dies under 1/4" are usually 1" diameter. Smaller dies are 13/16". I made an adapter to hold smaller dies. The short length of rod goes in the lathe tailstock and the die holder slips over. A setscrew holds the die in the holder. Here’s the die holder in the lathe ready for work.

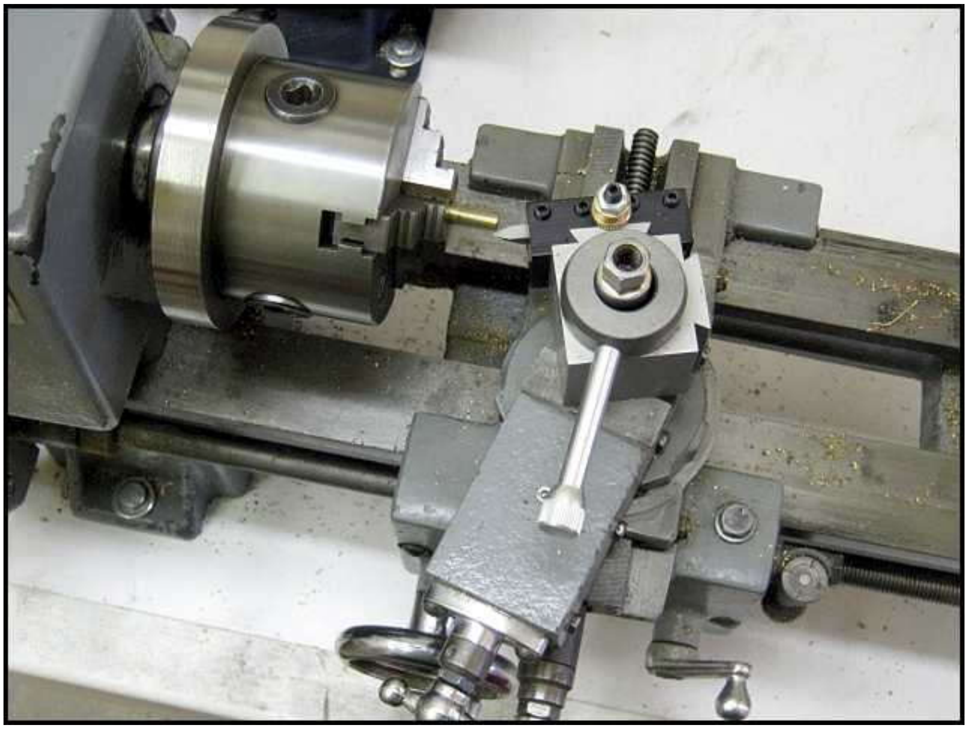


The tailstock lines up the die just like a tap holder does the tap. To use it, hold the lathe chuck stationary with the left hand and turn the die holder with the right. Go about 1/3 turn and back out to clear the chips. Use oil, even on brass. After a while you get in a rhythm with this thing, and threads cut in a hurry. It is impossible to cut accurate threads on a rod by hand. Invest in a ready made die holder or fabricate your own. First part to make is the valve seat. Chuck a length of 1/4" brass rod in the 3-jaw chuck. Drill and #39 ream about 1/2" deep.

The reason for #39 is that the hole thru the valve seat is 80% the diameter of the ball. #39 is .0998", which is the closest to 80% of 1/8”. You could get by with a 3/32" ream, which is probably what the commercial makers do. Using the die holder cut a 1/4"-40 thread for about 1/2" long.



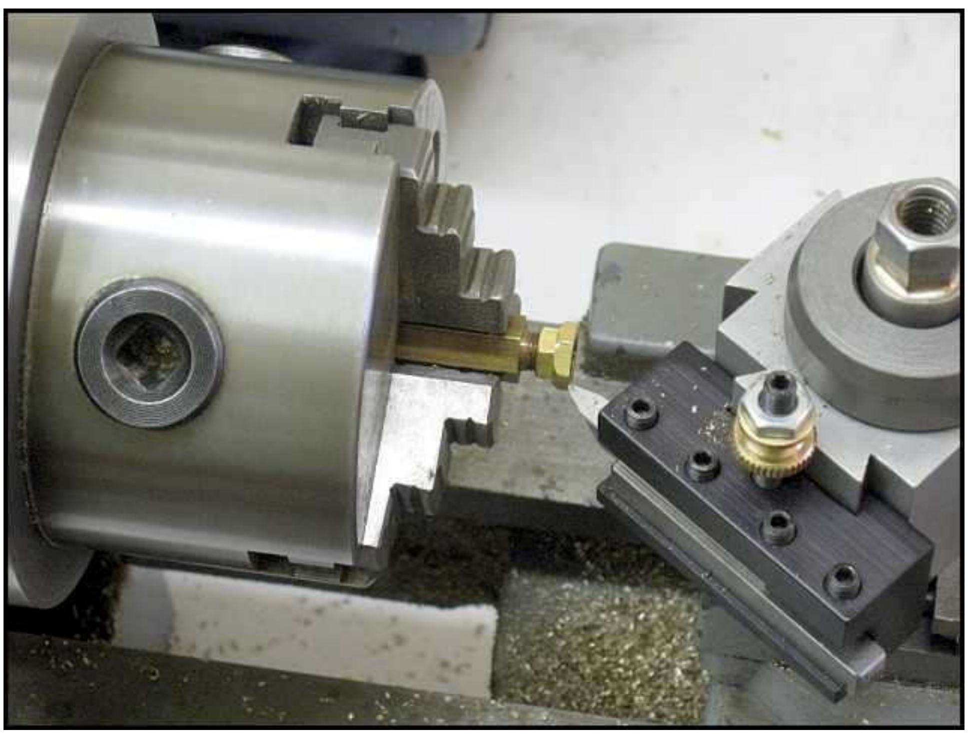
Next, set compound slide on the lathe to 15 degrees and face off the end of the valve seat. Run the bit outwards to pull burrs away from the reamed hole. Face deep enough to get into the good, clean reamed hole. This 15-degree edge needs be clean and sharp. Part off the seat to 3/8" length.



Now make the bonnet nut. Drill and tap 3/8" hex brass with 1/4"-40. Turn a nice chamfer on the edge. Rough hacksaw it off.

Putting a little nut like this in the lathe chuck to face off the rough-cut is nearly impossible to do. Instead make a chucking spigot with a jam nut.

Assemble the work piece on the spigot, secured with the jam. Chuck it up and face it clean.



Make these kinds of spigots, as you need them. Over time you will end up with you'll end up with a set. This particular spigot has 5/16"-40 on the other end. The valve bonnet is an easy turning job from 5/16" hex brass.

Here are all the parts for the valve body.

Assemble the body by jamming the bonnet nut and the bonnet.

That’s enough for today. Next time we will finish the safety valve. The next installment will have some very serious mathematical content. Have some scratch paper, stubby pencil and dirty eraser ready. No calculators allowed.

In the last installment we carefully machined a sharp 15-degree bevel on the edge of the ball seat. Now it is time to seat the ball to the valve seat. The ball we use is a precision stainless steel bearing ball. The ball has extremely close tolerances and a hardness approaching "Chinese Arithmetic". It should do fine.

To seat the ball, set the valve body on a flat hard surface. Drop in a ball. Use a length of brass rod as a drift punch. Get everything lined up and give the drift a pop with a hammer. Here is the set up.

The ball will make a slight spherical impression in the ball seat. The question is: how hard do you hit the drift with the hammer? I don’t know how to describe it, "medium light"(?) If done right, the ball will make an airtight seal if you suck on the bottom of the ball seat with your mouth. There should also be a very slight indentation left on the seat edge by the ball.

The valve stem comes next. It is a straight turning job from 1/8" brass rod. Turn the stem between centers on the lathe. Drill a #60 hole in the end of the rod to a depth of about 1/16". Follow up with a 5/32" drill bit to cut a shallow "V" notch in the end of the stem to center the ball over the valve seat. The #60 hole serves as a center hole for the lathe tailstock.

The final part to make is the stem adjuster nut. This nut bears against the valve spring and adjusts the valve to open at the desired pressure. Pressure adjustment on this valve can go from zero to total lock down.

The adjuster starts out from a short length of brass rod. Thread the rod with 1/4"-40 for a length of 1/4". Drill a #50 hole for a smooth slide fit with the valve stem.

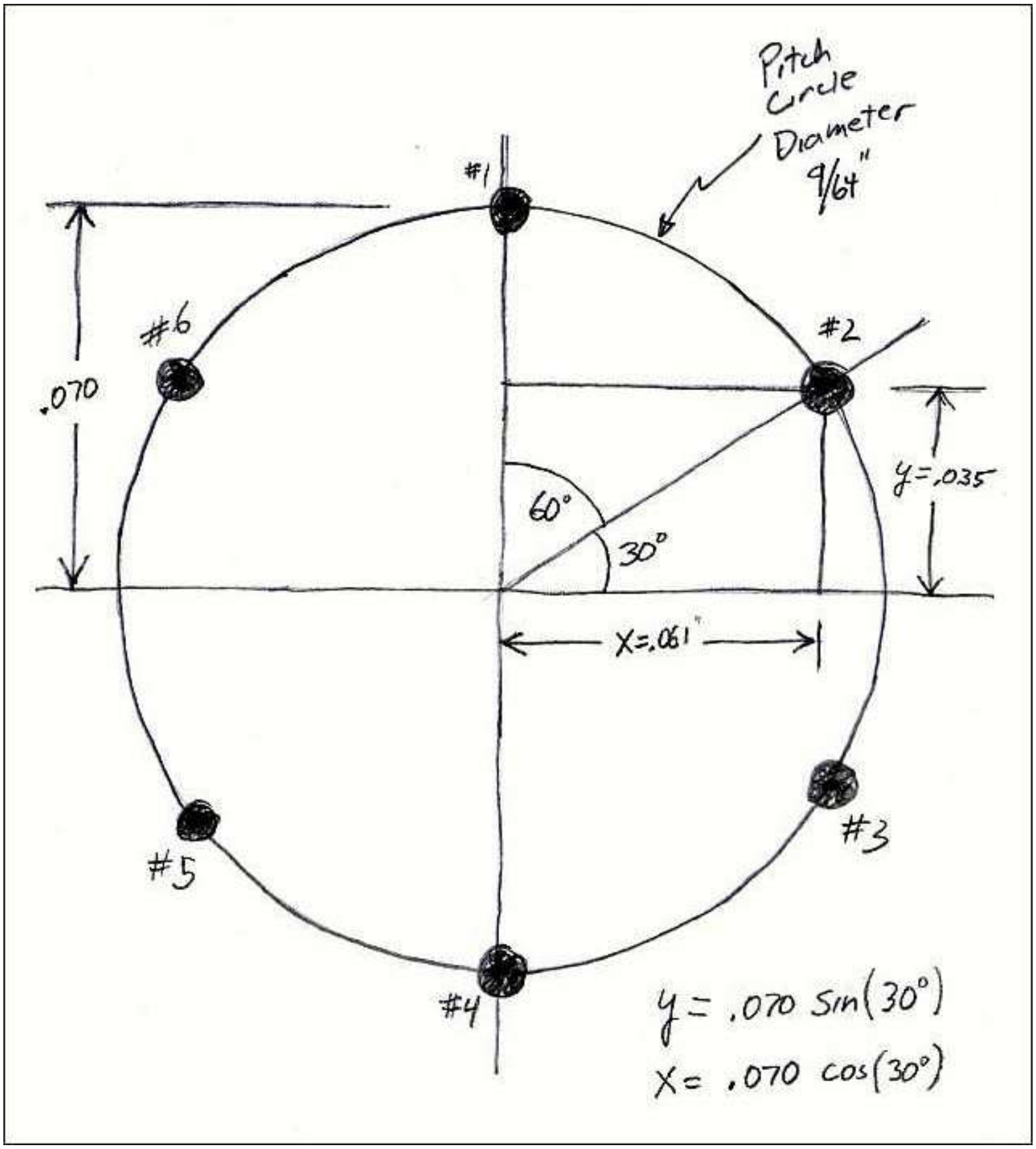
The safety valve drawing shows six holes, #57 in size, drilled in a hex pattern thru the nut. These are steam relief holes allow the escape of steam thru the valve body when the ball lifts. These holes are needed or the valve doesn't work. They are spaced at 60-degree intervals from the center. They lay on what is called a pitch circle. The diameter of the Pitch Circle in our case is 9/64" or .140". That puts them about half way between the outside edge of the center hole and the root of the thread.

There are a number of ways to layout and drill the relief holes.

1. Use a CNC machine.
2. Set up a rotary table or some indexing device on the mill to space out the holes on a 60-degree interval.
3. Use a drilling spindle on the lathe cross slide and index the lathe on 60-degree intervals.
4. Do a mathematical "bolt circle" calculation and use the X – Y table on the milling machine.
5. Layout the holes by hand, center-pop and drill.

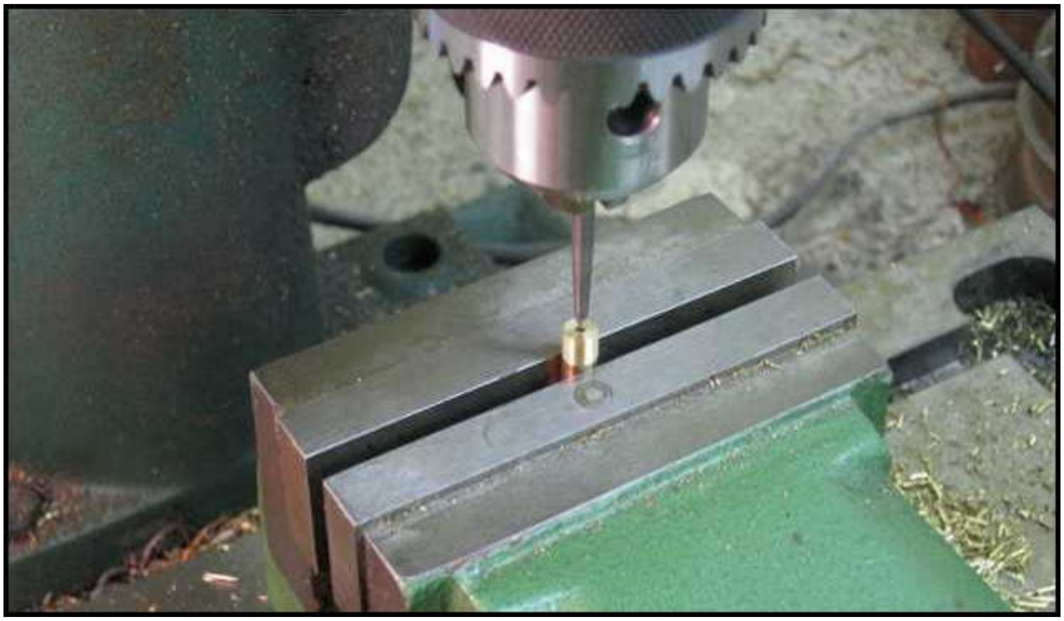
Option #5 is easiest way to go and will produce a perfectly satisfactory result. But, instead of doing it the easy way, we are going to use method #4. The challenge is converting angles from the center to X – Y coordinates for the milling table.

The following diagram shows the layout of the relief holes as if the stock were clamped in the mill vice. Holes #1 and #4 are easy to drill. They are simply plus and minus 0.070" from the center. Holes #2, #3, #5 and #6 require a combination of X and Y movements. It is those values of X and Y we need to find.

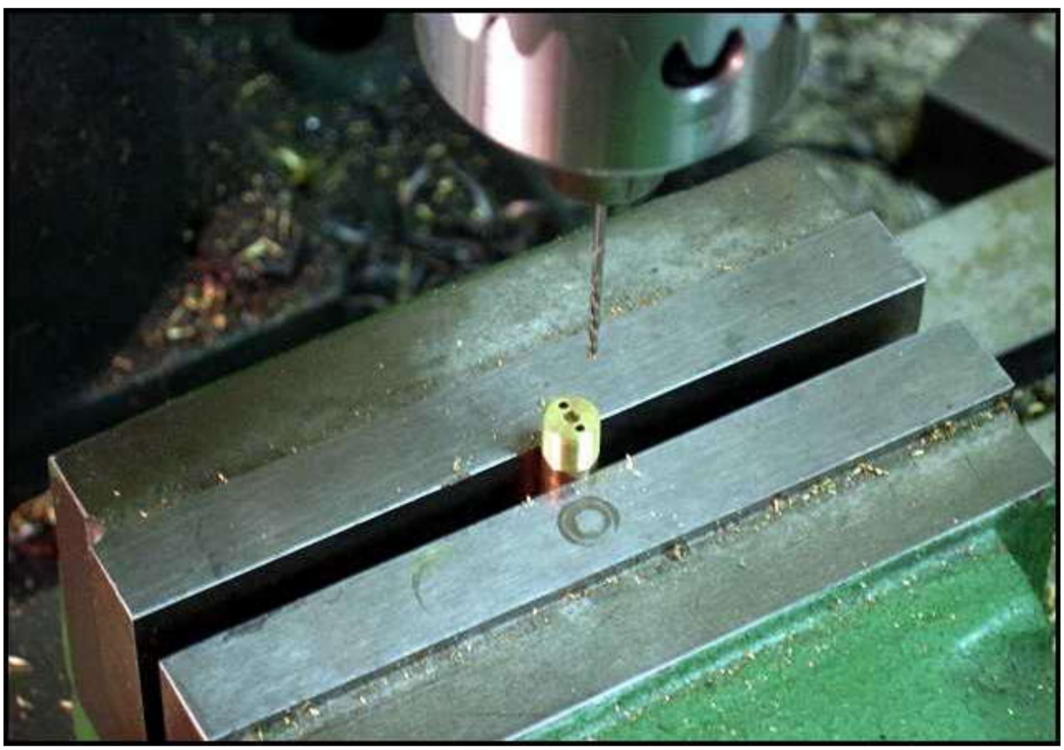


The diagram shows a convenient 30-60-90 degree right triangle that includes hole #2. As you know from your High School trigonometry class, the sine of an angle multiplied by the hypotenuse give the length of the side opposite the angle. In this case, the sine of 30 degrees is 0.500; the hypotenuse is 0.070". The Y distance from the center to hole #2 is 0.035". Similarly, the cosine of an angle multiplied by the hypotenuse gives the length of the adjacent side. The cosine of 30 degrees is 0.866", hypotenuse is still 0.070". They X distance from the center to hole #2 is 0.061". Since the remaining holes are equally spaced around the pitch circle, the values of Y=0.035" and X=0.061" will reach all of them.

Let's drill some holes. Clamp the adjuster nut stock in the mill vice and center it under the mill spindle. Use a center in the drill chuck to center the stock. Lower the center into the hole and adjust X and Y until center. You eye is a precision instrument and will get this right on.



Traverse the Y-axis by plus and minus 0.070" to drill holes #1 and #4. Use a center drill to spot the holes before switching to the smaller bit.



Now, using the values of Y=0.035" and X=0.061" traverse from the center to drill the remaining holes.

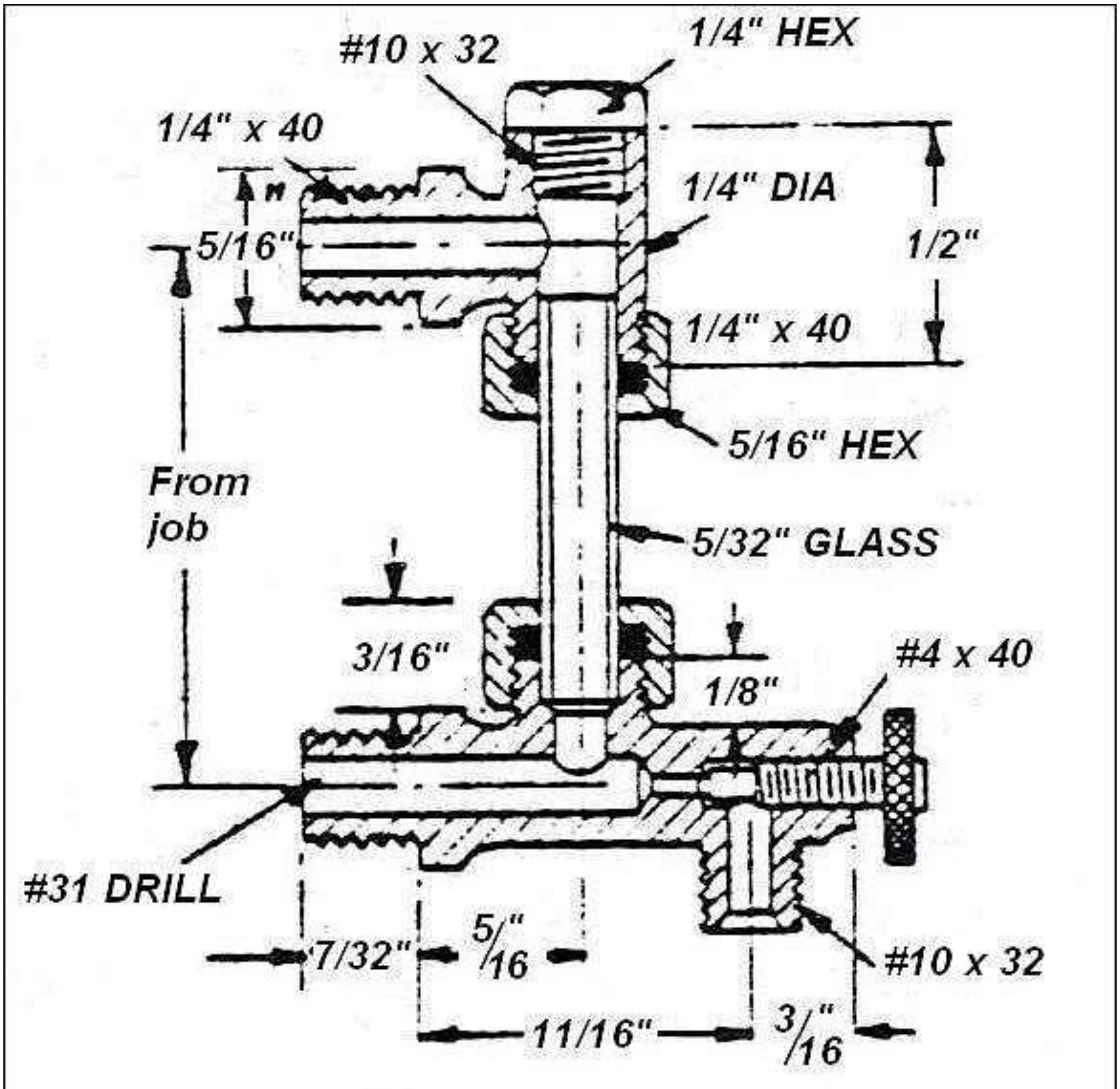
They came out spot on. The lead screws on my mill have a lot of backlash in them. That prevents me from simply running around and drilling the holes. I started from the center on every hole.

The last part is the spring. It is a precision stainless steel spring, with a diameter of 0.120", length of 0.250" and a wire diameter of 0.016". It has 5 full turns. The spring and ball (Item #4528K11) came from McMaster Carr.

Here is the safety valve ready to set.

The final thing to do on the valve is to set for pressure. We will do that later when we fire the boiler on steam. Next time we will work on the site glass. (See comment [C-20])

The design for the site glass, or water gauge is from LBSC. It is a design that he used on many of his Gauge 0 live steamers. His original plan called for 1/8" diameter glass tube. 5/32" glass is more widely available and I have a bunch of it. So we will increase LBSC's design by 25% to take advantage of larger glass tube. Here is the drawing. It is LBSC's drawing, but I added the plus 25% dimensions.

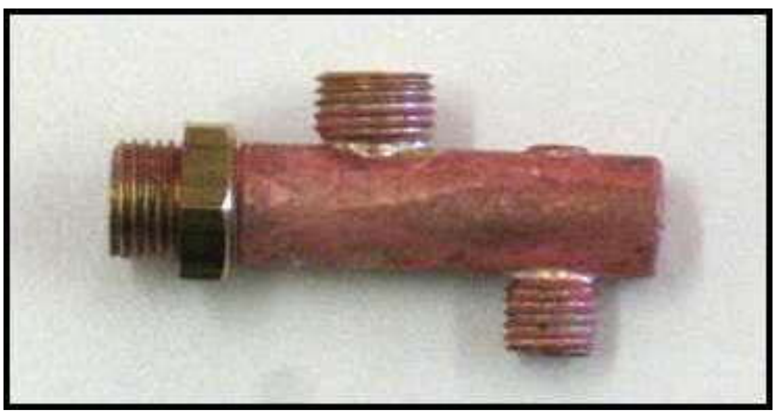


Water gauge.

The valve on gauge lower end is a blow down valve. The purpose of it is to ensure a proper reading in the gauge glass. Weird science happens sometimes in these small gauges that prevent accurate readings. Opening the blow down causes the water glass to drain out. Closing the valve allows the glass to fill back up to its actual level. While operating the engine, occasionally crack the blow down open for a half-second and close it. That will ensure an accurate reading. Sometimes small gauges work fine without a blow down. Sometimes they don't. It's better to have it and not need it, then to need it and not have it. Besides, they are too easy to make, so go ahead and do it.

Start work with the gauge lower end. It is a brass and silver-solder fabrication. Thread all the required parts before silver soldering.

The boss for the gauge glass goes into a blind hole. The boss for the drain is straight thru. You can do them either way. Going straight thru is better I think. It ensures the silver solder goes all the ways thru and makes the part solid. I cut the lower end stock off a bit too short on the drain end. Leave it about a quarter inch longer then I did, you see why shortly.
Silver-solder the lower end together.



Instead of threading the lower and upper end into a shoulder, I decided to use a jam nut instead. Chuck the lower end in the 3-jaw chuck by the drain end. This is why you need to leave it a bit longer. Fortunately I was able to grip it securely. Drill #31 (0.1200") 9/16" deep. This is the water passage.

Grip the lower end in the drill vise with the gauge glass spigot facing up. Drill #19 (0.1660”) 1/8" deep. This is a generous O.D. fit for the gauge glass. Drill #40 (0.0980”) just breaking into the water passage. #40 is the I.D. of the gauge glass.

Make up a female threaded chucking spigot to accept the gauge lower end.

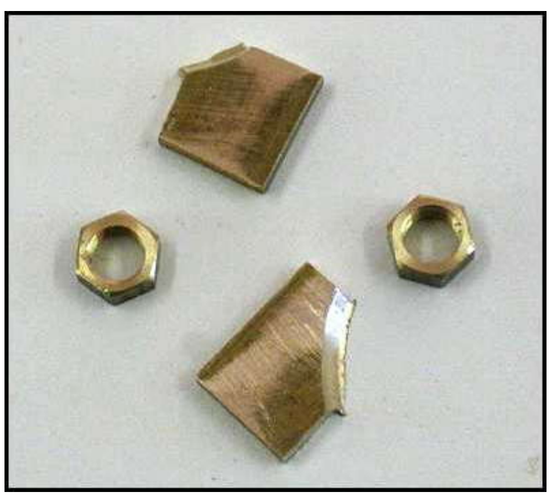
Chuck up the gauge lower end in the spigot. Machine off the excess material to the final length of the gauge lower end. Drill and tap for #4-40 to a depth of 3/8". Lastly, drill #55 (0.0520”) thru into the water passage.

Make a blow down valve spindle from a #4-40 machine screw. Turn the screw down to 0.080" diameter for a length of 3/16". File or turn a 60 degree included angle point on the spindle. Loctite or silver-solder a knurled nut to the spindle. With that, the gauge lower end is done.

Next, fabricate the gauge upper end; it’s done the exact same way as the lower end.

Silver-solder the parts together and machine as with the lower end.

The packing nuts for the glass tube are actually a silver solder fabrication. Drill and tap a 1/4"-40 hole into some 5/16" hex brass, then part off a 5/32" length. Cut some brass scrap, any size will do.

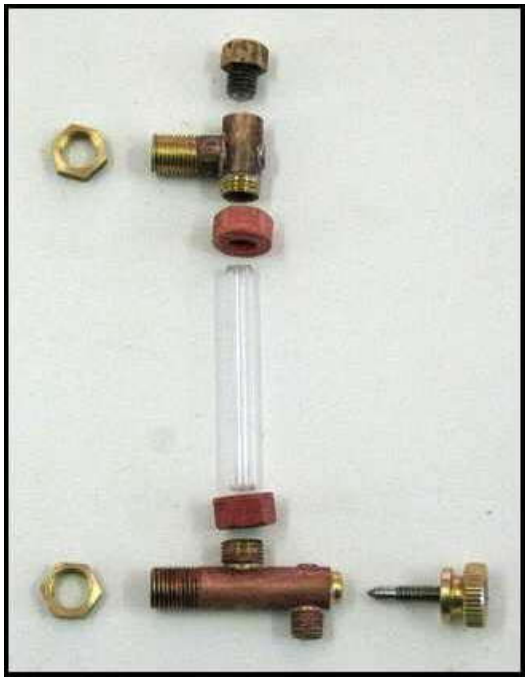


Silver-solder the threaded hex to the scrap. Use the least amount of solder possible. Too much solder can capillary up into the thread and ruin it. Find that threaded male chucking spigot you made earlier.

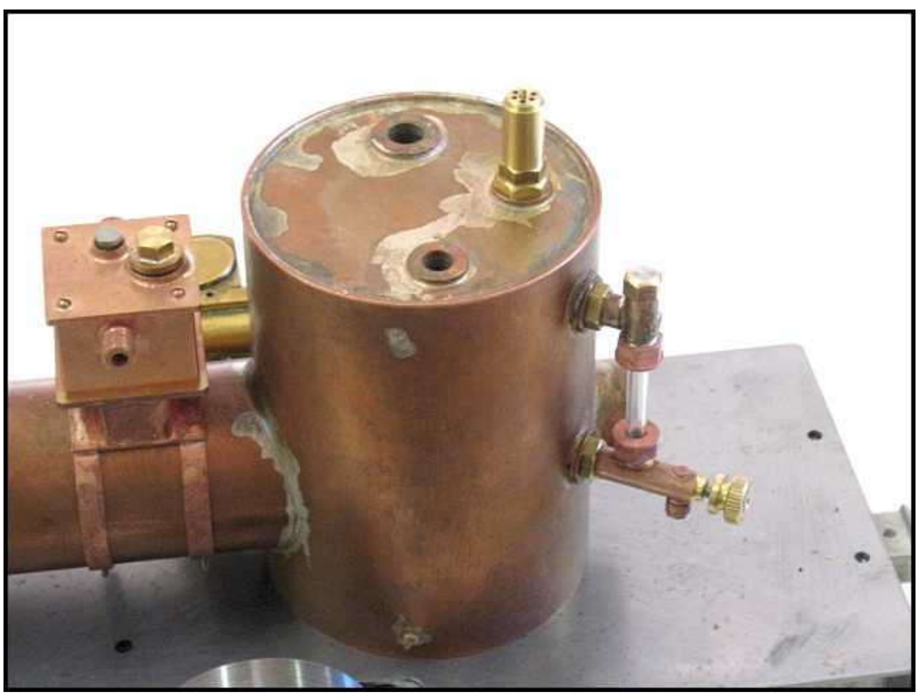
Chuck the blank nuts and spigot in the lathe. Drill #19 (0.1660”) thru.

With the nut still on the spigot, face to a total length of 3/16". Turn the waste brass off. At this point you can file the remaining brass off so the whole nut is hex shape. I left it round, looks OK.

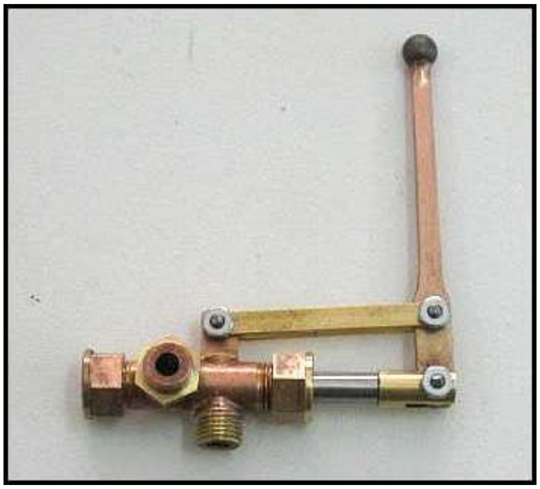
Make a plug nut for the gauge upper end. I could not find my 10-32 die, so the plug is a machine screw silver soldered into 1/4" hex brass. Of course, after doing the plug, I found the die. Cut a 1-5/16" length of glass tube. The best way is with an emory cut off wheel on the Dremel tool. Just lightly score the tube all around. It will snap off cleanly. The site glass is all done.



Put it on the boiler for a look-see.



That's lookin' sexy. We will eventually do a drainpipe for the blow down. Probably after the cab is done. Plumbing is almost done. Next time we will get on the throttle valve.



After a short break for another project, it's time to get back on Nina. Throttles for many Gauge 1 engines are simple screw down valves. Let's do something different and make a piston style throttle. Here's the completed throttle ready for the boiler. This view is from the bottom. The hole towards the left end goes into the boiler. The threaded portion facing downward goes to the engine.

The method of fabrication of the throttle is almost exactly the same as that which we used for the water gauge. The throttle body is a silver-soldered/brass fabrication, consisting of 3 parts. In the picture to the right are the three basic pieces that make up the throttle body.

In the picture to the left we see the rough "pseudo" casting of the throttle body, which is the result of having silver soldered its 3 foundational pieces together in their proper orientation

Here's the drawing for the throttle assembly (see end of this document **[Fig. 31]**):

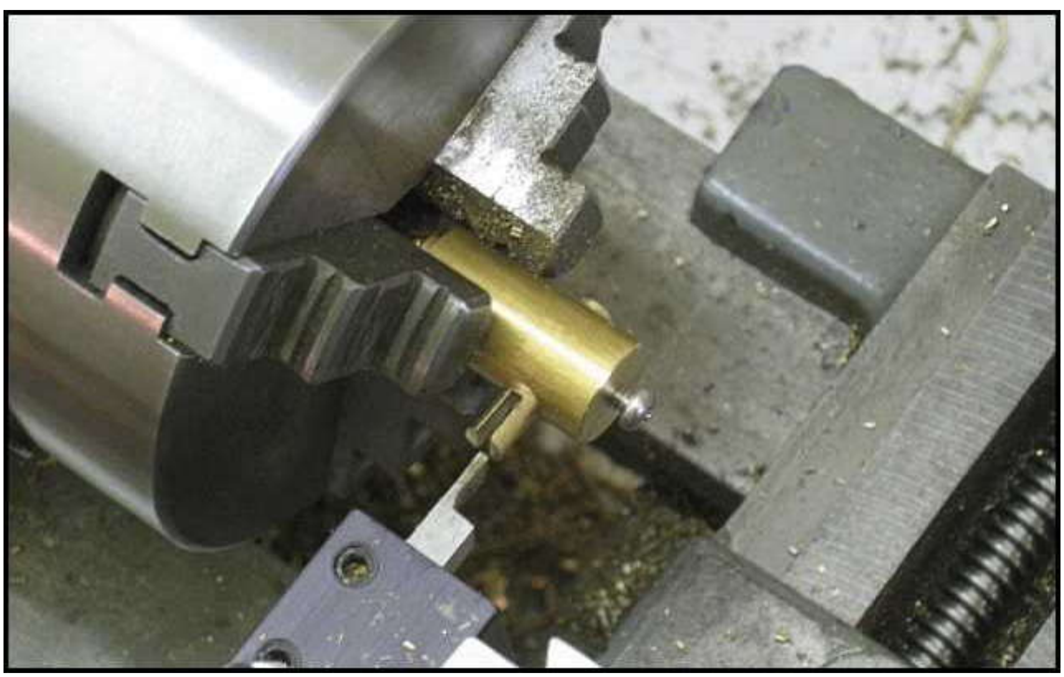
Throttle Drawing

Chuck the throttle body in a chucking spigot. Drill and ream 5/32" thru.

Grip the throttle body in the drill press vice and drill both passages 1/8". Everything done so far is just the same as what was done in fabricating the water gauge.

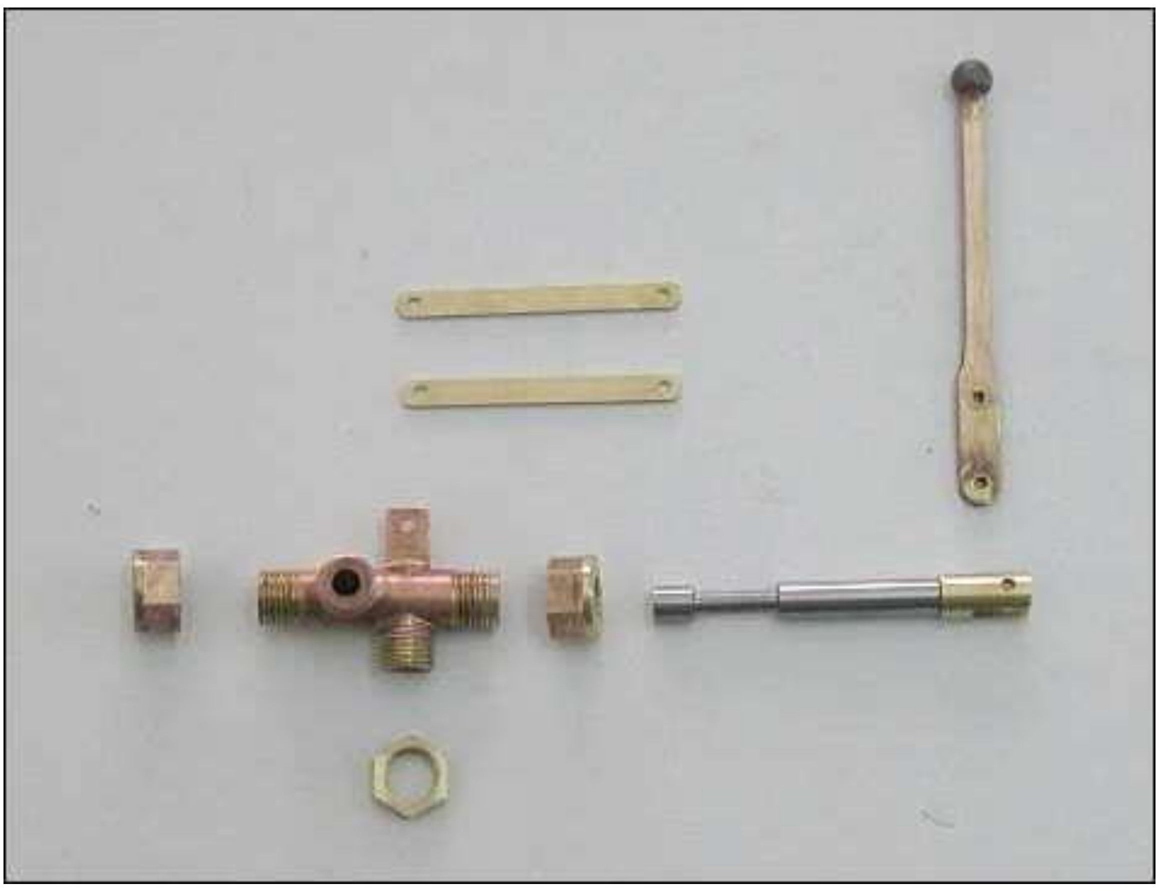
The throttle spindle is machined from 5/32" stainless steel. Lightly polish the rod with fine emery cloth and oil for a smooth sliding fit in the throttle body. Chuck the stock in the 3-jaw, securing the end with the tailstock. A #60 drill is sufficient for a center hole. Turn the slot in the spindle. Square the corners with a parting tool.

The fork end of the spindle assembles the same way as the piston and piston rod. Use a #2-56 machine screw with a dab of "Loctite" to secure the spindle and fork. The usual practice is to hacksaw and file the slot in the fork. Let's try something different. Make a little holding jig for a length of 3/16" diameter brass rod. Use a parting tool to take a plunging cut to form the slot. A set-up something like that depicted in the picture below. (See comments [C-25] & [C-26])



This is way easier than creating the slot with saws and files. Trim the fork to length and tap the end for #2-56, then assemble the spindle rod and fork.

The remaining parts are straightforward. The two links are from 1/32" x 1/8" strip brass. Drill them identically with #53 drill. #53 is a very close fit for #0-80 machine screws. The throttle handle is from 1/16" x 3/16" strip brass. The only thing critical about the handle is the 3/8" between holes. "Jazz" the throttle handle as desired. Two cap nuts are needed. Make them both the same way as for the water gauge glass. One cap is "blind" to seal the end of the throttle body. The other is a gland nut drilled #19 for a very generous fit for the spindle. Finally, a jam nut to lock the throttle body to the boiler bushing. Here are all the parts:



Assemble the throttle. The pivot points are all #0-80 machine screws. Hang it on the boiler.

There now, that's lookin' mighty sweet.

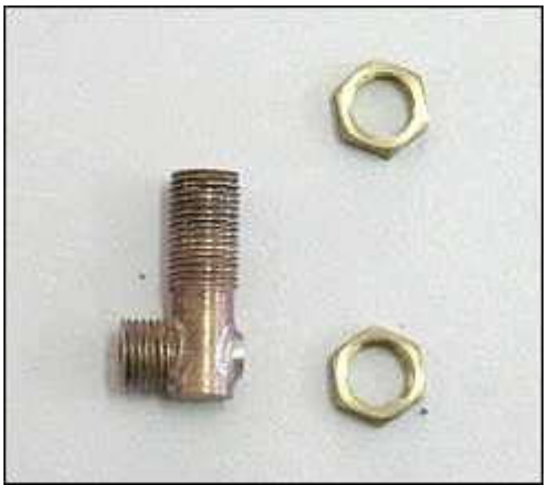
The "full throttle" position is with the handle straight back, as shown in the photo. The "throttle closed" position is either full left or full right. Either way shuts it off.

Next time we will get on the steam and exhaust piping and finish up the plumbing.

There are probably as many ways to install steam and exhaust piping, as there are ways to cook chili. The primary method I use is a nut to compress a flange against a flat fitting face. A small, thin Viton O-ring serves as the seal between the flange and the face. Viton is a reasonably high temp rubber that works wells in Gauge 1 steam applications. This method has worked well for me on all my scratch builds, so we'll stick with it.

An alternate method to install piping is with a "banjo bolt". Banjo bolts are used to install pipes into boiler bushings, and in our case to the engine manifold. A banjo bolt is essentially a very thick washer with a tube soldered into it. The banjo is attached to the bushing with a special hollow and cross-drilled bolt. More on banjo bolts in a moment.

First up are some 90-degree elbows. We need 2 "Street Ells" (male-to female thread) for the lubricator and one as a fitting to go thru the smokebox wall. The elbows fabricate and solder together just as with the water gauge and throttle. The street ells consist of 3 parts; all threads are 1/4" x 40 TPI. Here are the parts for one and another just out of the pickle tank:



The exhaust elbow thru the smoke box has a long leg and a short. The long leg goes thru the smoke box wall and is secured with 2 jam nuts.

For the piping, start at the throttle and work towards the exhaust end. From the throttle, I came out with 5/32" diameter thin wall copper tube. 1/8" would probably work fine, but I did not have enough 1/8" on hand to do the whole engine. Anneal the copper tube to soften it. Then with your favorite tube bender, bend and trim the tube until it fits between the throttle output and the lubricator input. Make up two nuts just as with the water gauge glass nuts. Turn and part off flanges about 1/32" thick and diameter that is a good close fit inside the nut. Here are the parts for the first pipe.

The O-rings are 3mm inside diameter and 1mm wall. They are available from McMaster-Carr and fit perfectly for this job.

Slip the nuts over the tube and silver solder the flanges.

Next up is the pipe from the lubricator output to the engine manifold has a nut-flange on one end and a banjo on the other.

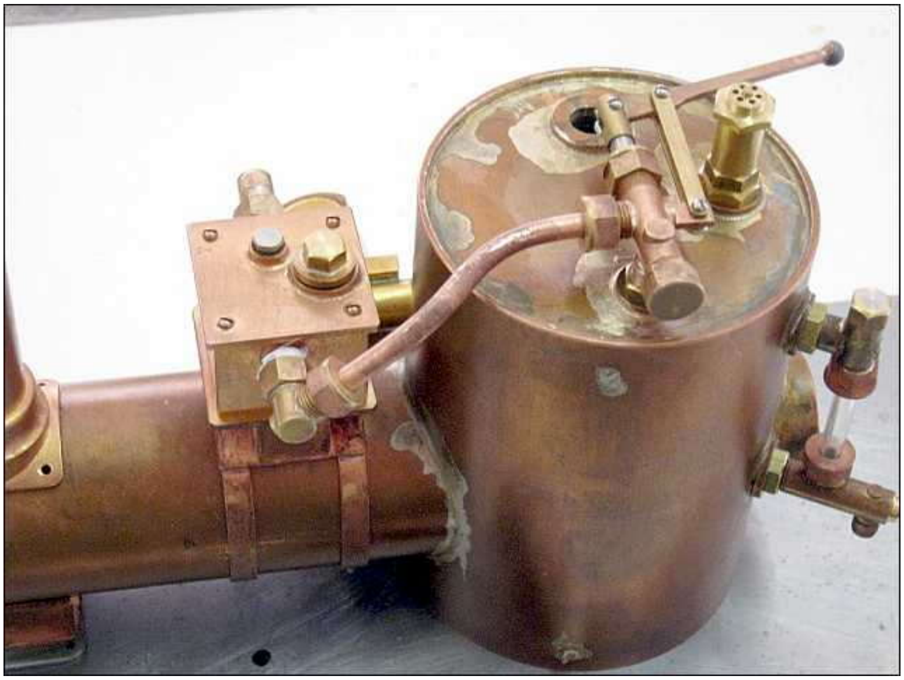
Here's the drawing for the banjo bolt (see end of this document **[Fig. 32]**):

[Banjo Bolt Shop Drawing]()

Here is the Banjo Bolt and the plumbing from the lubricator output to the engine manifold input all soldered up and ready to install. Notice that here I used 1/8" OD, thin wall copper tube.

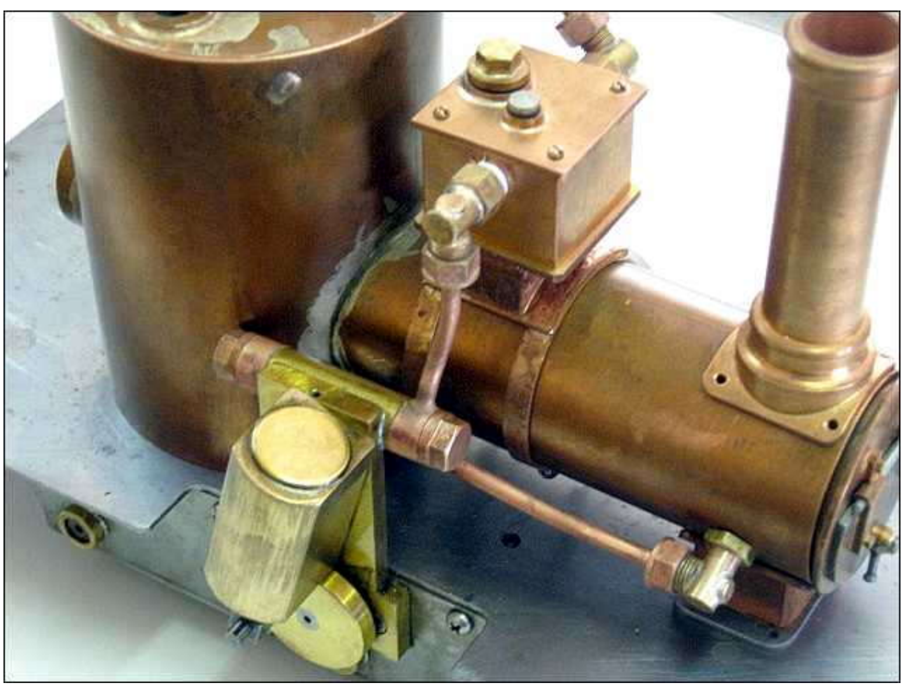
Here is the plumbing that goes from engine manifold exhaust output side (note the banjo fitting on the left) forward to the smoke box elbow input flare fitting.

Now install all the pipes, starting at the throttle. There are no O-rings installed for the dry fit, those only get put in at final assembly.

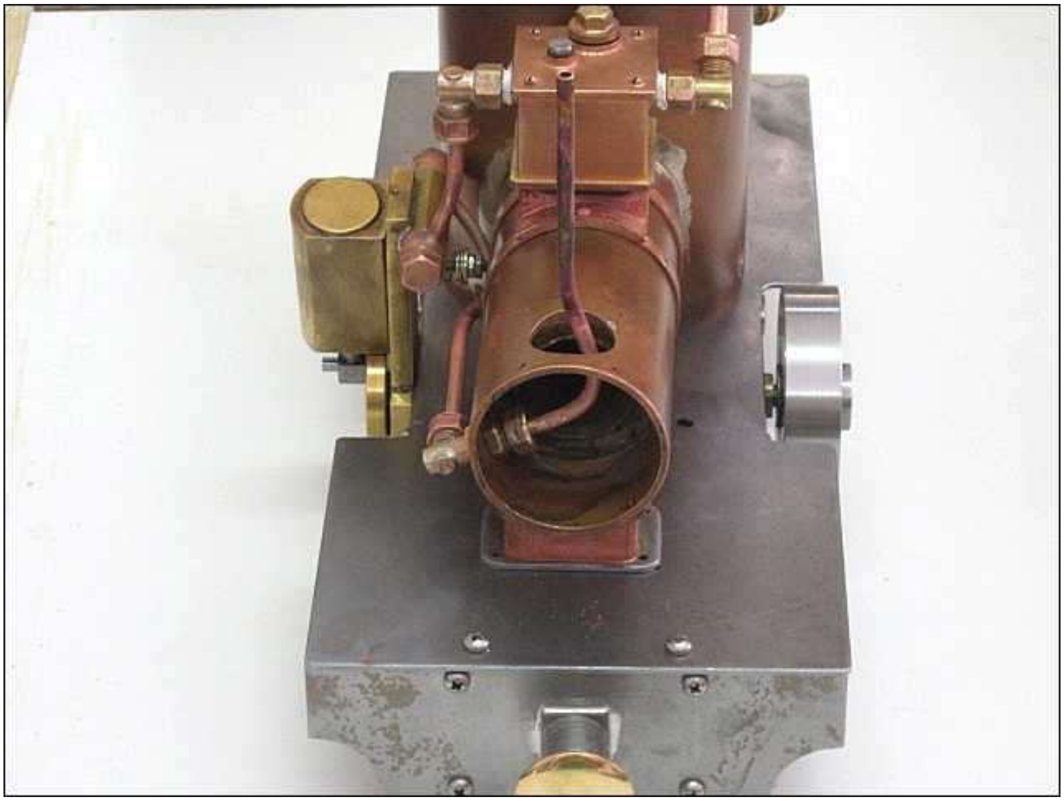


Notice that I decided to swap the location of the throttle and safety valve. By placing the throttle in the boiler bushing on the left side it centers the handle better, should work out OK.

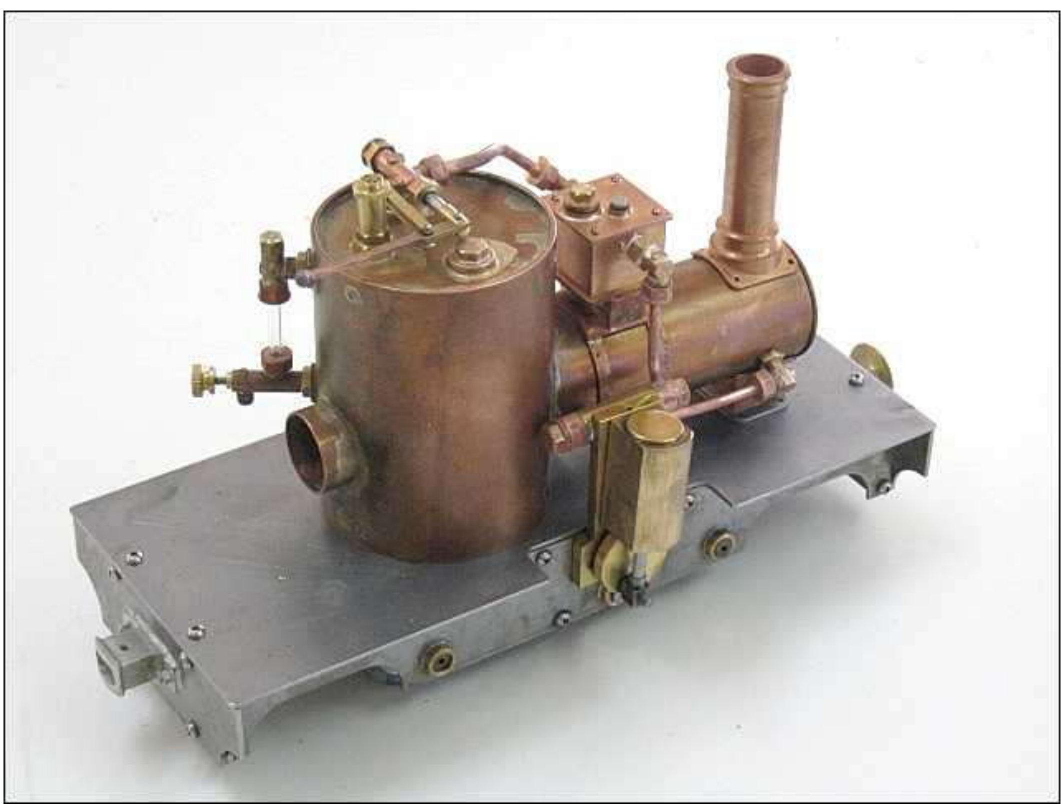
Next we install the plumbing from the engine manifold exhaust output leading to the smoke box input elbow. Loosening the lubricator will help in getting both of the pipes installed.



The last pipe to go in is the blast pipe. It's not really a blast pipe; it just gives the exhaust steam something decorative to do. Install it with a nut and flange. Trim the length so it is near the top of the stack.



So here is where it's at so far.



Lastly, fabricate a water fill plug for the last bushing on top of the boiler. I am thinking about making up a riser section with a nipple on the side and the water fill on top. Use the nipple for a pressure gauge outlet.

Looks more like a "moonshine still" than a steam locomotive.

The plumbing phase is all done. Next is the butane fuel system. I am trying to figure out where to put the fuel tank. Either inside the open top cab, or on the fender, forward of the flywheel. What do you guys think? (See comment [C-27])

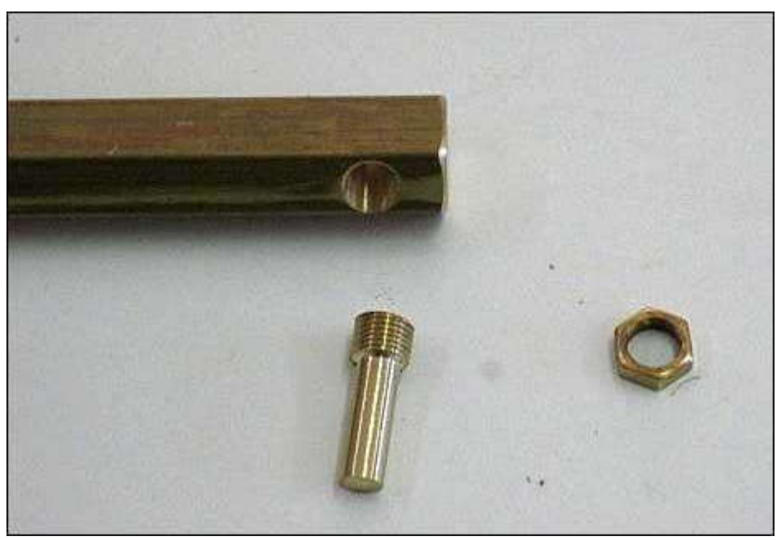
Just a short update on two little jobs completed before starting on the fuel system.

Long time MLS friend "Ora Banda" tells me that Australian boiler codes require a means to lock the pressure setting on a safety valve. During operation it is possible for the safety valve to jiggle loose and come apart. The usual method to lock the setting on the safety is with a jam nut. The fix is so simple; there is no reason not to do it.

The fix requires a simple modification to the existing valve body and fabrication of a jam nut. Chuck the valve body in the chuck spigot and turn off 3/32". That’s it. With the jam nut here’s our safety valve mod:

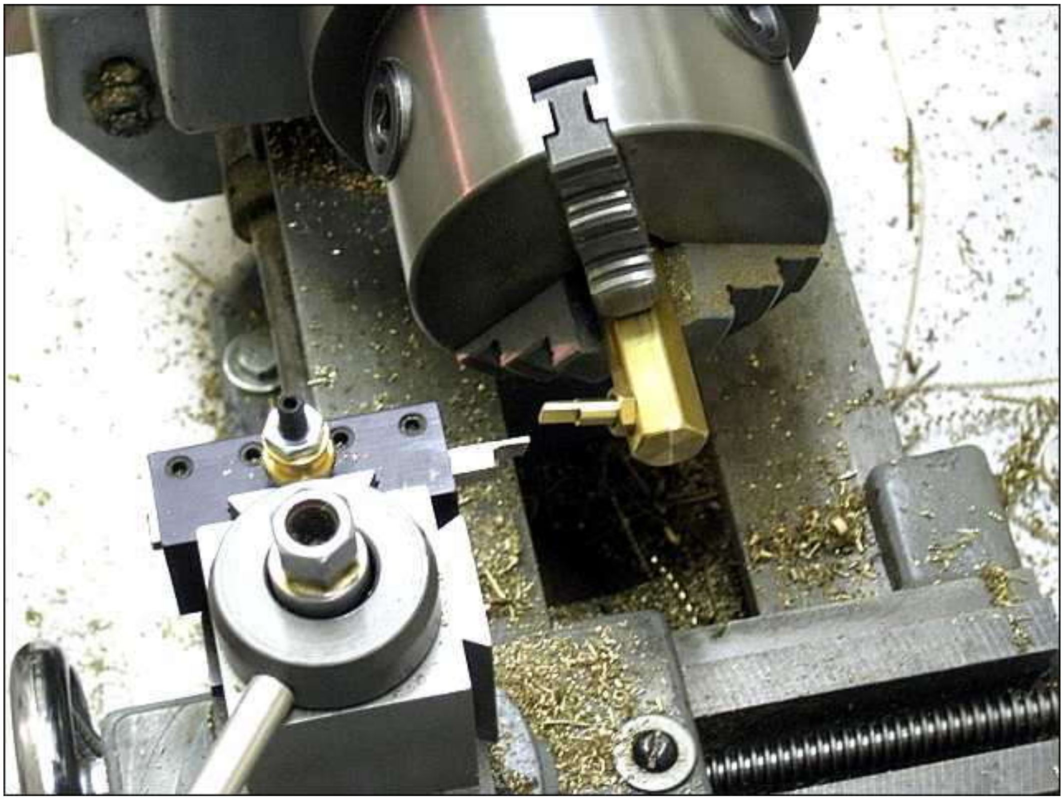
The safety is not set for pressure yet. It gets set later during a steam test of the boiler.

The second job is a new throttle body. The boiler nipple on the old throttle body is too short, making it difficult to install on the boiler. The drawing I made for the throttle body is correct. If you follow the drawing, the throttle body will install just fine.



In making the new throttle body, I used the fly-cutter method to machine the linkage tab. Make a threaded jig to hold the nipple.

Use the parting tool to shave down the sides of the linkage tab. It worked out sweet.



The new throttle body (one on the left) sits taller and is easier to get on the boiler.

Next week we'll start on the fuel system. The fuel tank is going inside the cab. The other day on the Internet I found a micro sized pressure regulator that might be worth an experiment. If Nina runs good, it may end up a test bed for "do-dads" like a pressure regulator. So for now I want to keep the fender position open.

Today let's get started on the fuel system by fabricating a fuel tank. Since Nina is a gas fired locomotive, the fuel tank is a pressure vessel. So build the fuel tank in the same manner as the boiler. Before starting there are some design considerations to go thru.

The filling adapter is a valve held closed by a spring. The fuel enters the tank thru the adapter while in liquid form. Almost like pouring water into a glass. Filling adapters are commercially available or you can "cannibalize" one from a refillable lighter or a small torch. Adapters screw into a bushing on top of the tank. Here are three adapters I have:

The adapter on the left came from a small Harbor Freight torch (that crapped out immediately). The thread is metric M5.0 x 0.5. The center adapter came from a micro pencil torch and also has a thread of M5.0 x 0.5. The adapter on the right came from Sulphur Springs Steam Models (unfortunately out of business) and has a M4.5 x 0.5 thread. That's the one I will use, because I have a tap for it.

The next consideration is the pressure inside the fuel tank. We need to test our tank as with the boiler to ensure it operates safely. The question is what kind of pressure are these tanks under? There are two types of fuel commonly used: 100% butane (lighter fuel or Chinese tabletop cooker fuel) or a mixture of 70% butane and 30% propane (Coleman brand camp stove fuel).

I found a chart that shows the pressure of these fuels under various temperatures:

Vapor Pressure (*psig*)			
Mixture	Propane (C_3H_8) %	30	0
	Butane (C_4H_{10}) %	70	100
Temperature (F)	-44	0.0	0.0
	-30	0.0	0.0
	-20	0.0	0.0
	-10	0.0	0.0
	0	2.3	0.0
	10	5.9	0.0
	20	10.2	0.0
	30	15.4	0.0
	40	21.5	3.1
	50	28.5	6.9
	60	36.5	11.5
	70	45.0	17.0
	80	54.0	23.0
	90	66.0	30.0
	100	79.0	38.0
	110	93.0	47.0

At 110 degrees F, the 70/30-mix fuel has a pressure of 93 PSI. As with the boiler, we'll test the fuel tank to twice the maximum operating pressure or 186 PSI. It is interesting to note that 100% butane "boils" at about 32 degrees F. Below that temperature, butane stays liquid. 70/30 mix boils at about –5 degrees F. In cold weather run with 70/30 mix or the burner may not work right.

While the tank fabrication was a success, the design didn't work out so well. The tank's fill connector and fuel control valve interfere with each other. So it's back to the drawing board.

With that done, let's build the tank. Here is the drawing for the tank parts (see end of this document **[Fig. 33]**):

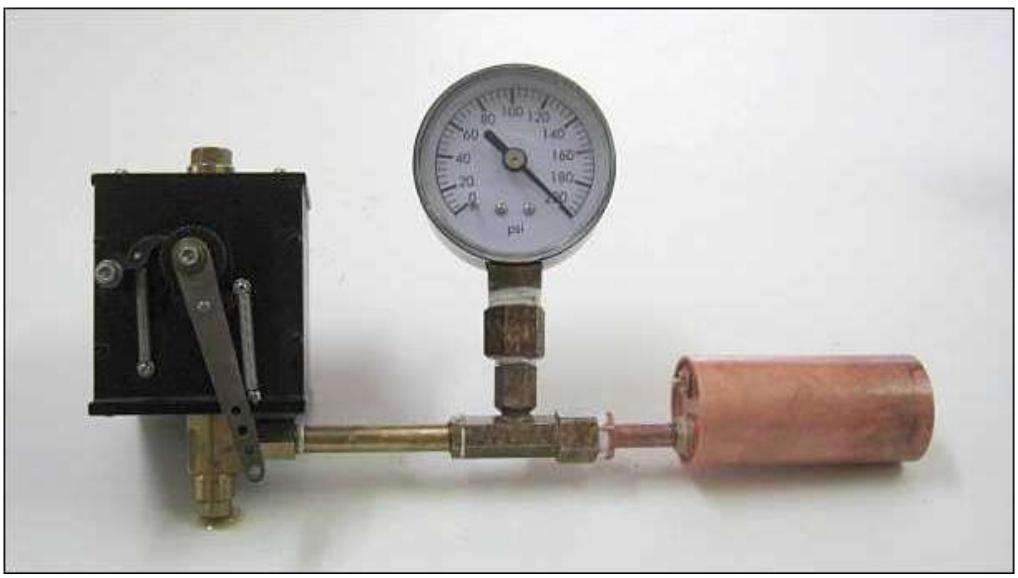
Fuel Tank - 1 Shop Drawing

Use the exact same techniques for the fuel tank as with the boiler. You are an expert at this, so not much more to explain. Here are the parts turned up and ready to silver solder.

And fresh out of the pickle tank.

Now for the pressure test. For the boiler we used a regular air compressor, but mine only goes to 120 PSI. My little hand water pump only goes to about 140 PSI. So for this test I used a mechanical oil pump I made for a 7.5" gauge live steamer. Here is the test set up.

Fill the pump and fuel tank with 30 weight motor oil and screw everything together. Start pumping.



At 200 PSI the oil pump bottom had a very small weep, but the fuel tank held strong.

If your pump does not reach 200 PSI, test the tank as high as you can. If you can only test to 120 PSI for example, then from the chart above you would have to use 100% butane fuel above about 85 degrees F. Or for added safety, use 100% butane all the time. Next time we'll get on the fuel valve. (See comments [C-28, 29, 30, 31, & 32])

Well – Change #1. The fuel tank I made last time is not going to work out very well. The fill adapter and gas valve are too close together, making a generally bad arrangement. So send that tank to recycle. The new fuel tank is horizontal. It is also made from 1" nominal copper pipe and is 3" long. It will have a slightly higher capacity and won't stick out quite as much.

All the parts are the same, with two exceptions. First, the new tank requires two mounting bushings instead of one. Second, the end plates are solid.

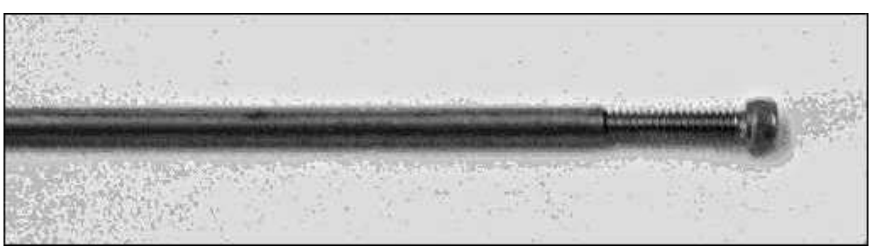
Without holes in the endplates, we cannot use the #8 sheet metal screw and wood block trick to secure the plates for turning. Instead soft solder a piece of brass round to the endplate blank.

And chuck the assembly in the 4-jaw for turning. Next, find the jig you used for aligning the water gauge bushings in the vertical boiler barrel. We'll need it to align the mounting bushings on the new fuel tank.

The remainder of the new fuel tank assembles and tests just as before. With the new fuel tank done, let's switch to the fuel valve. The fuel valve is similar to the bottom end of the water gauge. It's a needle valve with the addition of a packing nut to stop gas leaks around the needle stem when the valve is open. Here's the drawing of the major parts (see end of this document **[Fig. 34]**):

Fuel Valve Shop Drawing

The first part to make is the needle valve stem. We will use the old machine screw/rod trick to make the needle stem. Tap a #4-40 about 1/4" deep into a length of 1/8" stainless steel rod. Loctite a #4 machine screw.



Set the compound slide on the lathe to 5 degrees. Chuck the stainless rod and turn a 10-degree included taper for about 1/8" length. The small end of the taper should just fit into a #57 hole.

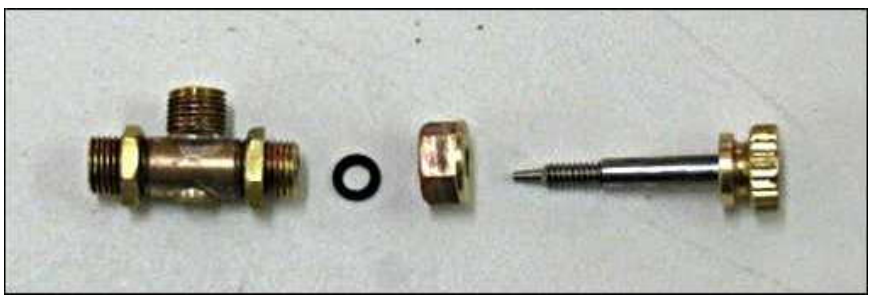
Cut the stainless rod to 1/2" length. Tap again for #4 x 40 and Loctite another screw. Fashion an appropriate knob for the needle valve.

Loctite the knob and the needle valve stem is ready to go.

The fuel valve body and packing nut are silver soldered assemblies as you did for all the plumbing parts. Silver-solder the valve body parts.

Using a chucking spigot chuck the fuel valve body in the lathe. Drill #31 to 1/4" depth. Drill #43 and tap #4-40 to 1/2" depth, finally drill #57 thru.

On the drill press/mill drill #57 in the output side, just breaking into the passageway. Make two jam nuts. Here are the finished parts ready to assemble.



And a picture of the assembled fuel valve, the bottom end screws into the fuel tank, the horizontal leg is the takeoff to the burner.

Here's the new fuel tank and fuel valve. Eventually the tank gets covered up by a cab and a coal bunker maybe.

Standing on the footplate is Jennifer. She's the company president's niece and the new payroll clerk. Since Jennifer came on board, there's been a lot of pay problems. Most of them are imaginary, but many are for real. The guys back in the shop are spending way too much time in the front office these days. I don't know how long she'll be around. Anyway, next time we'll get started on the burner. (See comments [C-33, 34, & 35] & [C-36, 37, 38, 39, 40])

I am going to build two different types of burners, then have a "burn off" to see which works better. One burner is the standard "poker" type used widely in gas-fired engines. The other is the blowtorch type burner that Mr. Glaser originally used for "Cracker". I don't recall seeing a blowtorch burner in a Gauge 1 loco, so this will be an interesting experiment.

Let's get started by making gas jets. Gas jets are normally made with highly precision drilling machines capable of drilling the 0.006" to 0.008" holes. I don't have that kind of machine, so we will have to use a different technique.

The technique to make gas jets comes from Mr. Dean Williams, an amateur clock and camera maker. His technique is shown on his website for the fabrication of a micro Bunsen burner. Here is Dean's page on the Bunsen burner, and while you are at it, check out his main page. He does incredible work with a Taig lathe.

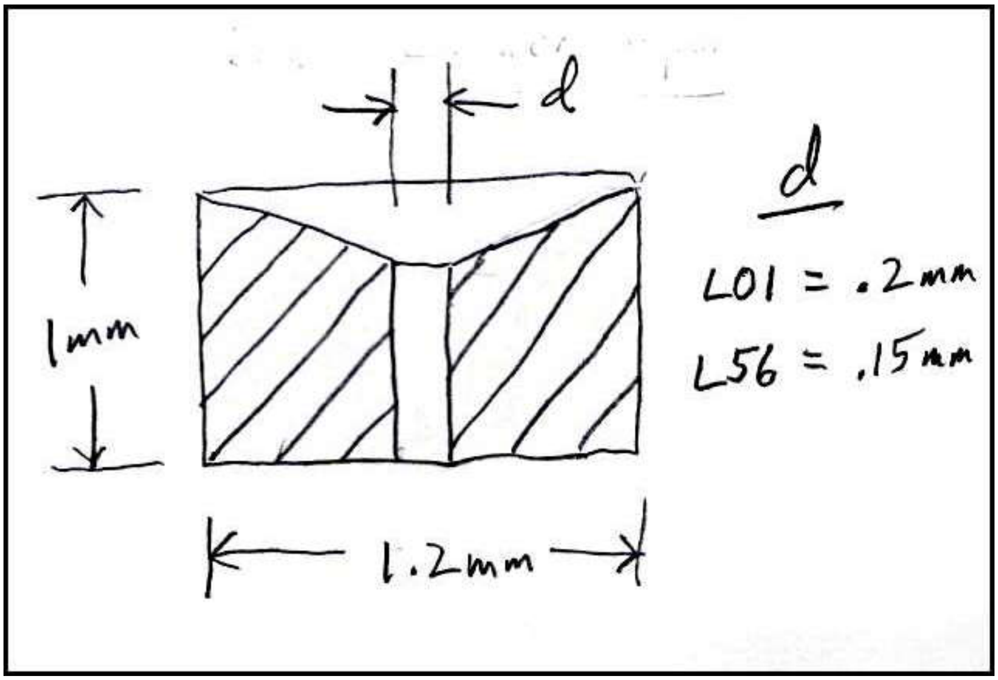
Dean's Williams Website

Dean's technique uses commercially available wristwatch bushings as the gas orifice. The bushings are the "KWM German Made" type available from the TimeSavers Company in Scottsdale, Arizona. TimeSavers has two bushings that will work for our applications.

- Size L-01 (**part number 11301**)
- Size L-56 (**part number 11356**)

The idea for the gas jet is to insert a wristwatch bushing into a #2-56 x 1/8" brass model hex bolt and install the bolt in the burner.

Here are the dimensions of the wristwatch bushing.



To make a jet, start with a jig to hold the model hex bolt. Cut a 1 1/2" or so length of 1/4" brass rod and face both ends clean. Drill # 42 hole 1/16" deep. Then drill and tap #2-56 about 1/4" deep. Screw in 1/8" #2-56 model hex bolt. The #42 spot drill ensures the bolt rests flat on the head.

Chuck the assembly in the 3-jaw. Lightly center drill and then drill thru with a #56 drill. Number 56 drill provides a very nice press fit for the 1.2mm diameter watch bushing.

For best results, rough drill with #57 or #58, then finish drill with #56. Finish the bolt drilling with a very small chamfer to break the sharp corner left by the drill. Just twist a countersink bit with your fingers.

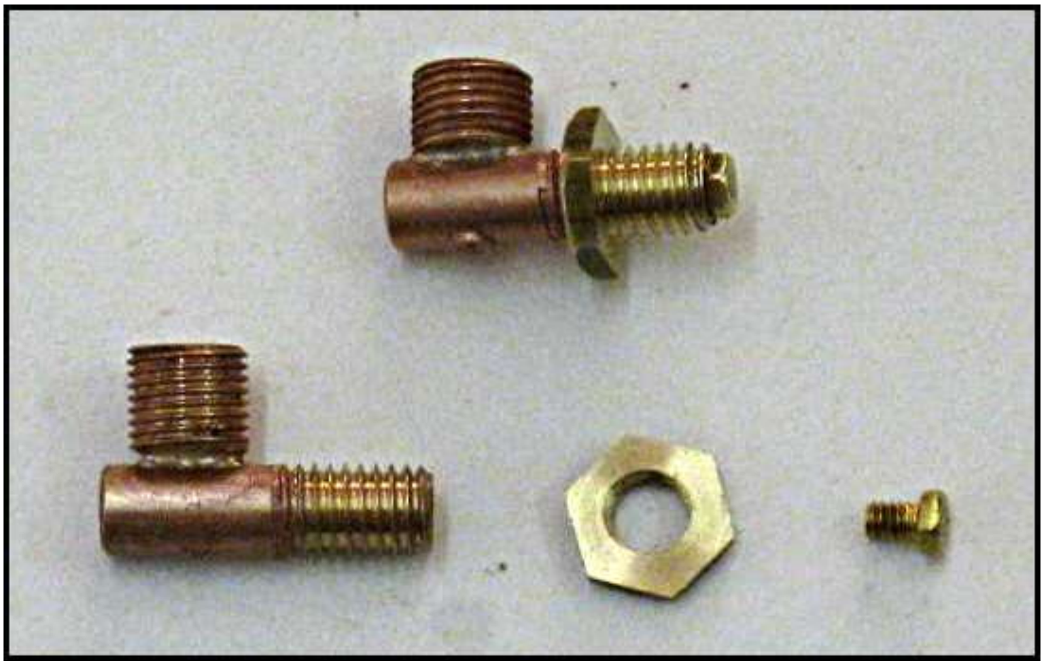
Now chuck the hex bolt and fixture in the drill press. Place a watch bushing on the drill press table with the flat face down. Lower the drill chuck, aligning the watch bushing with the hole in the hex bolt. Use a needle or long pin to move the watch bushing around. When aligned, press the watch bushing home.

Don’t be intimidated by the small size of the watch bushing. Getting it aligned and pressed in is easy to do. They key is the little chamfer, it helps align the watch bushing and prevents getting hung up on the edge of the hole.

Now fabricate two jet bodies that will screw into the back of the burner. Make them in the same fashion as the other plumbing and gas parts. You are an expert at this. Here is the drawing: (see end of this document **[Fig. 35]**)

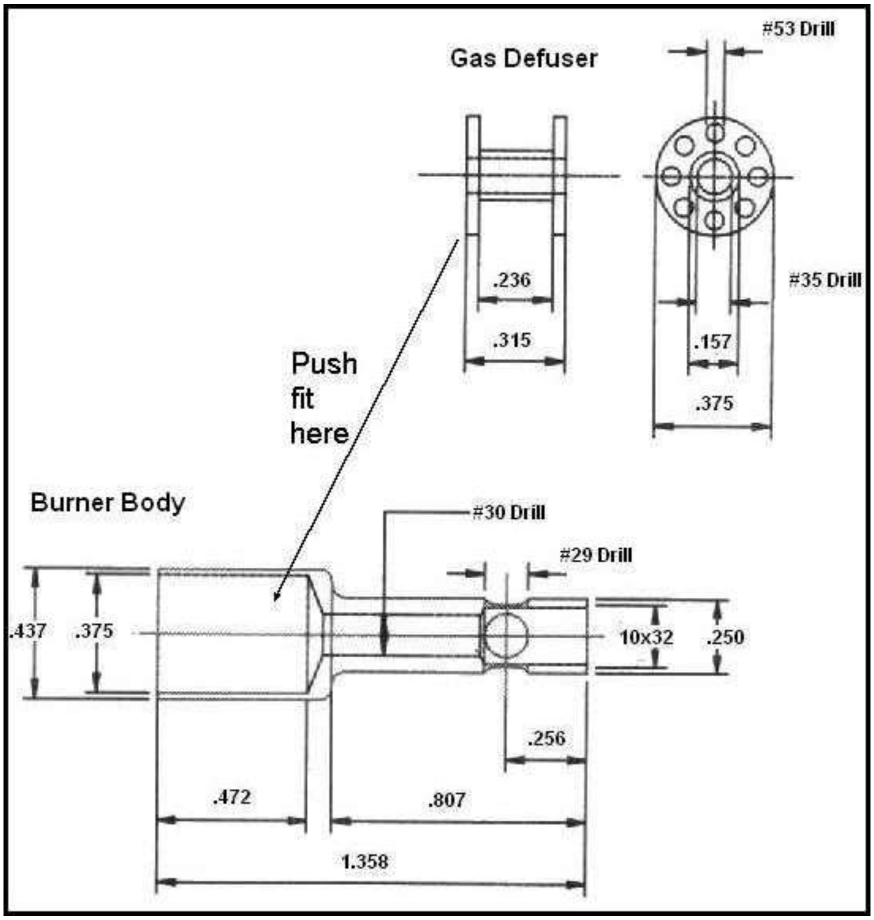
Jet Body Shop Drawing

Here are the jet bodies ready to install. The jam nuts will give some backward/forward adjustment for the jet.



I think these watch bearings will work great for jets. Looking forward to trying them in the burners. Next time we will get the burners done. (See comments [C-41, 42])

Today we are going to get the burners done and do an initial test to see how they do. The first burner is the "blow torch" burner that Mr. Glaser used in the original "Cracker" engine. The burner consists of only two parts: the burner body and a gas diffuser. I want to use Mr. Glaser’s burner as is, so convert the dimensions from metric to inch. This is Mr. Glaser’s drawing for the "Cracker burner, with dimensions changed to inch.



The gas diffuser is the difficult part to machine. It has eight equally spaced holes that fall on a pitch circle. Set up a pitch circle drilling operation, just as with the safety valve. It is not shown on the drawing, but the pitch circle diameter is 0.266". Machine the diffuser shell first and then drill it out. Here is the drilling set up for the gas diffuser.

Just as with the safety valve, I found it more accurate to traverse each hole from the center position.

The burner body is a straightforward turning and drilling job.

Ream the large hole in the burner body to accept the diffuser. The reamed hole will make a nice, light push fit for the diffuser.

Lastly, turn a 3/16" thick mounting ring that just fits inside the boiler flue. Blowtorch type burners need more air to operate then the mixer holes provide. Drill some 5/32" holes thru the mounting plate. Silver solder the mounting plate to the burner body and tap a couple 2 x 56 for mounting screws.

The photo shows six auxiliary air holes, but four are enough. Let’s see how it does.

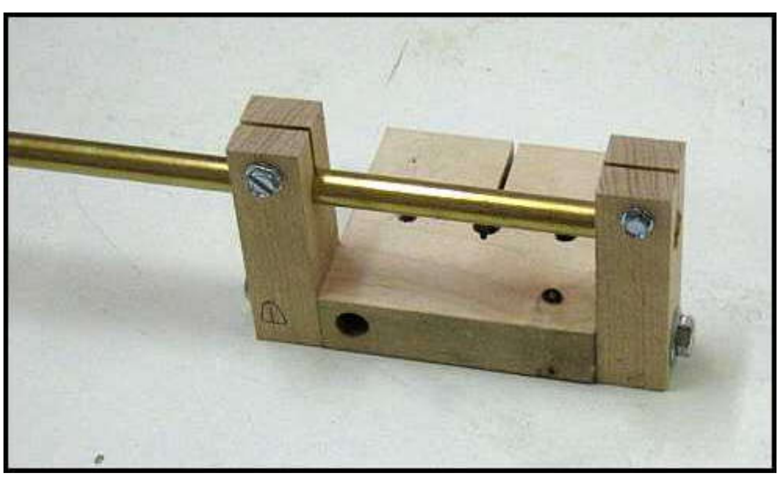
This burner requires a small jet. Use the L-56 watch bushing with a 0.15mm (0.0059") bore to make the jet. The L-01 bushing will not work; the burner won't light at all. With the small jet, this burner is a micro sized nuclear furnace. It burns wicked hot.

Next let's do a regular poker style, "Ruby" type burner. This burner is just a brass tube with slots sawed along the top. Here is the drawing: (see end of this document **[Fig. 36]**)

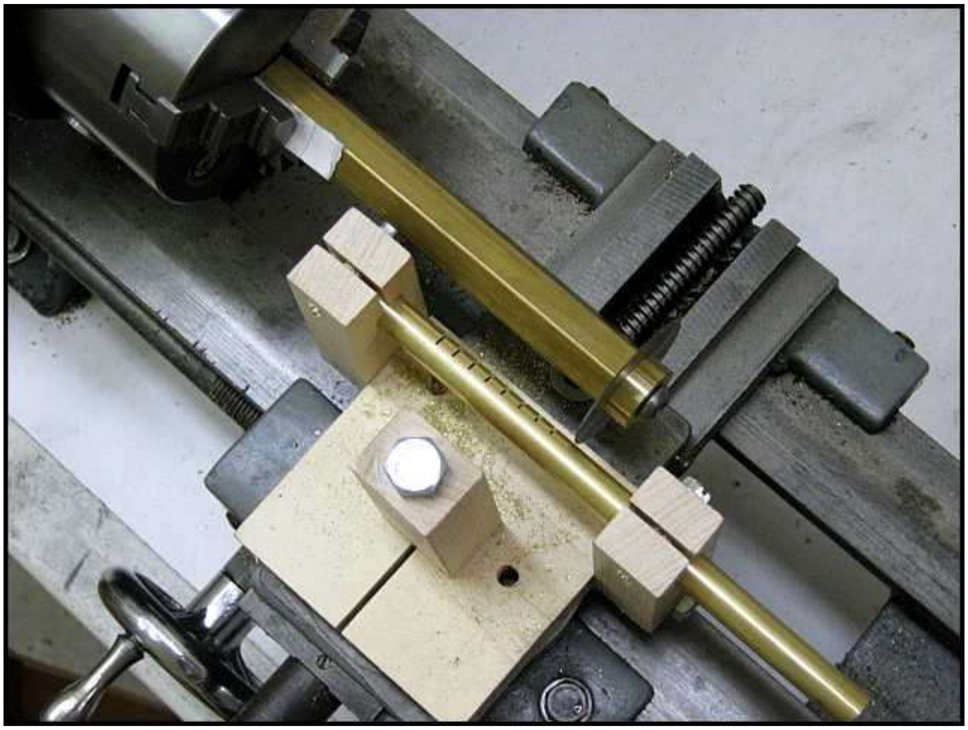
Poker Burner

There is a couple of ways to do the burner tube. You can drill out a 3/8" solid brass rod with 5/16" or use a 3/8" OD, 5/16" ID tube. I used tube, which is available from McMaster-Carr and others. There are 12 slots in the burner tube, each 0.020" wide on 7/32" intervals. The slots are wider at the rear end and get progressively narrower towards the front. Two options to cut the slots: cut them by hand with a jeweler's fret saw and a very thin blade, or with a circular slotting saw on the lathe. The fret saw is easier and would work fine, but we never do anything the easy way.

To cut the burner slots on the lathe, rig up a tubing holder from the wooden parts leftover from boring out the boiler barrel.



Mount the jig on the lathe cross slide and a 0.020" thick slotting saw blade on an arbor.



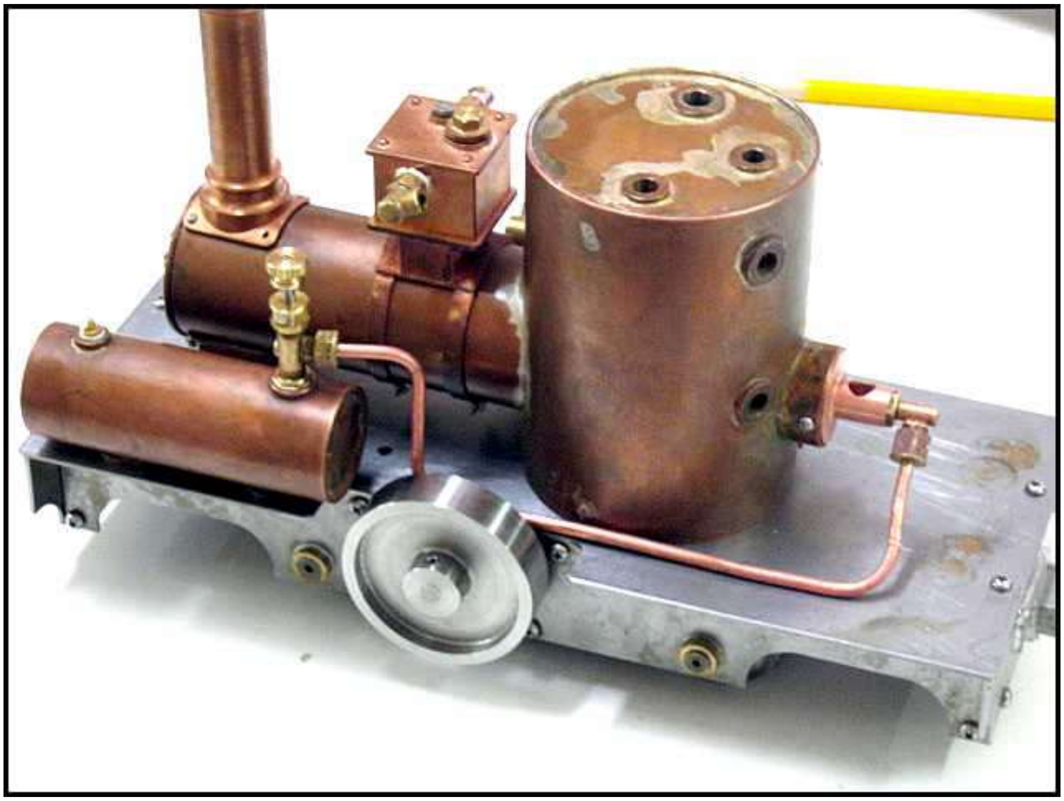
Advance and traverse the lathe carriage the required depths and intervals to make the slot cuts. They actually sell saw blade arbors for this kind of work, but I don't have one. Had to "jerry-rig" this arbor. It worked fine.

As with Mr. Glaser's burner, turn, tap and silver solder a mounting ring from 3/16" brass plate. Poker burners don't need auxiliary air holes. They draw all their air from the mixer.

Here is a test burn in open air using a larger, 0.20mm jet.

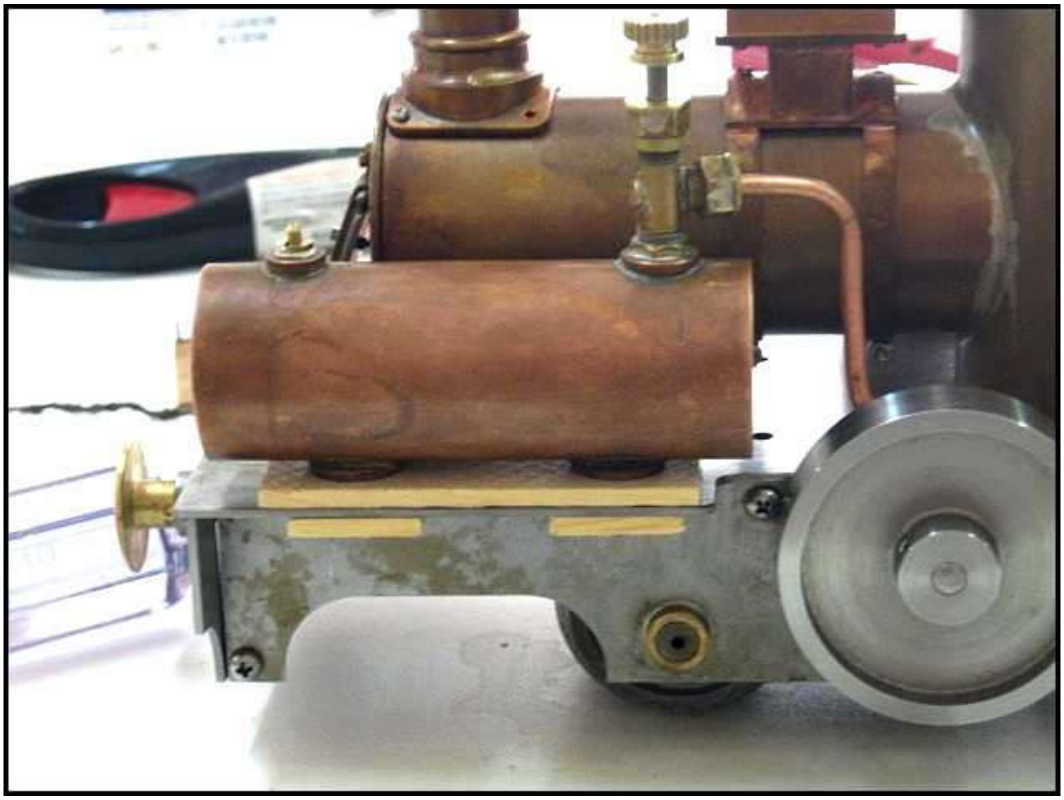
I played around with the poker burner in the boiler and discovered it worked best with a small jet. In open air, it would not light at all with a small jet. What happens inside the boiler is the important part.

I changed my mind and decided to mount the fuel tank on the fender. All the "contraption" stuff looks nice. Rig up a fuel line. Use a nut and cone type connector on the burner end of the fuel line. They seal very tight and handle heat better then a packing type connection.



With that, all the mechanical work on the "Nina" is done, just cosmetics left to do. Next time we will experiment with the burners, set the safety valve, re-assemble and pack all the glands. Then it's ready for the first steam trial. Getting nervous… (See comments [C-43 & 44])

Time to start testing and fixing all the bugs. First thing to play with are the two burners plugged into the boiler to see how they behave. Leave the top boiler plugs open so steam can escape during the test. Fill the boiler about 2/3 full. Have some heavy soap water and a Q-tip handy. Hook up a burner and light it. Wipe some soap water on each gas line joint to test for leaks. If there is a leak, then the soap water will make big bubbles. Right away there was a problem. The fuel tank started to overheat. Heat radiated thru the chassis and into the tank. The fix is to insulate the fuel tank from the chassis. Do this with a strip of wood under the fuel tank and wooden washers on the mounting screws. Something like this:



That did the trick. The fuel tank stays nice and cold now. I will come up with a better fix later, maybe. Probably 20 years from now it will still look like that.

The poker burner with a small jet is the one to use. While the blowtorch burner lights up very easy and burns hot, it does not heat this boiler very well. The flame blows thru the flue too fast and just heats up the smoke box. I will experiment more later, but for now, go with the poker. The poker burner is a little difficult to light. At first it whistles like a jet engine, very piercing irritating sound. After warming up a minute, it settles down. After a little gas burns off it works very well. Total burn time on one fill: 35 minutes.

Now start assembling the plumbing parts. Before boiling any real water, make a "Tommy bar" spanner like this:

The pins in the spanner engage the holes in the top of the safety valve and allow adjustments while keeping fingers out of the way.

Get the engine, tools and supplies ready for steam testing. Mount a large pressure gauge in the fill plug bushing.

The large copper tube loop below the pressure gauge is called a siphon. All steam pressure gauges need a siphon. When the boiler warms up and the first steam goes into the siphon, it condenses back to water and settles in the bottom of the siphon. Water acts as a barrier between the steam and the gauge. What actually operates the gauge is compressed air. Without the siphon, wet steam goes into the gauge mechanism and eventually damages it.

Now set the safety valve. This is done with live steam pressure, not compressed air. To set the valve, take off the locking nut and open the top until the spring is loose. Plug the remaining holes in the boiler and light it up. At first a lot of water will spit out of the valve, but when everything warms up, steam will flow. Use the “Tommy” bar to tighten the safety valve until the steam stops. Note the pressure on the gauge, if any. Let the boiler build more pressure until the safety lifts again. Keep tightening and noting the gauge pressure. Repeat the process until the safety lifts at about 30 PSI. Shut down the burner and let the pressure drop. Re-light and makes sure the safety lifts at 30 PSI. If all is well, put the lock nut on and sinch it down. Repeat the safety valve test several times to ensure it reliably lifts at 30 PSI.

This safety works very well. At 30 PSI, it sputters open/close and keeps the pressure right at 30 PSI. So far, no problems with it lifting, sticking open and draining the boiler.

Now let's install the water gauge. Wrap Teflon tape on the threads and screw into the boiler. Drop a #21 drill thru the water gauge top and adjust in/out until the bit fits nicely.

Tighten down the jam nuts. Make sure the drill bit is still free. The jam nut method is very secure. They compress the Teflon tape and make a super watertight seal. They are the way to go.

The watertight seal for the gauge glass is from rubber O-rings. I used metric O-rings with a 3mm ID and 1mm wall thickness. They stretch nicely over the 5/32" glass and inside the 1/4"-40 packing nut. Use 2 O-rings on each end of the glass. Tighten the packing nuts only finger tight, does not need much pressure to seal. The olden days of using graphite yard for water gauge packing are long gone. Don't waste your time, just get the O-rings.

Fill the boiler to about 2/3 glass, fire it up, lift the safety.

Now for another disaster. The (**bad words**) water gauge did not work. Water level would not register in the glass; it was nothing but a bubble. Then, it would only blow down water, no steam and not re-fill. Maybe the top end got plugged with Teflon tape or something. So I took it apart and discovered I never finished drilling out the top end. So, yes, it was plugged all right, with about 3/16" of solid brass. After drilling it out and re-installing, the water gauge worked like a champ.

That's a great water gauge from the old master, LBSC (Lillian "Curly" Lawrence 1883-1967). We are going to quit for now, I've had enough. We have a mega big disaster to solve next time.

Let's get Nina running on the rollers. Install all the steam and exhaust piping and the throttle in preparation for the first steam run. The packing nut joints use a single 3mm x 1mm O-ring. The banjo fitting on the steam side uses gaskets. Cut two gaskets from brown shopping bag paper and soak them in steam oil. Brown shopping bag is the best gasket material in the world. The exhaust side does not need gaskets.

Fill up the gas tank, put more water in the boiler, and charge the lubricator. Light it up and let the safety lift. Open up the throttle and see what happens.

The first steam run was a total disaster. The engine would barely kick over on it's own. It would turn a few times and stop. No power. Finally, it seized up solid and would not turn at all. I disassembled the engine. It took a pair of 12" channel lock pliers to pull the piston from the cylinder. There was a big chip brass stuck in the cylinder wall and it bound up the piston. Once that was out the piston moved freely again.

What was causing the lack of power? Somewhere in the design phase I made an arithmetic error and the piston ended up 3/32" too long. At top-dead-center the piston was just below the cylinder cover and clearly blocking the port hole. The steam opening started when the piston was about 1/3 way down, way too late. The exhaust closed way too early, probably causing compression near the top. Somehow, the engine ran fine on the air compressor. Steam from the boiler was a totally different outcome.

The fix was ugly:

Grind a big notch in the piston so the porthole is never covered. Actually, the notch in the piston works the best. The smaller volume in the cylinder at top dead center means less steam space to fill during the power stroke. That will save on steam consumption.

And, there was another potential problem. All along I was worried that the #47 holes in the cylinder and engine standard port faces were too small. So I enlarged all three to #40 (0.098"). These may still be too small, but for now, we will try them on steam.

After hooking everything back up and building steam, the engine took off like a gunshot. It ran long, strong and smooth. Here's a 16 second clip:

YouTube Video: Nina on the rollers

The first test run lasted 24 minutes before running out of fuel. That would have been the remaining fuel after an 11 minute warm up. On the second test I shut down the burner after the safety lifted and refilled the fuel. That run lasted 32 minutes before running out of water. I think with a full water fill, it should go 35 minutes and run out of fuel. That will be good.

The wheels turn at about 160 RPM, the engine about 680 RPM. That works out to about 1 foot per second. The throttle does not control speed very well; it's basically on or off. We'll see how it works on the track.

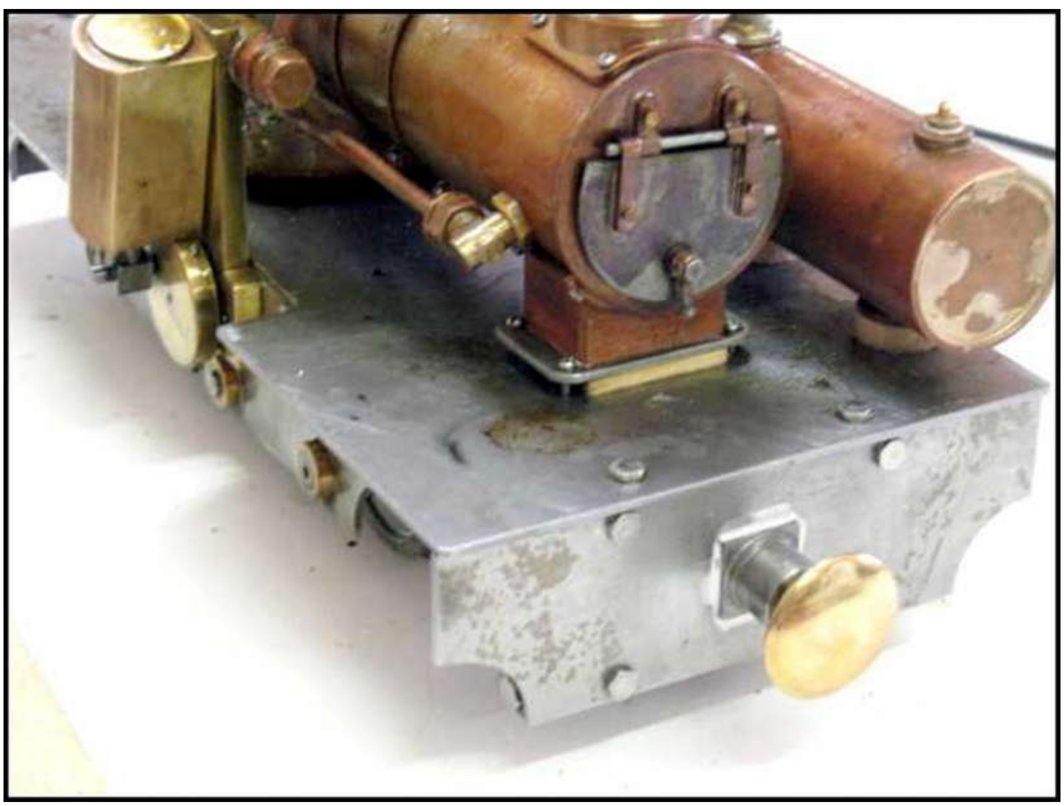
Nina will make its public debut at our next steam up on 2 Oct. Hopefully, since it runs on the rollers, it should run on the track.

There are some modifications to do before then. They include insulating the boiler from the frame, insulating the lubricator from the boiler and a little change to the burner. Getting nervous again… (See comments [C-45 & 46])

Before heading out the track, we need to do a few important modifications. The first two are critical, the others are optional.

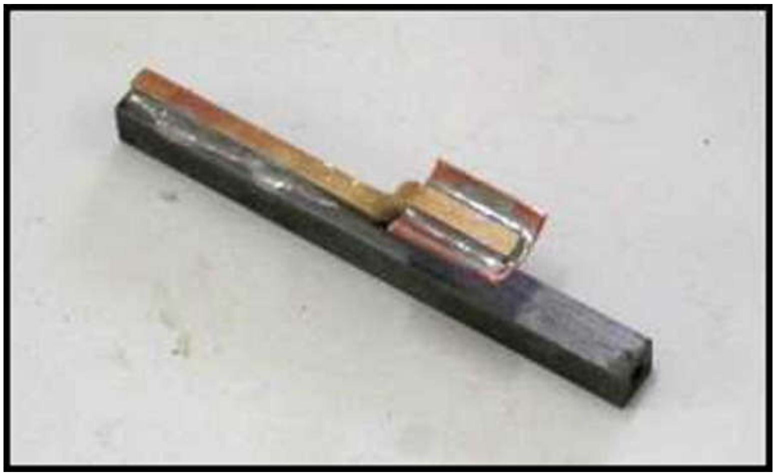
The first modification is to the burner. The original mounting collar places the burner in the middle of the flue. This is no good. There is not enough space at the top for the burner to operate correctly. Chuck the burner assembly in the 3-jaw and turn the mounting collar off. Fabricate and solder a new collar that sets the burner as low in the flue as possible.

Next insulate the boiler from the chassis. Use some 1/8" thick strips of wood under the boiler barrel and smoke box. Use a strip of wood under the footplate as a washer, so the boiler mounting screws don't transfer heat:

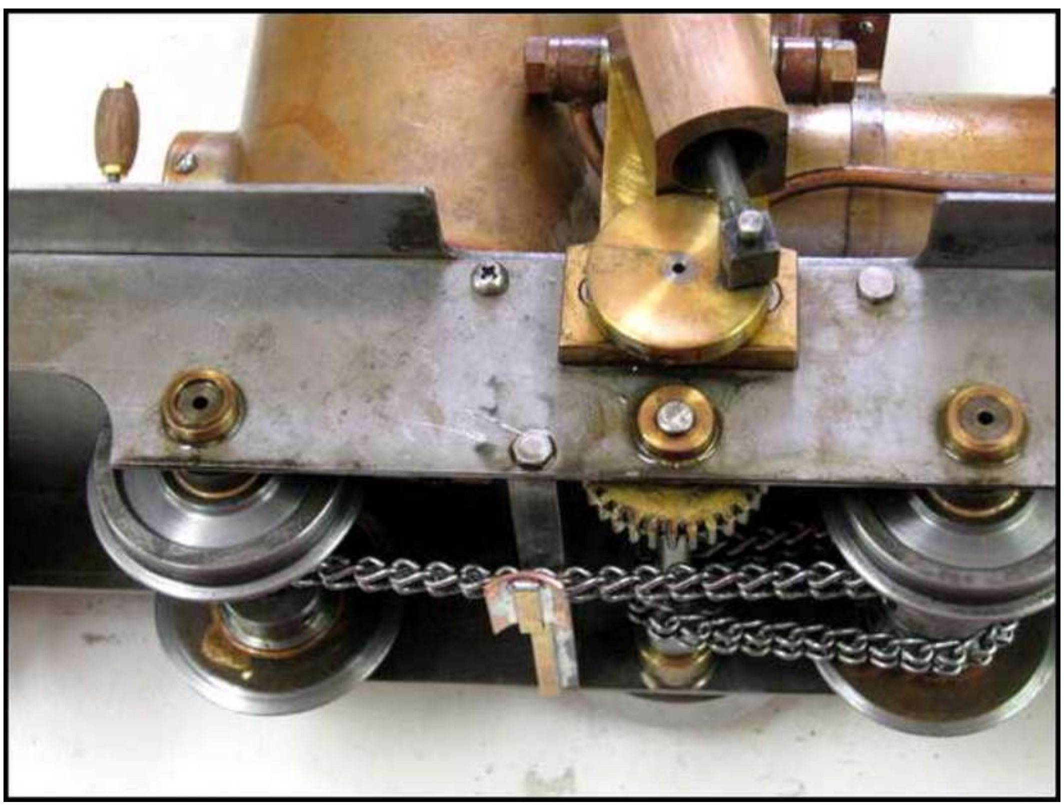


These fixes make a big difference. The burner is much easier to light. It pops on right away. Now you can crank the gas valve wide open and really get the burner going. Before, too much gas would blow the fire out. The run time on the fuel tank drops to about 25 minutes, but the increased fuel make the boiler steam much better. The insulation keeps the chassis cool to the touch. You can hold the engine in your bare hands for an entire run.

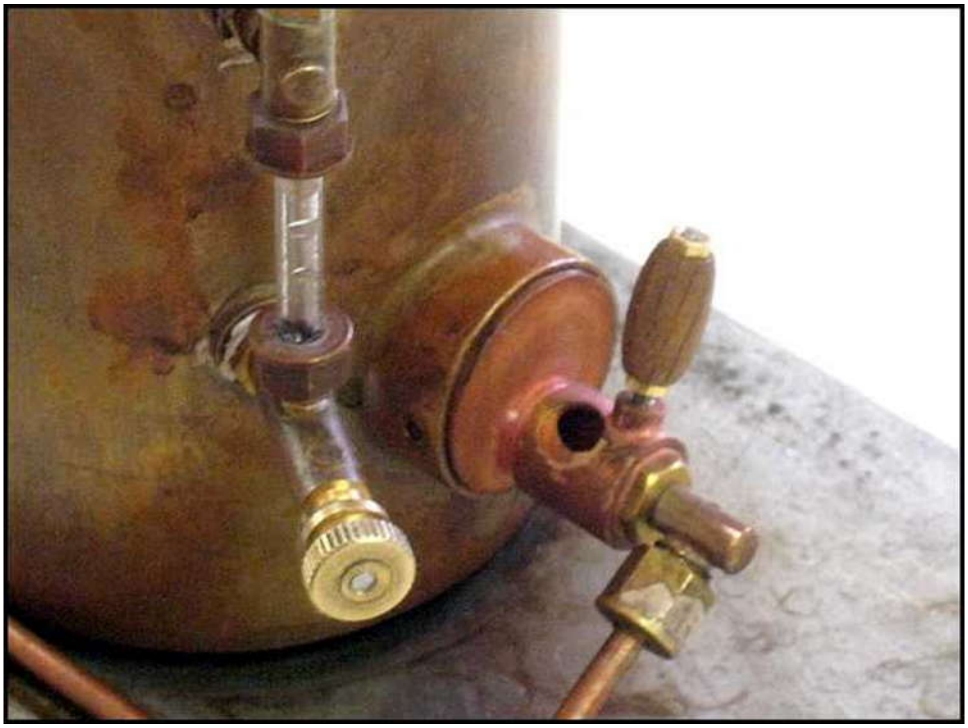
The next fix is on the drive chain between the axles. Ladder chain stretches. There is a worry that the chain could hang up in a switch and derail the engine. Remove the lower center frame stretcher and fabricate a little chain hanger from a section of smooth copper pipe and bend brass strip. Soft solder or screw the assembly to the stretcher:



That should keep the chain from dragging in the sleepers. While you are in there, change out the machine screws with some model hex head bolts.



The last thing is to make an air choke for the burner. It's a collar with a 1/4" hole drilled crosswise to match the mixer holes on the burner. Silver-solder a threaded stud to accept a 2-56 locking grub. Make a sexy wooden handle so the fingers don't get burned.



At first I thought the choke would be a cute, but un-necessary gadget. It turns out to be very handy. The choke takes out the annoying whistle and jet engine sound while the fuel tank burns down and the boiler warms up. While running, open up the air and get the burner rocking.

Now for the debut run. Service the engine in the usual fashion. Lubricate all bearing surfaces. Put about 5-ml real steam oil in the lubricator. Fill the boiler to the very top with fresh distilled water. Withdraw about 45-ml. It will appear as a full glass on the water gauge. Close the throttle. Charge the fuel tank and light up. After about 9 minutes, she'll be ready to go. Set switches on the track for the mainline and wait for a green light from dispatch. Open the throttle about 1/2 to 2/3. As you look at the flywheel, give it a spin clockwise, top of the flywheel going to the rear of the engine. Get out of the way or get run over.

YouTube Video: Nina Test Run Pt.-1

YouTube Video: Nina Test Run Pt.-2

YouTube Video: Nina Test Run Pt.-3

YouTube Video: Nina Test Run Pt.-4

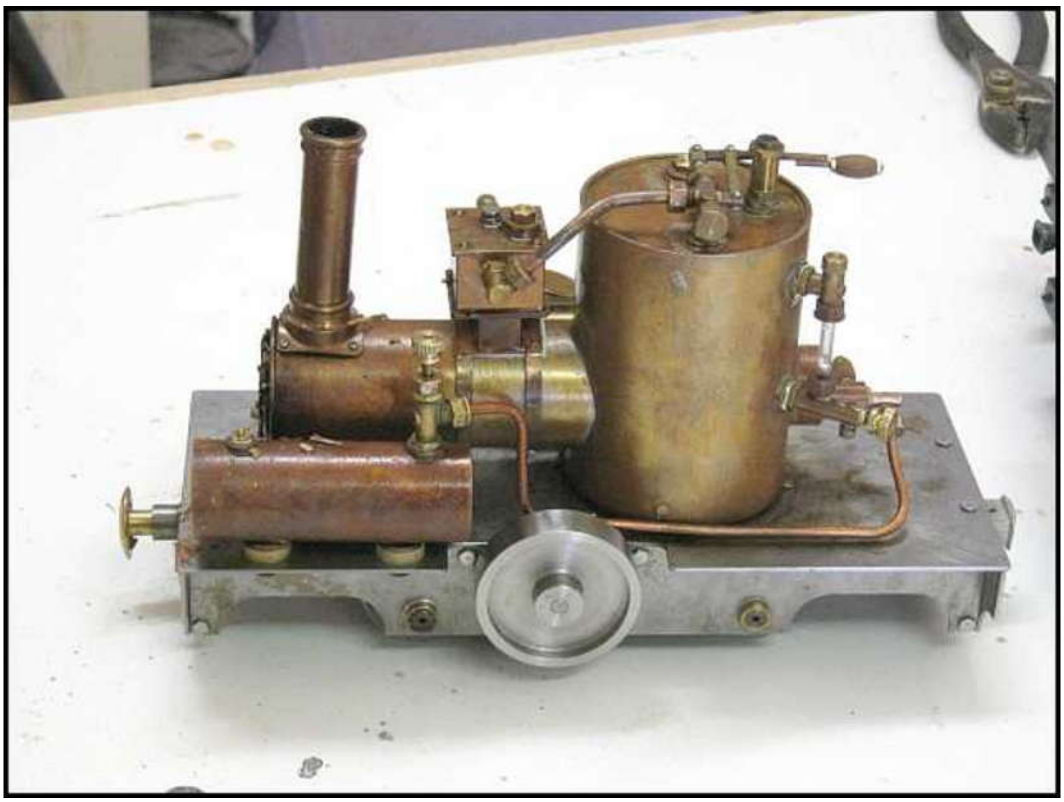
YouTube Video: Nina Test Run Pt.-5

It took 2 runs to learn how to run it and understand the quirks. After the learning curve Nina ran strong and smooth. It's a real messy engine at the start. Lots of water and oil splatter, but calms down quickly. I did not time it, but the run times were about 15 to 17 minutes without refilling the tank. It ran out of fuel before running out of water.

Overall, a great run day. I'm happy. Next time, we will work on a cab, some finishing details, paint and wrap this project up.

I have not forgotten, lost interest or quit the Nina project. It's just been getting run hard over the past 2 months. There's been a bit of a learning curve to running the engine, but I've got it down now. A run lasts 25 to 27 minutes and gets 12+ laps on our club's 300-foot mainline track. After building pressure, I shut down the burner and refill the fuel tank. The air choke on the burner is a very big help. It does a good job adjusting the air so the burner runs silent. Now that the motor is "broke in" and running very smooth, there is a lot more response in the throttle. Half throttle on long straights and full throttle on curves and grades. No sitting back munching on a cheeseburger, you have to follow this baby and "drive it".

Yesterday was a steam up and Nina got three long strong runs. On the 3rd run the engine had a catastrophic derail on a bridge and crashed hard to the ground. The crew escaped injury. The fire stayed lit, so I set it back on the track and finished the run. No damage other then a bent smokestack.



I don't like the new "aerodynamic" look, so that will get repaired.

Yesterday was quite humid in the morning, so the steam plumes were gorgeous.

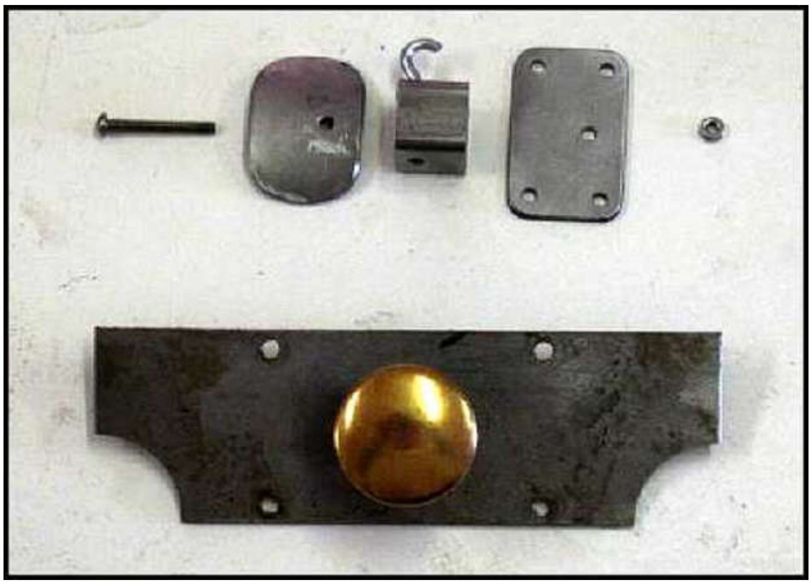
I am thinking about placing an order to clock parts supplier for some more watch bearings. Get the next 2 or 3 sizes up and experiment more with the burner.

Nina is going in to the shop next week for repairs, cosmetics and paint. Next steam run is 8 Jan. Little sweetheart should be in new shoes by then.

Took “Nina” off line last week to finally get it finished up. After a few months of successful running, it’s time to get this project wrapped up and move on to the next.

First thing to do is change out the front buffer; it’s not the correct type. Nina is more along the lines of a Welsh mining loco, so it needs a “chain and hook” style front coupler/buffer. Even though the front coupler will not get used, it still needs to look the part. The “link and pin” coupler on the back will stay.

The front coupler parts are from 1/16” steel plate, 1/2" square tubing and a small eyelet. Saw, grind and file everything to shape. Whatever shapes and styles you like.

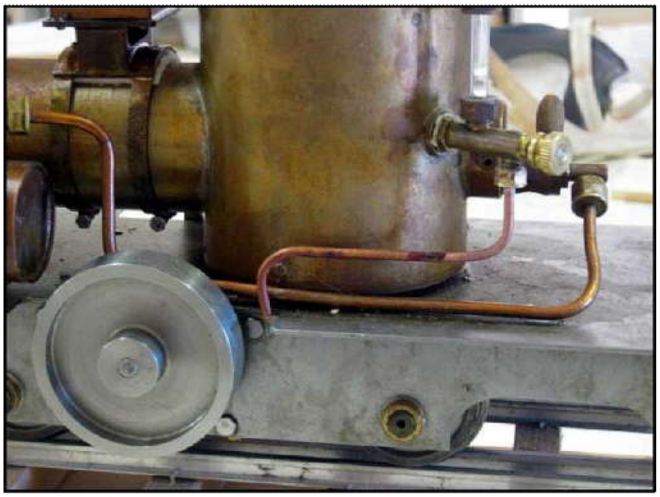


The coupler parts are held together with a single #2-56 screw and soft soldered together. Sweat off the old coupler. Drill for some #2-56 model hex head bolts and bolt to the front pilot frame.

That looks a lot better.

Next is a decorative brass band to go around the horizontal boiler shell. There are no other decorations on this engine, so we need to have something for the crew to polish. I am thinking about painting the boiler gloss black, with a flat black smoke box. The brass band will separate the two colors. Fabricate the band in the same manner as the bands used on the lubricator.

The water gauge lower end needs a drain tube for the blow down. Right now it just blows down on to the footplate and makes a mess. Fabricate a drain tube from 3/32" OD, 1/16" ID tube. Use 1/4" hex brass to make the #10-32 union nut. Run the drain either thru the footplate or out the side. After all the plumbing we've done so far, this job is a snap.



The gas and drain plumbing looks "Rube Goldberg", but the cab will cover up most of it.

Now for the cab, Nina's cab very loosely follows Welsh narrow gauge practice. It is a wooden cab, open top, opening out to the rear. The strategy is to laminate decorative wooden strips over a shell of model aircraft plywood. Installation is with #2-56 machine screws thru the footplate.

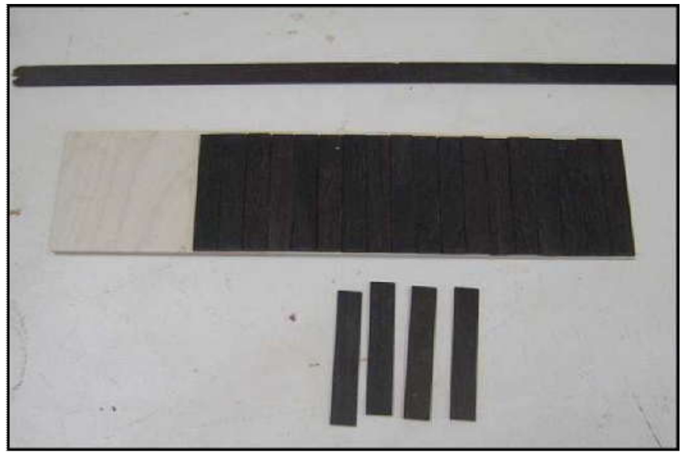
The decorative wood for Nina's cab is Cocobolo. Cocobolo is a tropical hardwood from Central America, similar to Rosewood. Fresh cut it is darker brown in color, but over time turns even darker. This 1/16" thick piece I have was cut 20 years ago and is nearly black now. Almost looks like ebony.

Tropical hardwoods are absolutely gorgeous and well worth the extra work to finish them. Most tropical hardwoods contain a lot of oil. Before gluing, completely wipe down the surface of the wood with alcohol or lacquer thinner to clean off the oil. Glue immediately with Titebond III. Other glues are chemically different and may not work.

Cocobolo is so hard you can use the same techniques as brass polishing to get it shiny as glass. Sand to 1500 grit, polish with pumice and water, rottenstone and oil next and finish up with "Brasso". Get out the supplies and make with the elbow grease. 400 grit sanding makes a nice finish too, or you can go all the way. Remember; complete finishing the decorative wood before cutting it up, it's a lot easier to finish one big piece than a zillion little ones.

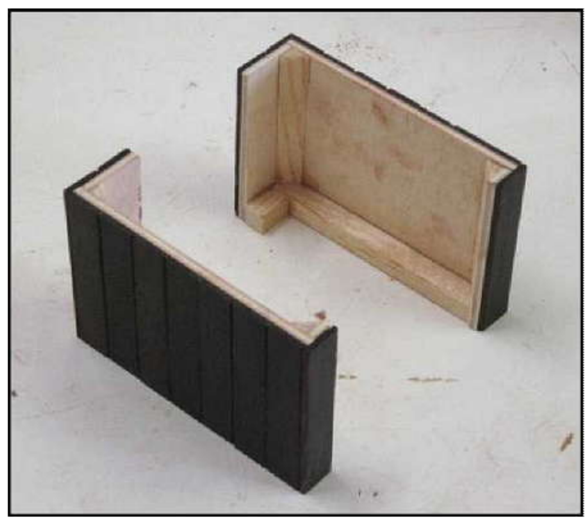
Fine sawdust from Cocobolo is toxic. If you breathe it in, it will feel like a steel wire brush going down your throat. Wear a good mask, and open the windows.

Cut strips and glue to the model aircraft plywood to form the sides.

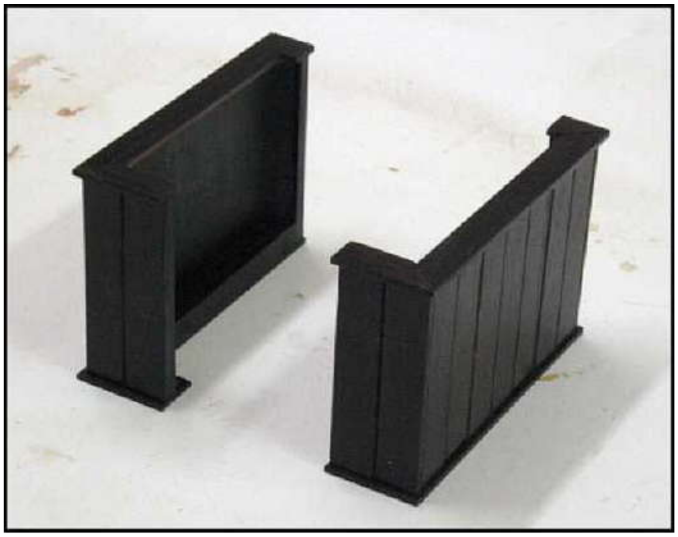


Cut some poplar strips for corner gussets and attachment gussets along the bottom.

Glue some plywood panels on the front and back. Glue strip wood over that.



Miter cut some strip wood for caps on the top and bottom.



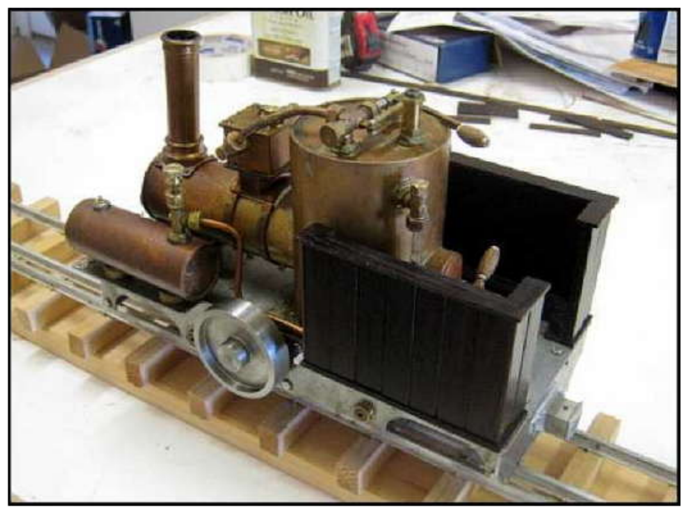
Take a very very light skim cut on the table saw or disk sander to true the bottom edge of the cab. Paint the interior flat black. Drill some holes along the bottom gusset for #2-56 machine screws to attach the cab to the footplate.

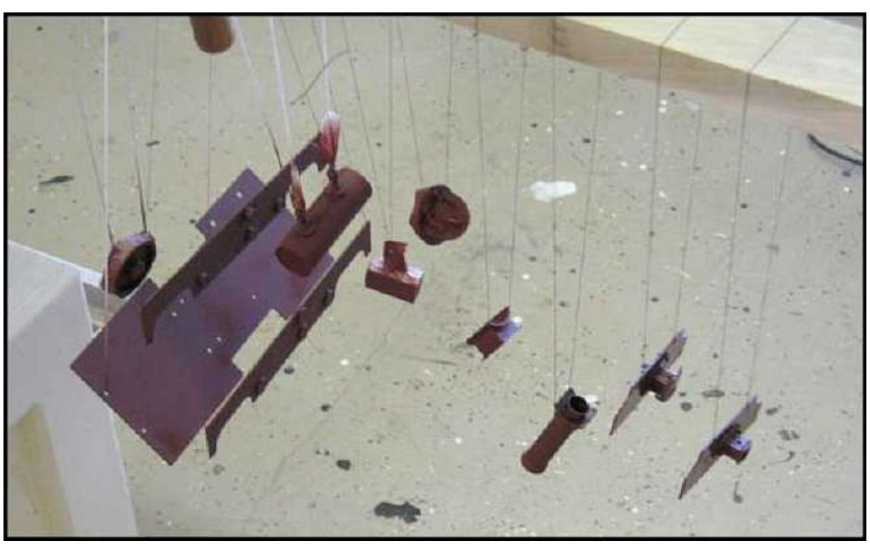
Finish the cab with a furniture oil rub down. Shellac, varnish and poly-urethane do not work on tropical hardwoods. Too much oil in the wood. They will just peal off in a few weeks.

Set the cab on the footplate for a prelim look.

Looks pretty good. The camera does not do justice to the Cocobolo wood. It is gorgeous.

That's it for now. Next time the engine gets blown apart for paint and final wrap up. (See comments [C-46 & 47])





Before disassembling the engine for paint, I had to fix the bent smokestack from the fall. A few bashes with a mallet fixed that. It looks better.

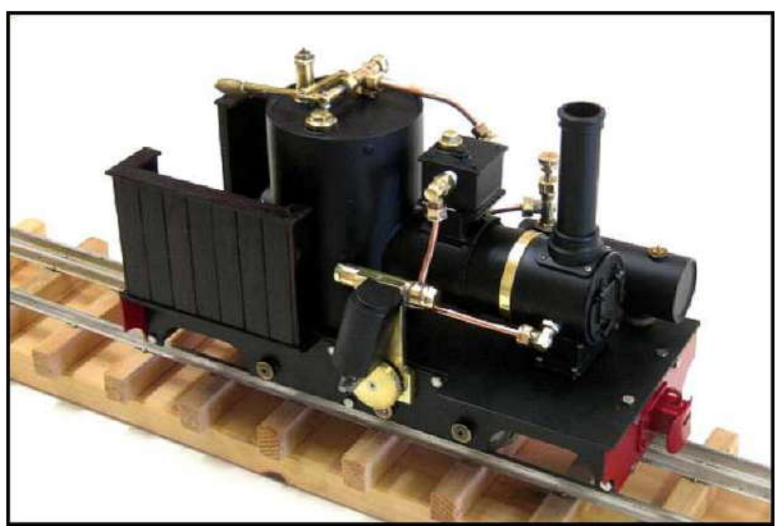
Time to disassemble the engine for final cleaning and painting. I clean everything first in lacquer thinner then hot soapy water. Don't' know if two cleaning steps really matter. It's just a habit.

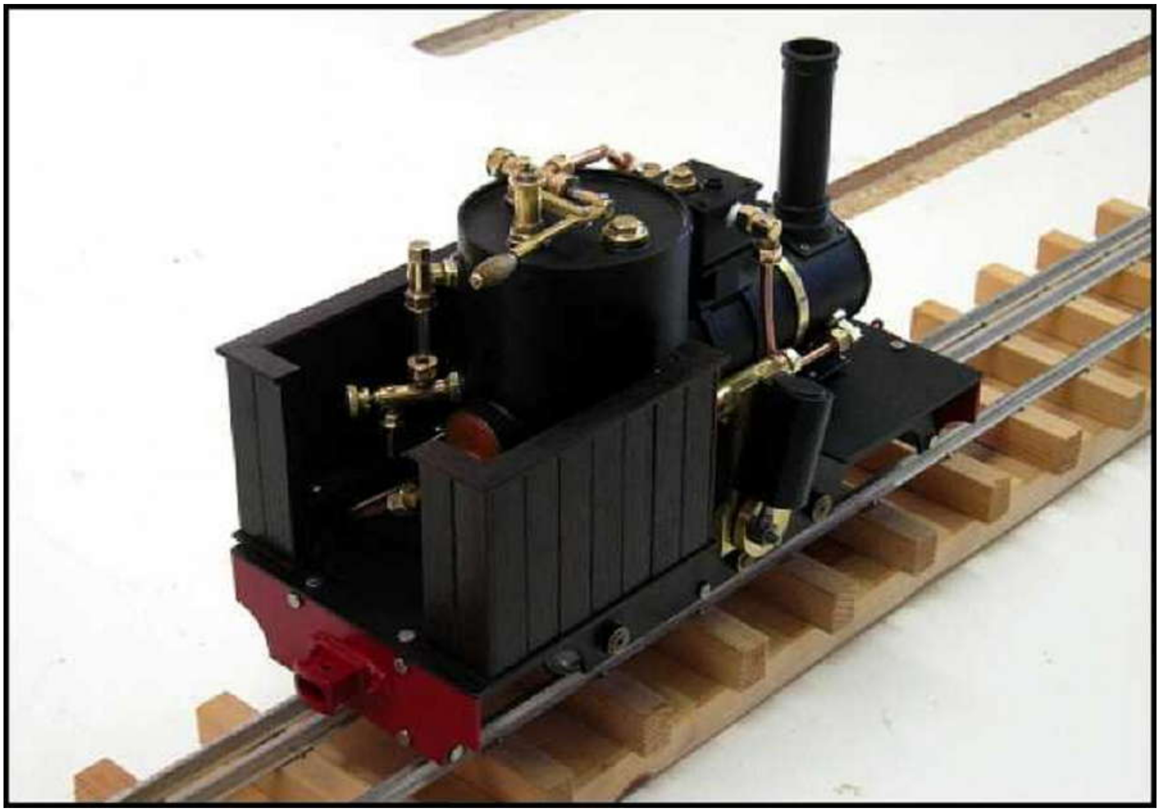
I really hate painting. I just want this part over. Get all the machined surfaces masked with tape and attach some means to hold the parts while painting. I just painted everything with "Rust-Oleum" rattle can paint. Red Oxide primer to start off.

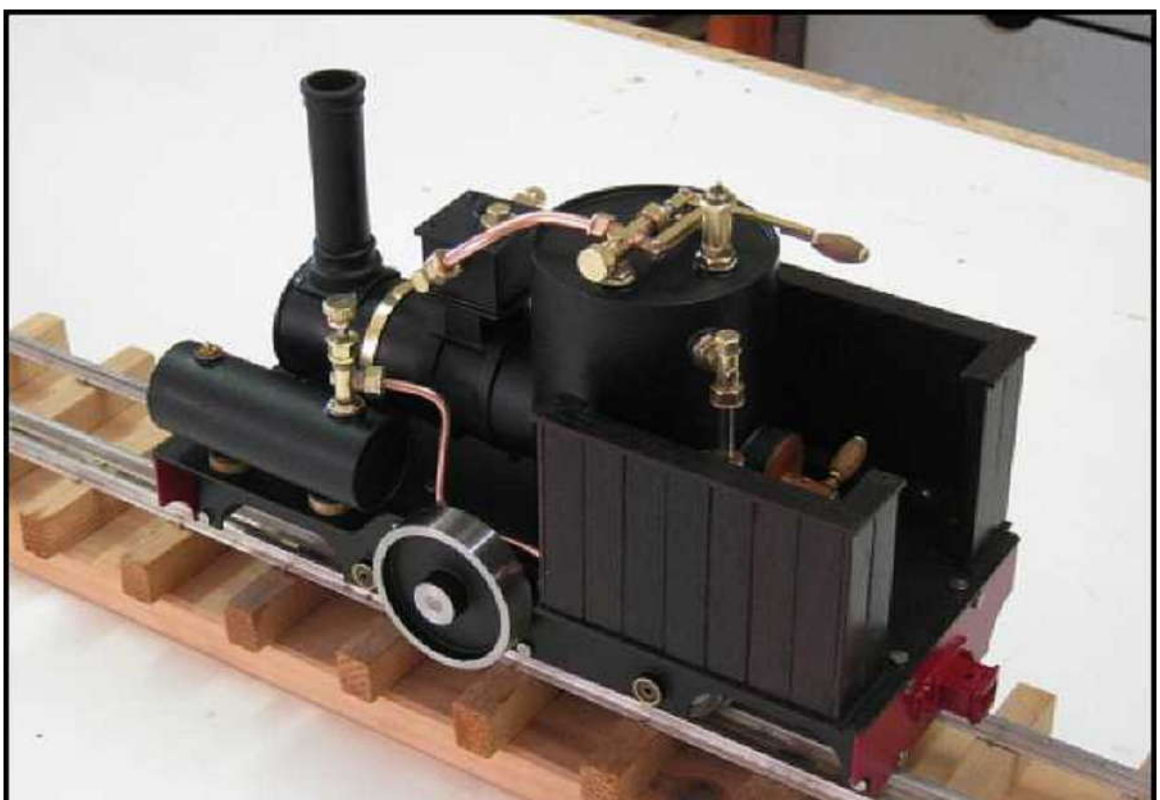
The original intent was gloss black with flat black smoke box. It quickly became evident that gloss black would look too toy like. So everything went flat black. The end sills and couplers got dark red with a coat of flat clear.

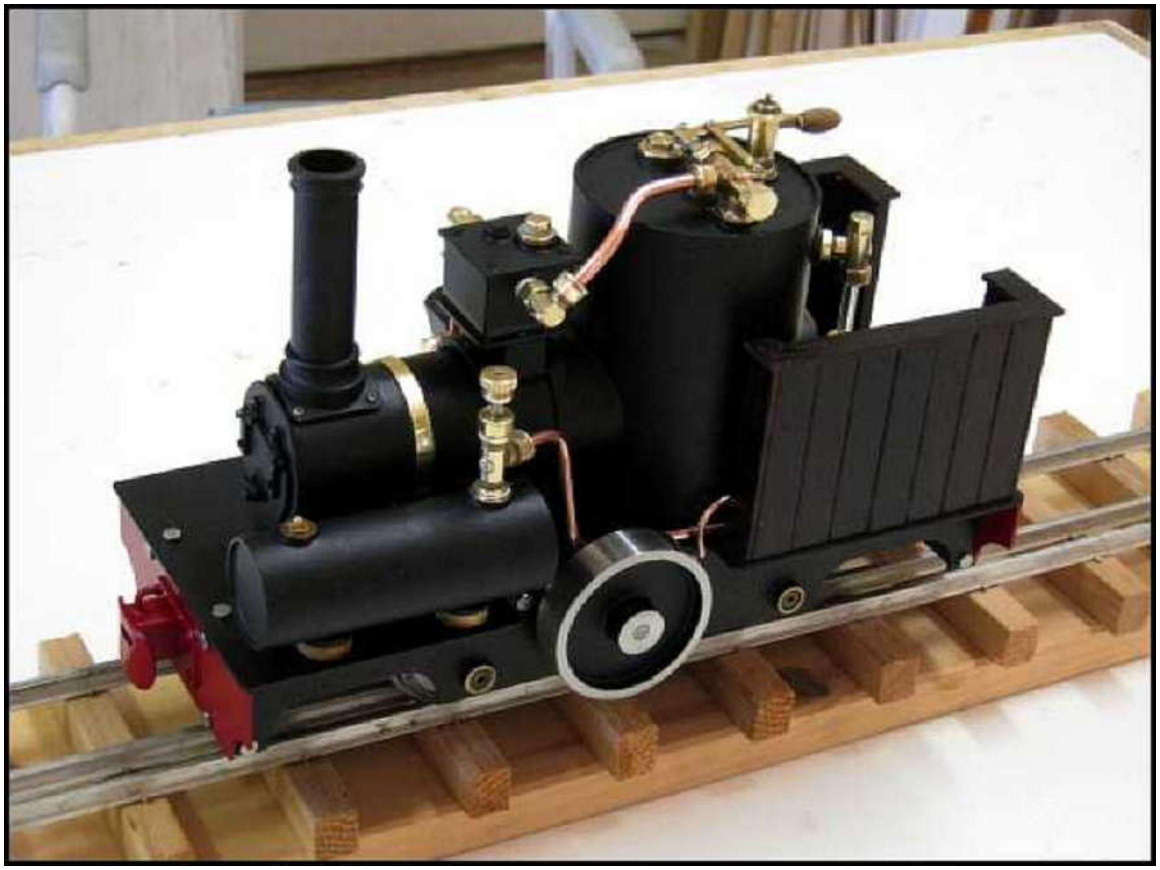
Next is getting on the brass and copper. By now everything is really tarnished and has discoloration from silver soldering. Run everything over the buffing wheel with some fine rouge compound. That will get it most of the way there. Get out the Brasso and have at it. It's a lot of work, but certainly worth the effort.

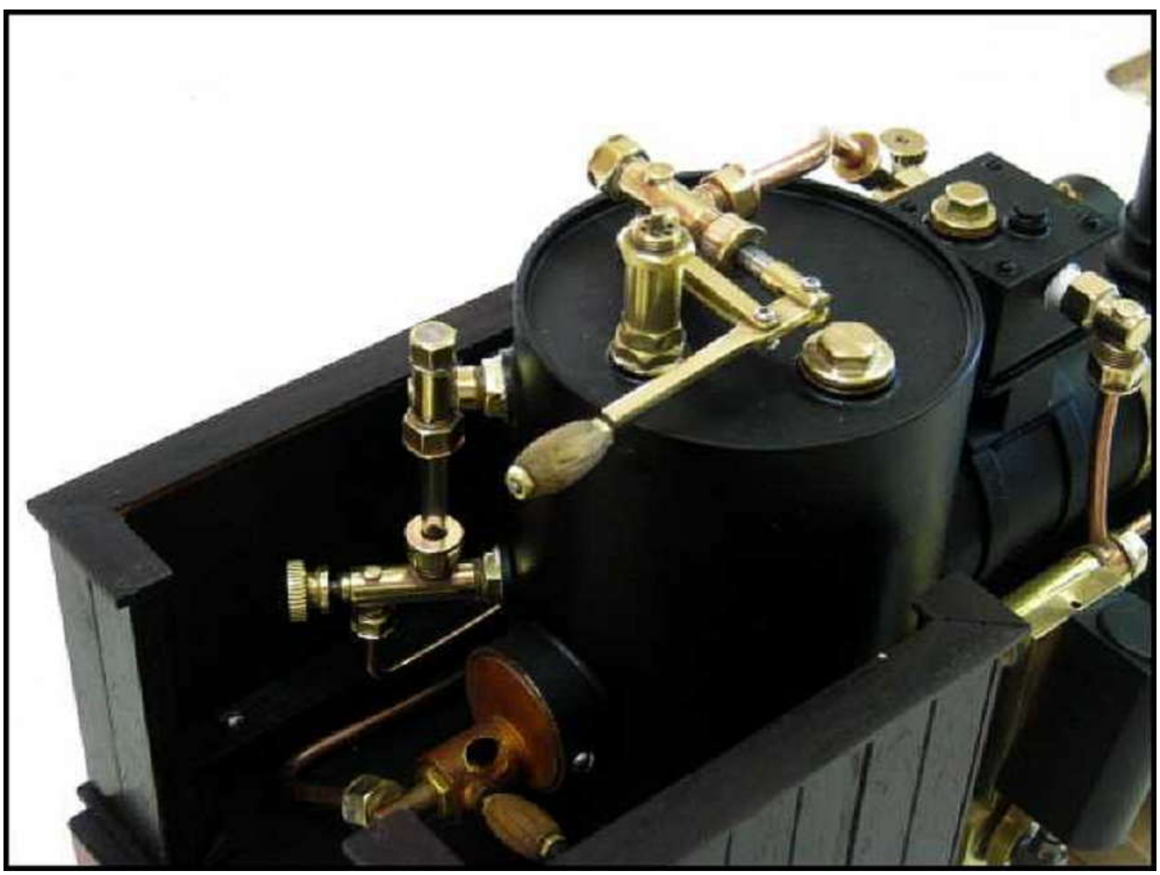
Re-assemble everything and attach the cab. And with that Nina is all done.











The boiler steams fine. The lubricator does the job. The safety valve is very reliable. The water gauge works perfectly and blows down just right for an accurate reading. The throttle is a good design too. The burner works OK. I am going to experiment with some different jets. I ordered some 0.25mm and 0.30mm watch bearings and will them a try.

Looking back at it, the only thing I would do different build a double acting motor. While the single works fine, a double would just be better. The way the engine is set up, changing out the cylinder would not be difficult to do. Redesign the engine standard and cylinder. Use the existing crankshaft and modify the steam pipe. I would also make the rear foot plate and cab about 1/2" or more wider. The back looks too narrow.

Thanks for all the kind comments, words of encouragement and those who stopped by for a look along the way. Almost 24,000 "reads" on this article. I very much appreciate your interest in the project.

Comments & Answers To Questions Posed

C-1 – Larry Newman: 22 Feb 2010 02:28 PM

NICE SAVE!`

C-2 – Winn Erdman: 24 Feb 2010 05:40 PM

Would it be any fun if we always did things right the first time? Nice work, Bob.

C-3 – Larry Green: 25 Feb 2010 07:29 AM

We all experience these little "miscalculations". Learning how to work around them is what makes the craftsman. As long as it isn't posted here with great photos and text, who is to know? Keep it up Bob--this is turning out to be a great thread to encourage others to try scratch building for the first time. BTW, how old is your Atlas lathe?

R – Bob Sorenson: 25 Feb 2010 10:37 AM

I was really sweating “brass tacks” on that gear fix. But everything turned out fine and the project continues smoothly. Hopefully that will be the only glitch.

Larry: My Atlas is the newer version with the square headstock. I bought this one new in 1978.

C-4 – Havoc: 26 Feb 2010 04:42 AM

I would like to put forward a different way of making the wheels. As you did it Bob you can't be sure that all wheels end up the same as you have to reset your slide between each wheel. Certainly not if you have to grind your tool or change a tool.

- Turn the wheels roughly to size (1mm oversize) and then in the lathe drill the blank.
- Ream the blanks.
- Put a piece of metal that at one side has a center point for your tailstock center and that slides over the axle diameter you'll use.
- Put another piece of metal in the chuck and now turn a stub that just fit your wheel blanks and sticks out long enough so that with the previous piece you can push with the tailstock center against your wheel.
- Now each time turn all blanks to profile, one step at a time so you do not have to reset the slide between wheels.
- Turn the back flat.
- Put the backside angle of the flange.
- Turn the front side angle of the flange.
- Turn the cone on the wheel.
- Bring the cone to final diameter.

R – Bob Sorenson: 27 Feb 2010 08:15 PM

Havoc’s method of turning wheels is “more correct” than what I did. I was being lazy and using the hub for a chucking spigot. If you ever turn regular disc wheels, you will have to use Havoc’s method.

C5 – Havoc: 28 Feb 2010 04:30 AM

I hope I'm not too late: did you provide a little flat on the axle for the grub screw? Otherwise you can have the issue that once you tighten the grub screws that a bit later you cannot get anything off the axles. The grub screw bites in the axle and raises the metal around it a bit. If your holes are a good fit it becomes impossible to take it apart. I know because I can't take my cracker apart anymore because of this...

R – Bob Sorenson: 28 Feb 2010 12:00 PM

Havoc: That's a good idea. These setscrews are cup point style and are starting to ding up the axles. Next time they are out I will do that.

C-6 Havoc: 05 Mar 2010 04:33 AM
Once you have one you will find that you do more milling than turning. A mill is a better investment than a pillar drill and XY table. Not only can you use it to drill holes, but all the squaring of plate you did, the thinning and the contouring of your support would be possible in 1 single clamping to the mill table.
R – Bob

C-7 Henner Meinhold: 15 Mar 2010 09:04 PM
Bob, this is really funny. I don't have problems with 1/2" reamers. I always get a mirror-like surface, even wit a small Sherline . On the other hand, I have never managed to make a decent rivet connection. They are either loose, look horrible or both! BTW, in a German forum I read about another trick to get a smooth bore for a cylinder: Finish slightly undersized and then press the greased ball of a ball bearing through. I have not tried this yet, but it seems to work well.
R – Bob Sorenson: 16 Mar 2010 10:52 AM
It may be the ream too. It's not a good quality. I need to invest in a good set. The ball bearing trick sounds interesting. That would eliminate the problem of a tapered bore. I will give that a try.

Thanks Henner: What's the link to the German site? These handy translators let you see what more folks are doing.

C-8 Henner Meinhold: 17 Mar 2010 09:24 PM
Bob, the link is:
http://www.buntbahn.de/modellbau/vi...gel#230824

Also check out: Some pretty amazing scratch built locos.
http://www.buntbahn.de/modellbau/vi...m.php?f=23
C-9 Eric Maschwitz: 17 Mar 2010 11:48 PM
There are some really amazing scratch built engines on there like this one made by some guy named "Henry"... ...wait a minute, Henry......Henner.........hmmmmm. ;-)
R – Bob Sorenson: 21 Mar 2010 04:12 PM
Henner, Eric: Thanks for those links. That website is like opening up a bunch of Christmas present. And all you have to do is "read the pictures".

C-10 Cap'nBill: 03 May 2010 08:15 AM
I've picked up a lot of little tips for machining! Especially like the collets for the lathe! Questions: First time I've seen piston with no ring, what kind of clearance allows this to work? Hope to see some pics of the soldering process. When I built my stationary boiler with 3" copper, I found that using my Mapp gas torch, the only way I could get enough heat was to 'bury' the tube in a BBQ starter 'bucket', adding a blower to the charcoal, and then apply the torch where I was soldering.
R – Bob Sorenson: 03 May 2010 10:56 AM
Bill: The clearance is on the order of 0.002". The reason I say that is because I built an engine once and used ordinary solid bronze bearings as cylinder sleeves. The piston was ground stainless. That was the tolerance according to the bearing specs. For this engine, it was all trial and error fit. I used the boring bar until the fit was "medium" then the lapping bar got the burrs out and it was an "easy" fit.

The boiler is all soldered up and awaiting pressure test. The next write up will have all that.

C-11 Kent Killam: 05 May 2010 09:39 PM

Bob, I have enjoyed reading this thread, and I loved the last post. Your back ground on solder, torches and flux, followed by step-by-step instructions make the thought boiler making less daunting. Can't wait for the next installment of "As the Boiler Builds".

C-12 Henner Meinhold: 05 May 2010 09:45 PM

Bob, your thread is really great. It is interesting, how different techniques yield the same results. Here my 2 cents:

1. I use 3 little dents on the boiler shell from a center punch to keep the end plates from sliding.
2. To stop solder from flowing into unwanted areas use ordinary White Out.
3. Break corners of e.g. boiler end plates; otherwise the solder refuses to penetrate the gap.
4. I prefer citric acid (available from McMaster or home brew shops). It works well and is much safer. With sulphuric acid your clothes will always develop tiny holes after a couple of days.

Keep the pictures coming!

R – Bob Sorenson: 06 May 2010 04:47 PM

Kent: As a tease, the boiler is all done and awaiting pressure test. It's getting exciting.

Henner:

1. I should have thought of that.
2. I will try that next time. I also heard pencil lead (graphite) works too. Forgot to try it this time.
3. I did break the corners. Forgot to mention that. There is a very slight chamfer on both sides. In fact, all sharp corners in contact with solder got knocked down with a file.
4. I saw the citric acid on McMaster-Carr. I will get some on the next order. What ratio do you mix it?

C-13 Cap'nBill: 04 Jun 2010 01:37 PM

As much as I enjoy watching your build, Bob, I look forward to learning some new machining technique! In the process of making a' boring tool' out of one of my old mower shafts..........I save this old junk. Keep building, and I'll keep learning!

C-14 Richard Kapuaala: 04 Jun 2010 01:45 PM

Man, that is sweeeet. I especially like the way you set up the fly cutter on the lathe it really puts meaning in the old saying 'there's more than one way to skin a cat'… even though the prospects of skinning a cat kind of creeps me out.

R- Bob Sorenson: 06 Jun 2010 04:31 PM

Bill, Richard: Thanks. One of the amazing things about the old school Brit builders is how they could squeeze so much capability out of limited machinery. All of these ideas came from them. After playing around with the fly-cutter, I am thinking about investing in a regular boring head.

C-15 Henner Meinhold: 07 Jun 2010 01:51 PM

Bob, it is always a delight to see the next chapter of your progress with Nina. Your way of doing things will definitely add to my arsenal of procedures 🙂. However, one thing is kind of funny: So far almost all of the replies came from the "usual suspects". Do the "buy and run" guys think scratch building is for the "poor", who cannot afford to buy a "real" locomotive or should you have started a big 4-10-4 to get their attention? I personally like to buy tools, design something and then build it. The finished product is much nearer to my heart than anything I purchased (OK, sometimes I cave in and buy an Accucraft loco...). I guess, you are in the same boat. So, why is the response to your excellent thread comparatively meager?

R- Bob Sorenson: 10 Jun 2010 02:38 PM

Thanks Henner. More important then actually building this engine is that, hopefully, folks can pick up a few useful tips for their shop. I like building my own because simply because of the satisfaction of figuring them out, coming up with the steps to do the work and seeing the progress. Plus the result is far better in quality then anything you can buy. They are designed and built right. This engine will run perfectly for years to come. And, honestly, there are some "bragging rights" that come along with building your own.

Scratch building is not necessarily a poor man's hobby. Most scratch builders know that by the time they buy materials and tools, they could have bought the same item for nearly the same price. Especially on the first engine, if you have to buy the lathe just to start. Most of Nina is from leftover material and existing tooling, but there is still a $$ investment in it. If I bought all the materials and the little tooling, I would have come in cheaper just buying a Regner Konrad or a Berkley Cricket.

Can't wait to get this baby on the track and start on the next project.

C-16 benny2.0: 11 Jun 2010 01:59 PM

I would rather make something from scratch them by some off the shelf "cookie cutter". You find that a lot with motorcycles and cars. I love to have things that no one else has. I love when people ask me "where did you by that" and I tell them "I fabricated it". When are we going to see some video.

C-17 Rodney: 11 Jun 2010 03:04 PM

Bob, I have followed along with you on this and have learned a few thing along the way. Your work is outstanding. It's amazing you have done all the machining without a mill. I've been around live steam for the last 5 years and I recently bought a Accucraft Forney. This winter I want to start on a loco. I have Kozo's book on "Building The New Shay" and a friend, Richard Snyder (R Snyder on the forum) has his Climax book. Before starting any building on loco, I going to try to cut the Climax gears and see if I can do it. May have a local shop custom CNC grind the cutter for them. That would be one variable I would not have to deal with. I have a 8 inch import rotary table. Need to make or buy the indexing plates for it though. I also have a tilting table that the rotary table will fit on, so I think I have about everything I need.

I will agree about what you said about the cost of tools and materials. I look at it that if I can buy the tools and materials for the cost of a loco and then all I have is time in it, I think I'm farther ahead cause when done I have the tools still and the next one will be cheaper.

R – Bob Sorenson:

Videos will come in September. Our local live steam group is off for the summer and we get back together 4 Sept. There will be a secret test run at an undisclosed location before.

I have a mill and have been using it, but only as a drill press. It helps to have the X-Y table to quickly move from one hole to the next without having to set up each time.

Check out Mr. Dean William's website. He's got a great class on gear cutting. You should make your own cutters, it can be done. I have worked with both water hardening and oil hardening tool steel. Both cut very well and are easy to harden and temper. Oil hardening steel is more forgiving to harden. Both temper well in salad oil, just like Kozo does it. Use a candy thermometer for tempering. Kozo's flour and water method is for cooks. Kozo's gears are not true involute so they are going to slip over each other anyway. If they are off a bit and have some backlash, they will still work. Plus you could run them in with some fine lapping compound to work out kinks.

Ed Hume, who used to post around here, did a Kozo Climax in Gauge 1 narrow gauge using a scale of 1mm = 1/32". If you could get a hold of Ed, he'd get you pointed in the right direction.

C-18 Rodney: 14 Jun 2010 01:28 AM

Bob, OK I will give cutting the cutter a try. Where do I get the tool steel?? Thanks for Dean's website. The locos I want to build will be 20.3 narrow gauge also and will try to get a hold of Ed. Thank again for this informative build, cause I need to learn how to do this stuff.

R – Bob Sorenson: 14 Jun 2010 11:43 AM

Rod: I have done business with 4 online metal suppliers. All are good outfits.

McMaster Carr

Metal Express

Online Metals (do a search on "tool steel")

Speedy Metals

C-19 Cap’nBill: 28 Jun 2010 07:13 AM

Couple questions for you, Bob: I noticed in your lubricator, you drill a #60 hole in the inlet/outlet...is that all that's needed to transfer condensate/oil? Also, I see an end mill (?) in the tool post where you’ve bored the 1 x1. I hadn't seen that technique. Lastly, your engine reminds me of one of the earliest Climax engines.... Seattle Car Co. 101. Decided on a finish mode yet?

R – Bob Sorenson: 28 Jun 2010 05:04 PM

Hi Bill. The hole for the lubricator is very small. #60 is on the high end. This one would be OK down to a #72. Many of them even have a needle valve adjustment. A friend of mine who oversees my work showed me the end mill as a boring bar trick. It works great. The style of this engine is going to be old UK, 2 foot quarry engine. Open cab, made from some Hawaiian Koa leftovers. Here's 2 ideas:

This one is a modified Regner Konrad by Rob Bennett in the UK.

I do not have the name of the owner of this engine named "Sir Arthur". It is a modified Regner "Lumber Jack"

C-20 Cap’nBill: 01 Jul 2010 05:29 PM

Boy! Sure hope she's goin' to have a whistle! Actually, I just want to see one built. I need to practice making the 'D' bits.... didn’t have much luck making one last try.

R – Bob Sorenson: 03 Jul 2010 03:49 PM

Bill: No whistle planned for this one. But, maybe, we'll see.

C-21 Jason Kovac: 03 Jul 2010 04:00 PM

I like the idea of making the union nuts that way; I have always drilled and finished with a D bit and bottom tap. A real pain in the ass. Looking goot I need to get back to the Idris, work takes up too much time

C-22 Henner Meinhold: 04 Jul 2010 04:33 PM

Bob, I like the way you make the water gauge. I think I will pick up your idea and replace some of my old ones with your design. If it were not for the stupid day job....

C-23 jgallaway81: 05 Jul 2010 10:02 AM

WOW!!!! I'm always impressed with the skill the people on this forum display. Its actually intimidating to see the finished product, because it seems that no one ever seems to make a mistake.

Anyways, I have a couple questions... 1) What seals the glass to the taps coming off the boiler? I know there are nuts on each end, however I don't understand how you get a water/steam-tight seal? 2) Have you considered a second, larger diameter glass tube that would sit around the nuts? This way if the main glass were to ever break, the second one "should" keep the pieces from flying around. On any locomotive in compliance with the current FRA regs is required to have safety glass surrounding the main water sight glass.

R – Bob Sorenson: 05 Jul 2010 11:16 AM

Jason: I don't remember where I saw that method. It works very well, but a slow process. Bottoming taps don't really get all the way to the bottom and the nuts end up being over long. With 40 TPI thread, you could probably get a nut as short as 5/32".

Henner: On this gauge I learned that it works out better to have the bosses go all the way thru. The silver solder flows completely around the part and makes it solid. It was so much easier to drill and tap. The jam nuts are a new experiment, although LBSC used them sometimes. I think this one will work fine.

jgallaway81: Oh, there are plenty of mistakes; you should see the junk drawer. The glass gets sealed with graphite-impregnated yarn wrapped around and tightened down with the nut. It's the same yarn plumbers used to seal the stem of a faucet. The upper and lower ends get a wrap of Teflon tape before going into the boiler bushings. I have not seen anyone use a second glass on a gauge this small. Commercially made gauges don't have them either as far as I know. Knock on wood; I've not had one break under pressure.

(Note: Teflon® tape — commonly known as "Thread seal tape", "PTFE tape", "tape dope", or "plumber's tape" — is a polytetrafluoroethylene (PTFE) film cut to specified widths for use in sealing pipe threads.)

C-24 Jason Kovac: 05 Jul 2010 04:51 PM

Bob - I have a 2nd bottom tap that has the tip ground all the way to a full thread. Pain that you have to tap 2x but I can get to the full flat. Real pain though still drilling the depth. Usually I end up having to flip around and reface the top to make the thickness there i want it after parting. I mounted a 1" dial indicator to my tail stock for a reference but still its all by eye for setting 0

C-25 Henner Meinhold: 27 Jul 2010 09:52 PM

Hi Bob, making a fork using the parting tool: Another one for the "tips and tricks" folder! Thanks for all your effort with this thread.

C-26 Cap'nBill: 28 Jul 2010 07:54 AM

How many 'fork' type fittings I've made with the Dremel wheel, hack saw, jeweler's saw, and file.....and they never look right. Now we know how to make a professional looking fitting! BTW, Bob, how do you grind your tool for turning stainless? I seem to wind up with burrs and can't quite get a nice smooth finish.

R – Bob Sorenson: 28 Jul 2010 12:25 PM

Hey guys: I really wanted to do the fork from square stock, but did not have any. a 17/64" hole would work for 3/16" square stock. More experimentation need on this technique.

Bill: Alloy #303 stainless steel is free machining and easier to use than regular. I just use a regular sharp steel tool; take light cuts to avoid heat and a lot of oil. Even then I get burring too. The burrs come off with a light rubbing with a fine file and oil. The surface is OK. The best thing is to avoid turning it. Use stainless for shafts and such where the milled surface is good enough.

C-27 Henner Meinhold: 01 Aug 2010 10:25 PM

I would place it inside the open cab and disguise it as a coalbunker.

C-28 Gerald: 25 Aug 2010 07:39 AM

Hi Bob, I was told by one of the manufacturers of model fuel tanks that they are required to test to 350psi. He also suggested that the fill adapter be plumbed in so that it will only allow the tank to be filled to between 2/3 and 3/4 full to allow for expansion.

C-29 Jason Kovac: 25 Aug 2010 09:25 AM

I guess those requirements don’t apply to out little locos as every loco I’ve seen gas fired when you fill the tank until the filler bleeds you get liquid out of the valve. I think if you filler is below your takeoff then you would never have that issue. I’ve yet to see a tank designed in that way.

C-30 Nutz-n-Bolts: 25 Aug 2010 11:22 AM

Remember too, that the filler will stick out into the tank some, so once the liquid meets the bottom of the filler that amount of air/gas is trapped in the tank. Also a longer bushing that extends past the end of the filler could be used to allow for extra expansion room.

C-31 Steve Ciambrone: 25 Aug 2010 02:02 PM

Roundhouse tanks are designed so when they are full there is a space for gas and the liquid does not get into the supply line or burner. This is as simple as having the fill valve attached to the tank and not at the top of a neck portion or above the burner valve. It is really as simple as the correct placement of the fill valve to prevent the issue.

For my engines not designed so, I just turn on the burner valve until I hear only gas, turn it off, wait until the gas is dissipated, then light the burner, stops the flame thrower effect out of the smoke box.

C-32 Chas: 26 Aug 2010 05:50 AM

I started reading this at lunchtime yesterday from the start and just finished it up while waiting for something to finish here at work this morning. Your step by step makes me think that IF I had the equipment I could build a Nina too! Maybe someday! Thanks for sharing this with us....

R – Bob Sorenson: 27 Aug 2010 05:14 PM

Gerald: I looked around for a standard to test Gauge 1 fuel tanks. The only thing I found was a guy who tested to 400PSI simply because he did not have a figure to go by. I wanted to do a little better so I found some published data on gas vapor pressures. After your reply, I looked for another, independent set of data. The two sets I found match. At 110 degrees F, 70/30 butane/propane mix has a pressure of 93 PSI. I think testing to twice that pressure, which is a widely published boiler test standard, is sufficient.

Jason, Steve, Nuts-n-bolts: You are right. You have to let some gas out to purge the liquid; otherwise it's impossible to light.

Hi Chas: How are you doing?

C-33 Gerald: 28 Aug 2010 06:08 PM

Here is some more on Gas

http://www.altenergy.com/PDF%20Files/PropDataPdf.PDF

C-34 Steve Shyvers: 29 Aug 2010 09:10 PM

Bob, One of these days (soon!) I'm going to get a chance to read the entire "Nina" thread. There just doesn't seem to be enough time to keep up with all the really neat projects that everybody's doing.

C-35 Henner Meinhold: 29 Aug 2010 09:21 PM

Bob, in my cylindrical fuel tanks I add a stay. It is probably not necessary, but can't hurt either. When will be the first test run of Nina?

R – Bob Sorenson: 30 Aug 2010 12:13 PM

Gerald: I saw that chart too. It was at the EngineeringToolBox.com website. It was the source for the 200-PSI test pressure.

Steve: Agreed, not enough time to review everything. We'll just have to wait for the "Reader's Digest".

Henner: I don't know when the first run will be. I was hoping for this weekend, but stuff keeps getting slipped. A question for you, I want to order some citric acid for "pickle bath". How do you mix it?

C-36 Henner Meinhold: 30 Aug 2010 08:53 PM

Bob, I just add one tablespoon of citric acid, let it dissolve and add some more, until the solution is saturated - some citric acid powder staying undissolved. You need about 2 tablespoons/quart (wild guess, it's been some time since a made a fresh solution...).

C-37 Richard Jenkins: 31 Aug 2010 12:21 PM

What do you use as a container for the pickle bath for silver soldering? I'm going to be taking my first stab at silver soldering in the next few days, so I'm finding the info about the acid solution very useful, but presumably if I pick the wrong material for the container it could react with the acid and weaken it over time, or worse yet eat through and spill everywhere! Does the soldered part need to cool completely before going into the pickle solution, or should it go in while it's still relatively warm (but presumably not hot enough to boil the solution)?

C-38 Henner Meinhold: 31 Aug 2010 02:42 PM

I use one of these Tupperware plastic boxes. I did not have problems with melting or chemical attack. Let the part cool down to "black" and then lower it into the bath with tongs. Once the "steaming" has ceased, you can safely drop it. We did this even with a big Garret boiler without problems. With citric acid you don't have to worry about splashes, of course wearing goggles doesn't hurt 🙂. We used tongs from Ikea for about $3 to handle the parts.

C-39 Bob Sorenson: 31 Aug 2010 05:08 PM

Hey Richard: I use sulfuric acid (battery acid) for pickle, mixed about 10 to 12 parts water, 1 part acid. Store it in a Tupperware container. Store the container outdoors when not in use. The fumes are corrosive and will eat everything. Let the parts cool on their own to room temperature. Use tongs or wrap a copper wire around the part before putting in the tank. Rinse in running water while rubbing with a brass wire brush. Uuuu so shiny. I am switching to citric acid as Henner here pretty soon.

C-40 Steve Ciambrone: 31 Aug 2010 05:14 PM

So I am assuming most items in the shop are safe with citric acid in a sealed container or during use.

I have banned Muriatic Acid from my shop; it will leach from the original plastic bottle and make things rusty. I was not using it for trains but something else. *(Historically called muriatic acid or spirits of salt; Hydrochloric acid is a solution of hydrogen chloride (HCl) in water; acid was first produced from vitriol (Sulfuric/Sulphuric acid) and common salt.)*

C-41 Larry Newman: 04 Sep 2010 09:02 AM WOW! WOW! WOW! Bob, This is one of the most useful ideas I have seen in a long time! Thanks for posting it! C-42 Mark Scrivener: 13 Sep 2010 03:51 PM Looking good Bob! I haven't forgotten about the drawings, just sitting patiently waiting to see the finished project to see what changes happen ;). BTW - I checked your source for gears - turns out they only have hub-less gears for that size in brass. I was shocked to see the price for the gear set - 2 gears, plus the 3 chain gears and the ladder chain was $63.55 before shipping or tax! Ouch! Might just have to put that rotary table to work and cut my own gears. R – Bob Sorenson: 15 Sep 2010 12:04 PM Larry: These wristwatch bushings are working great for jets. The really great thing is making a jet that fits the burner, what a plus!! And making them in any shape, size and thread you need. I am going to order some more bushings. They make a 0.1mm (0.0039") as well. Mark: Thanks for doing the drawings. It's a big job and will take time. Yes, the gears were pricey. Gear and sprocket making is on the lists of "to do's"
C-43 Mark Scrivener: 15 Sep 2010 01:25 PM Funny I was just wondering what the fuel tank would look like on the side as a faux air tank...Very nice! On the drawings - ever hear the definition of involved vs. committed as it relates to ham and eggs? The chicken is involved, the pig is committed. Well, I just ordered a whole pile of materials to build a Nina, so now I am committed!!! Oh yea, and I plan to cut my own gears too. R – Bob Sorenson: 15 Sep 2010 05:56 PM You and me both. Had victorious results today on five major boiler firing tasks, so I feel better about your "commitment". Tomorrow, Nina might get on the test rollers. Fingers crossed
C-44 rkapuaala: 16 Sep 2010 02:35 PM Keep up the good work Bob, on construction and communications as well. I really look forward to reading this thread and watching your progress. R – Bob Sorenson: 18 Sep 2010 08:13 PM Hey Richard, thanks.
C-45 Howard Maculsay: 22 Sep 2010 03:44 PM It always feels good to dodge the bullet.... nice recovery. C-46 Benjamen: 22 Sep 2010 07:42 PM I love the end result. It came out really well. Don’t forget your camera and get some video of it pulling a big load. You have inspired me to start a project of my own. I think I will have some time to start it this winter. R –
C-46 deWintonDave: 18 Feb 2011 02:03 AM Excellent project Bob. Well done. I'm back on MLS now. Best wishes, R – Bob Sorenson: 18 Feb 2011 11:52 AM Thanks Dave. Good to see you again. You must have a few thousand miles on your deWintons by now..
C-47 Jason Grimm: 18 Feb 2011 04:10 PM That is looking very nice, it's amazing to see how just adding the cab changes the look of the locomotive. I have been watching your progress, and wishing I had 1/10 of your skill and knowledge. I'm looking forward to see how it looks all painted up. :) R – Bob Sorenson: 20 Feb 2011 09:50 PM Thanks Jason. Sometimes it's better to be lucky then good..

Live Steam 0-4-0 “Nina” – Check Off List		
Done	Quantity	Description
☐	1	**Chassis – Side Frames** (see pages 2 - 9) ☐ 2 – Frames – 9.251” x 1.250” (Machined from 16 ga. cold rolled, bright steel sheet) ☐ 2 – #4-40 x 1/4” Rnd Head Screws & Nuts (to secure frame blanks in waste area) ☐ 7 – #4-40 x 1/4” Round Head Screws & Nuts (to secure frame blanks in drilled holes) **Chassis –Frame Spreaders** (see pages 9 - 14) ☐ 1 – Split Collet (Drilled thru 11/32”) (Machined from 1/2" round steel rod) ☐ 7 – Frame Spreaders 1/4" x 1/4" x 2-3/4” (Machined from 1/4" square steel bar) ☐ 14 – #4-40 x 1/4” Round Head Screws (reuse 7 screws used to clamp frames) **Chassis –Frame Bearings** (see pages 14 - 17) ☐ 4 - Flange Bearings (axle (4)) (ID-1/4”, OD-3/8”, length-3/16”, flange OD-1/2”, flange thick-1/16”) (Machined from 1/2" round bearing bronze rod, Alloy #932 (SAE 660)) ☐ 3 - Flange Bearings (counter shaft (2), crankshaft (1)) (ID-3/16”, OD-3/8”, length-3/16”, flange OD-1/2”, flange thick-1/16”) (Machined from 1/2" round bearing bronze rod, Alloy #932 (SAE 660)) ☐ 1 - Flange Bearings (main crankshaft (1)) (ID-3/16”, OD-3/8”, length-9/32”, flange OD-1/2”, flange thick-1/16”) (Machined from 1/2" round bearing bronze rod, Alloy #932 (SAE 660)) ☐ 2 – Axles Blank 1/4" diameter (Rough unfinished) (Machined from 1/4" round stainless steel rod) ☐ 1 – Crankshaft Blank 3/16” diameter x ??” (Rough unfinished) (Machined from 3/16" round stainless steel rod) ☐ 1 – Counter Shaft 3/16” diameter x ??” (Rough unfinished) (Machined from 3/16" round stainless steel rod) **Chassis –Transmission & Drive** (see pages 17 - 29) ☐ 1 – Brass Hub-less Pinion Gear (14 tooth) (Stock Drive Products – Item #A-1B11-N32014) ☐ 1 – Brass Hub (for pinion) () ☐ 1 – Brass Hub-less Gear (30 tooth) (Stock Drive Products – Item #A-1B11-N32030) ☐ 1 – Brass Hub (for gear) () ☐ 2 – #6-32 x ??” Setscrews Cup Point (for pinion & gear) ☐ 4 – Wheel Blanks 1-17/32” diameter x 1/4" thick (finished size ???) (Machined from 2" round steel rod) ☐ 4 – Wheel Hub Blanks (Machined from 5/8" round steel rod) ☐ 4 – #6 -32 x ??” Setscrews Cup Point (for wheels)

Live Steam 0-4-0 “Nina” -- Check Off List

Done	Quantity	Description
☐	See Page 1	**<u>Chassis –Transmission & Drive</u>** (continued) ☐ 1 – Sprocket 7-tooth (Stock Drive Products – Item #A-6C-8-1907) ☐ 1 – Stop Collar 1/2" diameter x 1/4" thick thru bore 3/16” (for counter shaft) (Machined from 1/2" round brass rod) ☐ 1 – Split Collet (for trimming 14-tooth sprocket hubs) ☐ 3 – Sprocket 14-tooth (Stock Drive Products – Item #A-6C-8-1914) ☐ 2-feet – Ladder Chain – Size #19, 0.185” pitch (Stock Drive Products – Item #A-6Y-8-9) **<u>Chassis End Beams / Hardware & Footplate</u>** (see pages 29 - 34) ☐ 2 – End Beams 4” x 1-1/4” (Machined from 16 ga. Cold rolled, bright steel plate) ☐ 1 – Front Buffer U.K. Style 7/8” diameter (Machined from 1” round brass rod) ☐ 1 – Buffer Box (Machined from 1” square steel rod) ☐ 1 – #2-56 x ??” Screw – Round Head (for buffer/buffer box assembly) ☐ 1 – Coupler Link & Pin 7/8” (Ozark Miniatures – Item #4018) ☐ 1 – #4-40 Nut (for coupler) ☐ 1 – Footplate 9-1/2” x 4” (Machined from 16 ga. Cold rolled, bright steel plate)
☐	1	**<u>Engine Standard</u>** (see pages 34 - 38) ☐ 1 –Standard 2-1/4” x 1-3/16” x 3/16” (rough size) (Machined from 3/16” brass plate) ☐ 1 – Manifold 3/8” diameter x 1” long (finished size) (Machined from 3/8” round brass rod) ☐ 2 – #4-40 x ??” Flat Head Screws & Nuts (for engine standard mounting)
☐	1	**<u>Flywheel</u>** (see pages 38-39) ☐ 1 – Option ‘A’ – 1-11/16” diameter x 1/2" thick with 5/32” rim (Machined from 2” round stainless steel (#303 or #416) or cast iron rod) ☐ 1 – Option ‘B’ – 1-7/8” diameter x 15/32" thick with 1/8” rim (Machined from 2” round stainless steel (#303 or #416) or cast iron rod) ☐ 1 – #6-32 x ??” Setscrew Cup Point (for flywheel hub)
☐	1	**<u>Crankshaft Assembly</u>** (See pages 39-41) ☐ 1 – Shaft 3/16” diameter x 4+” long, round stainless steel rod ☐ 1 – Disc 15/16” diameter x 13/64” thick, round brass rod ☐ 1 – Wrist Pin 1/8” diameter x 9/16” long, stainless steel rod

<table>
<tr><th colspan="3">Live Steam 0-4-0 “Nina” -- Check Off List</th></tr>
<tr><th>Done</th><th>Quantity</th><th>Description</th></tr>
<tr><td>☐</td><td>1</td><td><u>Steam Cylinder</u> (see pages 41-54)
☐ 1 – Cylinder Body Blank 7/8” diameter x 1-3/8” long
(Machined from 7/8” bronze alloy #932 round rod)
☐ 1 – Wood Lapping Mandrel (maple or oak) 0.500” diameter x 4” long
☐ 1 – Cylinder Top Cover Blank 3/4” diameter x 1/4” thick
(Machined from 7/8” bronze alloy #932 round rod)
☐ 1 – Cylinder Trunnion Pin 5/32” diameter x 7/16” long
(Machined from 5/32” stainless steel round rod)
☐ 2 – #4-40 x 1/2” Screws (for trunnion pin ends)
☐ 1 – Drilling Jig – Steam & Exhaust Ports 2-1/2” x 3/8” x 1/8” (finished size)
(Machined from 1/8” cold rolled steel or brass plate)
☐ 1 – Drilling Jig Spacer 3/8” diameter x 3/8” thick
(Machined from 3/8” round/hex brass rod)
☐ 1 – Surf ace Plate 1/2" x 8” x 10” (for lapping port faces)
(Scarp piece of 1/2" thick plate glass)</td></tr>
<tr><td>☐</td><td>1</td><td><u>Piston Assembly</u> (see pages 55-59)
☐ 1 – Big End
(Machined from 1/4" square cold rolled steel (CRS) rod)
☐ 1 – Piston Rod 5/32” diameter x 5/8” long
(Machined from 5/32" round stainless steel rod)
☐ 2 – 4-40 x 3/8” Screws (for piston rod ends)
☐ 1 – Piston 1/2" diameter x 9/16”
(Machined from 1/2" round stainless steel rod)</td></tr>
<tr><td>☐</td><td>1</td><td><u>Boiler Assembly</u> (see pages 59 - 79)
☐ 1 – Vertical Barrel 2-1/2” diameter x 3-1/2” long copper pipe
(Machined from 2-1/2" type M copper pipe)
☐ 1 – Horizontal Barrel: 1-1/2” diameter x 4” long copper pipe
(Machined from 1-1/2" type M copper pipe)
☐ 1 – Boiler Flue: 3/4" diameter x 5-1/2+“ long copper pipe
(Machined from 3/4" copper coupler pipe)
☐ 1 – Top Endplate – Vertical Boiler Barrel
(Machined from 1/8" copper plate)
☐ 1 – Bottom Endplate –Vertical Boiler Barrel
(Machined from 1/8" copper plate)
☐ 1 - Front Flue Plate
(Machined from 1/8" copper plate)
☐ 5 – Bronze Plumbing Bushings 3/8”, tapped thru for 1/4"-40
(safety valve, throttle valve, sight glass, & pressure gauge)
(Machined from 1/2" round bronze rod)
☐ 2 – Bronze Blind Mounting Bushings 1/4", tapped for 6-32
(Machined from 1/2" round bronze rod)
☐ 1 – Sight Glass Bushing Mounting Jig 2” x 3/8” x 1/8”
(Machined from 1/8" cold rolled steel plate)</td></tr>
</table>

Live Steam 0-4-0 “Nina” – Check Off List		
Done	Quantity	Description
☐	1	**<u>Stack Assembly</u>** (see pages 79 - 85) ☐ 1 – Stack Tube, 5/8” diameter x (as desired) long (Machined from 1/2" type ‘M’ copper pipe) ☐ 1 – Stack Base (Machined from 1" square brass bar) ☐ 1 – Stack Base Flange (Machined from 1-1/2" copper pipe coupling) ☐ 1 – Stack Top Cap (Machined from 1" round brass rod) ☐ 4 – #0-80 Screws (to attach flange to barrel)
☐	1	**<u>Smoke Box Saddle Assembly</u>** (see pages 85 - 86) ☐ 1 – Saddle Base Plate (Machined from 1/8" cold rolled steel plate) ☐ 1 – Saddle Block (Machined from 1" square brass bar) ☐ 1 – Saddle Barrel Flange (Machined from 1-1/2" copper pipe coupling w/no stop)
☐	1	**<u>Smoke Box Front Assembly</u>** (see pages 86 - 90) ☐ 1 – Fronts Piece (Machined from 1/4" brass plate) ☐ 1 – Door (Machined from) ☐ 2 – Door Strap Hinge Long (Fabricated from 1/8" x 1/32” brass strip) ☐ 2 – Door Strap Hinge Short (Fabricated from 1/8" x 1/32” brass strip) ☐ 1 – Door Handle (Fabricated from)
☐	1	**<u>Lubricator Assembly</u>** (see pages 90 - 94) ☐ 1 – Tank 1” x 1” x 7/8” (Machined from 1" square brass bar) ☐ 1 – Steam Pipe 1/4" x 1-1/2” (Machined from 1/4" round brass rod) ☐ 1 – Tank Lid 1-1/8” square (Machined from 1/16" brass plate) ☐ 4 – #0-80 Screws (to attach lid to tank) ☐ 1 – Filler Plug Bushing 5/16” diameter x 1/4" (drill thru & tap for 1/4"-40) (Machined from 3/8" round brass rod) ☐ 1 – 1/4"-40 Hex Head Screw (for fill plug) ☐ 1 – Cleanout Plug Bushing 3/16” diameter x 1/8” (drill thru & tap for #4-40) (Machined from 3/8" round brass rod) ☐ 1 – #4-40 Hex Head Screw (for cleanout plug)

Live Steam 0-4-0 “Nina” – Check Off List		
Done	Quantity	Description
☐	1	**<u>Lubricator Stand Assembly</u>** (see pages 94 - 96) ☐ 2 – Boiler Barrel Straps 1/32” thick x 3/8” wide x (Machined from 1/32" thick brass strip) ☐ 1 – Stand Base Plate 1-1/8” square (Machined from 1/16" thick brass plate) ☐ 1 – Stand Spacer (Machined from 1" square brass bar) ☐ 1 – Stand Top Plate (Machined from 1-1/2" copper coupling w/no stop) ☐ 2 – Strap Clamp Tubes 3/8” long (Machined from 1/8" OD brass tube) ☐ 2 – #0-80 Hex Screws & Nuts (for strap clamps) ☐ 4 – #0-80 Hex Screws (to attach stand to tank)
☐	1	**<u>Safety Valve Assembly</u>** (see pages 96 - 107) ☐ 1 – Valve Seat (Thread 1/4"-40 for 1/2") (Machined from 1/4" round brass rod) ☐ 1 – Bonnet Nut 1/8” thick (Tap for 1/4"-40) (Machined from 3/8” hex brass rod) ☐ 1 - Chucking Spigot & Jam Nut (Turn & thread one end for 1/4"-40) (Machined from 3/8” hex brass rod) ☐ 1 - Valve Bonnet 5/8” long (1/2” turned round, 1/8” hex nut, tap 1/4"-40) (Machined from 5/16” hex brass rod) ☐ 1 – Stainless Steel Ball 1/8” ☐ 1 – Valve Stem 17/32” long (Machined from 1/8” round brass rod) ☐ 1 – Stem Tension Adjuster Nut (Thread 1/4"-40 x 3/16”) (Machined from 1/4" round brass rod) ☐ 1 – Stainless Steel Spring (Type 302) (McMaster-Carr Item #9435K11 – Precision Compression) (OD 0.120”, wire size 0.016” round, LOA 0.250”, ends: closed & ground)
☐	1	**<u>Sight Glass/Water Gauge Assembly</u>** (see pages 107 - 114) ☐ 1 – Upper Body (Machined from 1/4" round brass rod) ☐ 1 – Lower Body (Machined from 1/4" round brass rod) ☐ 1 – Valve Spindle, Blow Down Valve (Machined from #4-40 x 1/4" round brass rod) ☐ 1 – Knurled Brass Thumb Nut (#4-40) ☐ 1 – Sight Glass Tube (5/32” OD, 0.0980” ID, 1-5/16” long) ☐ 2 – Gauge Glass Packing Nuts (Machined from 5/16" hex brass rod)

<table>
<tr><th colspan="3">Live Steam 0-4-0 “Nina” – Check Off List</th></tr>
<tr><th>Done</th><th>Quantity</th><th>Description</th></tr>
<tr><td>☐</td><td>1</td><td><u>Throttle Assembly - Piston Type</u> (see pages 114 - 119)
☐ 1 – Throttle Body
(Machined from 1/4” round brass rod)
☐ 1 – Piston & Piston Spindle
(Machined from 5/32” round stainless steel rod)
☐ 1 – Piston Spindle Fork
(Machined from 3/16” round brass rod)
☐ 1 - #2-56 Machine Screw
☐ 2 – Links, Throttle Handle
(Machined from 1/32” x 1/8” x 1-1/16” brass strip)
☐ 1 – Throttle Handle
(Machined from 1/16” x 3/16” brass strip)
☐ 2 – Cap Nuts
(Machined from 5/16” hex brass rod)
(1 – Cap Nut - Blind, (Throttle Body End Plug)
(1 – Cap Nut, Piston Spindle Packing)</td></tr>
<tr><td>☐</td><td></td><td><u>Locomotive Steam Plumbing</u> (see pages 119 - 124)
☐ 1 – Throttle to Lubricator Plumbing
1 – Steam Pipe
(5/32” O.D. thin wall copper tube)
2 – Steam Pipe Flanges
(1/32” thick brass washers)
2 – Brass Cap Nuts
(Fabricated from 5/16” hex brass rod, Tapped 1/4”-40)
2 – O-ring Gaskets
(McMaster-Carr – Pt. No. 9263K511)
1 – Street Ell 90°
(Fabricated from 1/4" round brass rod)
☐ 1 – Lubricator to Engine Manifold Input Plumbing
1 – Street Ell 90°
(Fabricated from 1/4" round brass rod)
1 – Steam Pipe
(1/8” thin wall copper tube)
1 – Steam Pipe Flange
(1/32” thick brass washer)
1 – Brass Cap Nut
(Fabricated from 5/16” hex brass rod, Tapped 1/4”-40)
1 – O-ring Gasket
(McMaster-Carr – Pt. No. 9263K511)
1 – Banjo Sleeve
(Machined from 3/8” round brass rod)
1 – Banjo Bolt
(Machined from 3/8” hex brass rod)
☐ 1 – Engine Manifold Exhaust Output to Smoke Box Elbow Plumbing
1 – Banjo Bolt
(Machined from 3/8” hex brass rod)
1 – Banjo Sleeve
(Machined from 3/8” round brass rod)</td></tr>
</table>

Live Steam 0-4-0 “Nina” – Check Off List

Done	Quantity	Description
See Previous Page		Locomotive Steam Plumbing (see previous page) Engine Manifold Exhaust Output to Smoke Box Elbow Plumbing (continued) 1 – Steam Pipe (1/8” Thin wall copper tube) 1 – Steam Pipe Flange (1/32” thick brass washer) 1 – Brass Cap Nut (Fabricated from 5/16” hex brass rod, Tapped 1/4”-40) 1 – O-ring Gasket (McMaster-Carr – Pt. No. 9263K511) 1 –90° Elbow (male to male) (Fabricated from 1/4" round brass rod) ☐ 1 –Smoke Box Elbow to Stack (blast pipe) Plumbing 1 – Steam Pipe (1/8” thin wall copper tube) 1 – Steam Pipe Flange (1/32” thick brass washer) 1 – Brass Cap Nut (Fabricated from 5/16” hex brass rod, Tapped 1/4”-40) 1 – O-ring Gasket (McMaster-Carr – Pt. No. 9263K511)
☐		**<u>Fuel Tank - 1</u>** (see pages 125 - 128) ☐ 1 – Gas Filling Adapter (‘Cannibalize’ from used lighter or torch, or purchase new.) ☐ 1 – Fuel Tank Blank (1” O.D. Nom. copper pipe, 2-3/8” long, or to suit) ☐ 2 – Fuel Tank End Pieces (1/8” thick copper plate disks, turn to fit) ☐ 1 – Fuel Tank Mounting Bushings, Blind - Bronze (BD-Tapped #10-32 x 7/16”, FD-1/2”, FW-1/32”, SD-5/16”, SL-1/2”) ☐ 1 – Fuel Tank Fill Bushing - Bronze (BD-Tapped M4.5 x 0.5 - Thru, FD-15/16”, FW-1/16”, SD-9/32”, SL-3/16”) ☐ 1 – Fuel Tank Burner Feed Bushing - Bronze (BD-Tapped 1/4"-20 x Thru, FD-7/16”, FW-1/16”, SD-3/8”, SL-3/16”)
☐		**<u>Fuel Tank – 2</u>** (see pages 128 - 129) ☐ 1 – Gas Filling Adapter (‘Cannibalize’ from used lighter or torch, or purchase new.) ☐ 1 – Fuel Tank Blank (1” O.D. Nom. copper pipe, 3” long, or to suit) ☐ 2 – Fuel Tank End Pieces (1/8” thick copper plate disks, turn to fit) ☐ 2 – Fuel Tank Mounting Bushings, Blind - Bronze (BD-Tapped #10-32 x 7/16”, FD-1/2”, FW-1/32”, SD-5/16”, SL-1/2”)

Live Steam 0-4-0 “Nina” – Check Off List		
Done	Quantity	Description
	See Previous Page	Fuel Tank – 2 (Continued) ☐ 1 – Fuel Tank Fill Bushing - Bronze (BD-Tapped M4.5 x 0.5 - Thru, FD-15/16”, FW-1/16”, SD-9/32”, SL-3/16”) ☐ 1 – Fuel Tank Burner Feed Bushing - Bronze (BD-Tapped 1/4"-20 x Thru, FD-7/16”, FW-1/16”, SD-3/8”, SL-3/16”)
☐	1	**Burner Fuel Valve** (see pages 129 - 132) ☐ 1 – Needle Valve Stem 1 – Valve Stem Blank (1/8” Dia. Round stainless steel rod, 1/2" long) (Drilled & tapped #4-40 x 1/4" both ends) 2 – Machine Screws (#4-40 x 5/8”) 1 – Knurled Thumb Nut (#4-40) ☐ 1 – Fuel Valve Body 1 – Body Blank (Machined from 1/4" round brass rod 7/8” long) 1 – Output Nipple (Machined from 1/4" round brass rod, 1/2” long) 1 – Packing Nut (Machined from 5/16” hex brass rod & flat brass scrap) 2 – Jam Nuts (Machined from 5/16” hex brass rod)
☐	1	**Gas Jet Assembly #1** (see pages 132 - 135) ☐ 1 – Gas Jet (L01 – 0.2mm) 1 – Jet Drilling Jig (Machined from 1/4” Dia. Round brass rod, 1-1/2" long) 1 – Machine Screw - Brass (#2-56 x 3/16”) 1 – Gas Jet Bushing (Size L-01 **part number 11301**) ☐ 1 – Gas Jet Body 1 – Body Blank (Machined from 3/16” Dia. Round brass rod, 5/8" long) 1 – Fuel Inlet Nipple (Machined from 1/4” Dia. Round brass rod, 7/16" long) 1 – Jam Nut Hex- #10-32
☐	1	**Gas Jet Assembly #2** (see pages 132 - 135) ☐ 1 – Gas Jet (L01 – 0.15mm) 1 – Jet Drilling Jig (Machined from 1/4” Dia. Round brass rod, 1-1/2" long) 1 – Machine Screw - Brass (#2-56 x 3/16”) 1 – Gas Jet Bushing Size L-56 (**part number 11356**)

<table>
<tr><th colspan="3">Live Steam 0-4-0 “Nina” – Check Off List</th></tr>
<tr><th>Done</th><th>Quantity</th><th>Description</th></tr>
<tr><td></td><td>See Previous Page</td><td>Gas Jet Assembly #2 (Continued)
☐ 1 – Gas Jet Body
1 – Body Blank
(Machined from 3/16” Dia. Round brass rod, 5/8" long)
1 – Fuel Inlet Nipple
(Machined from 1/4” Dia. Round brass rod, 7/16" long)
1 – Jam Nut
(Nut Brass Hex #10-32)</td></tr>
<tr><td>☐</td><td>1</td><td><u>Gas Burner Blowtorch Type Assembly</u> (see pages 135 - 138)
☐ 1 – Gas Burner Body
1 – Body Blank
(Machined from 7/16” or 1/2" Dia. Round brass rod, 1-3/8" long)
☐ 1 – Gas Diffuser
1 – Diffuser Blank
(Machined from 7/16” or 1/2" Dia. Round brass rod, 3/8" long)
☐ 1 – Gas Burner Mounting Ring
(Machined from 3/16” brass plate, to a snug fit inside of boiler flue)</td></tr>
<tr><td>☐</td><td>1</td><td><u>Gas Burner Poker Type Assembly</u> (see pages 138 - 140)
☐ 1 – Poker Burner Tube
1 – Body Blank
(Machined from round brass tube, 3/8" OD, 5/16” ID, 3-5/8” long)
1 – Tube Slotting Jig
(Made from scrap hardwood)
1 – Tube End Plug - Solid
(Made from scrap brass plate or round rod)
1 – Tube End Plug – Drilled & Tapped (#10-32 for jet)
(Made from scrap brass plate or round rod)
☐ 1 – Gas Burner Mounting Ring
(Machined from 3/16” brass plate, to a snug fit inside of boiler flue)</td></tr>
</table>

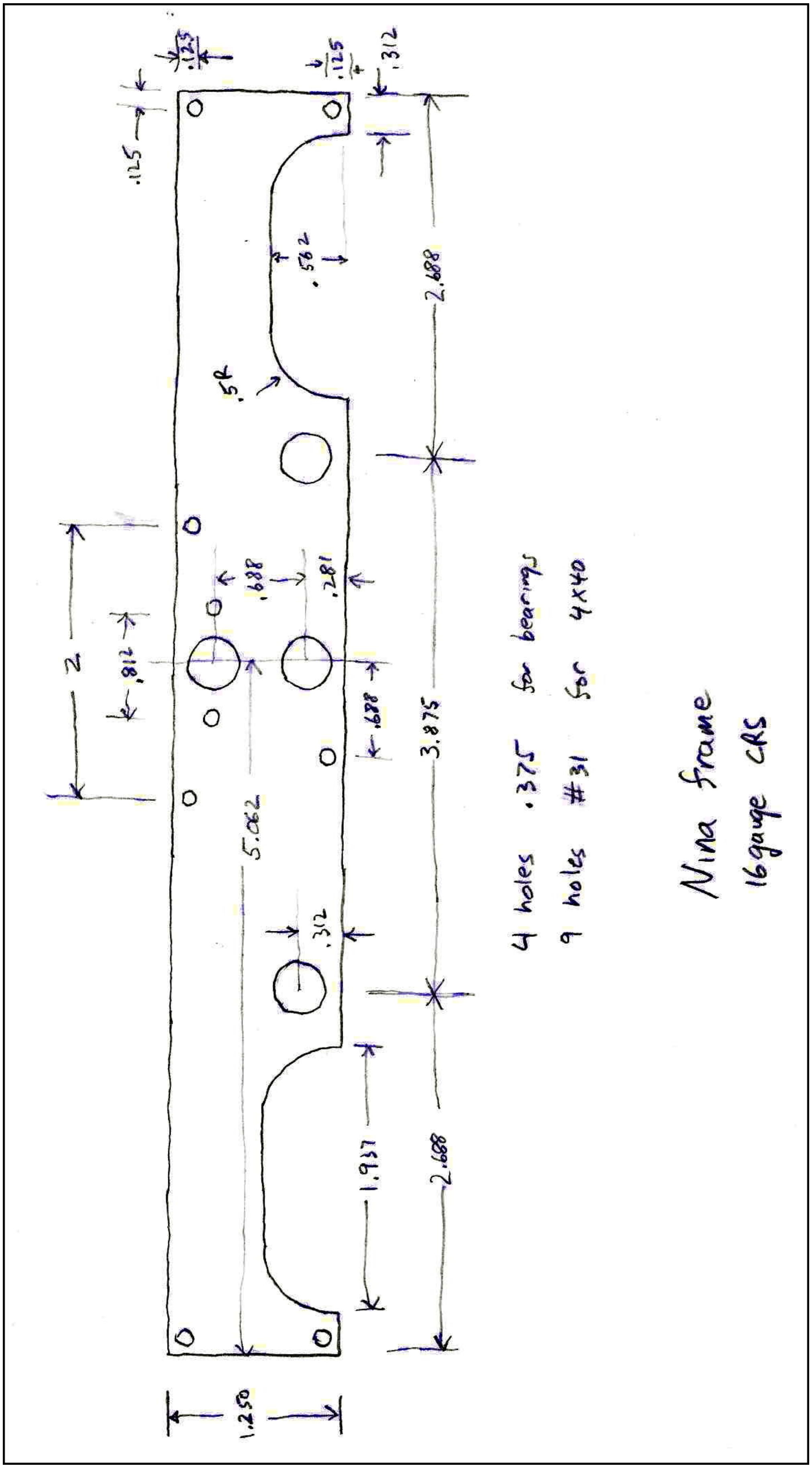


Figure 1: Side Frame Drawing

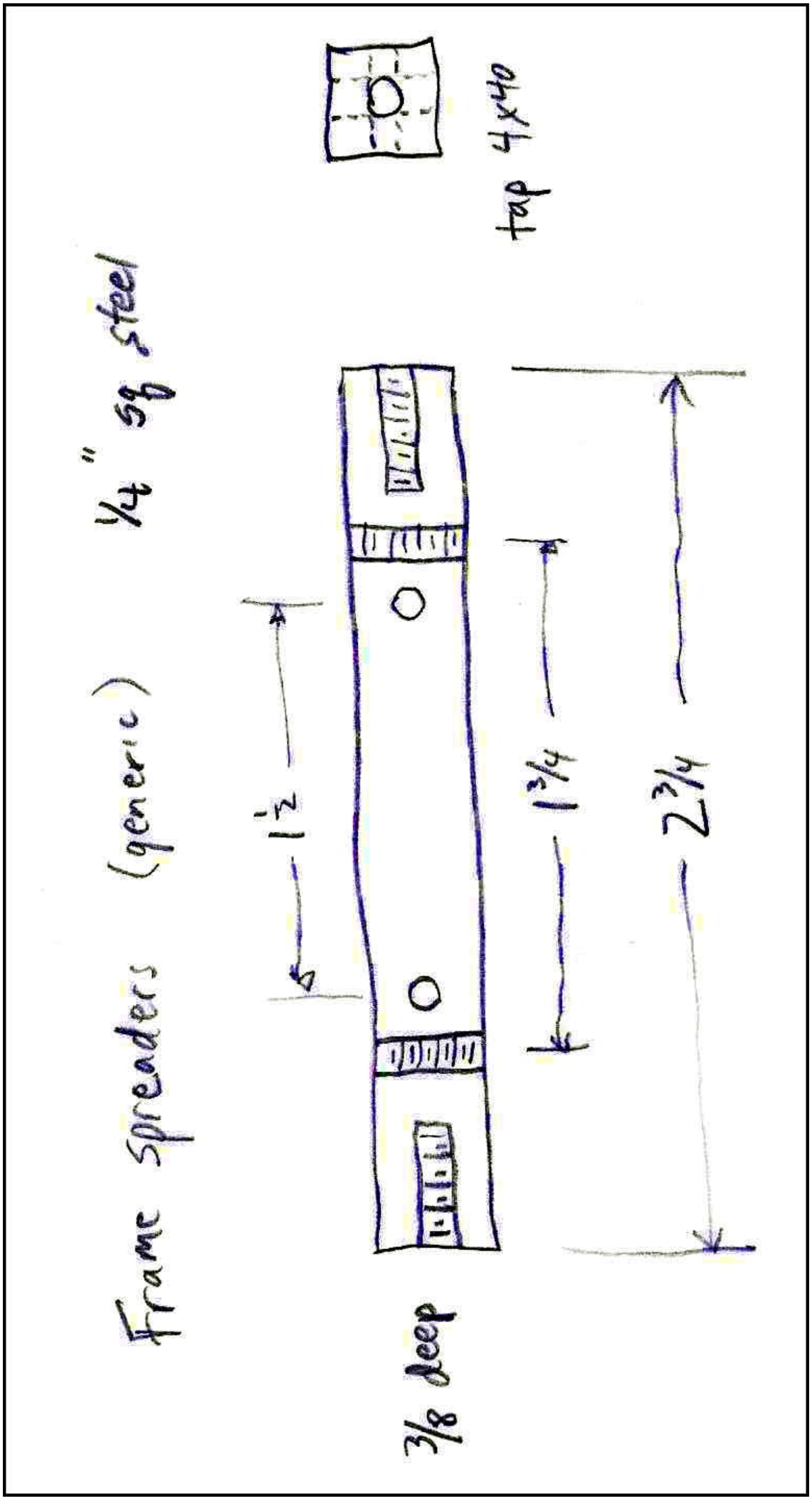


Figure 2: Frame Spreader Drawing

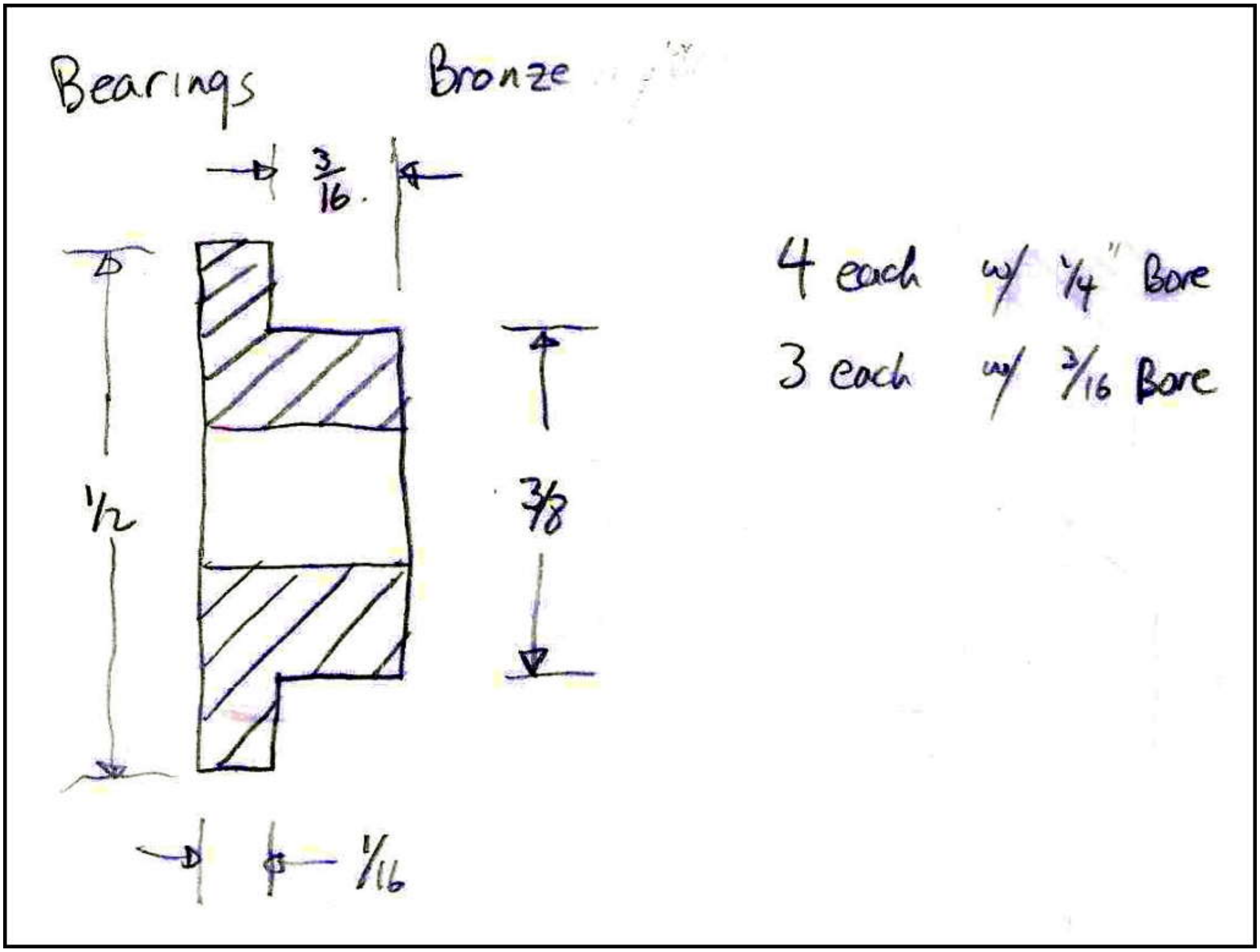


Figure 3: Bearings; axle (4), Counter Shaft (3)

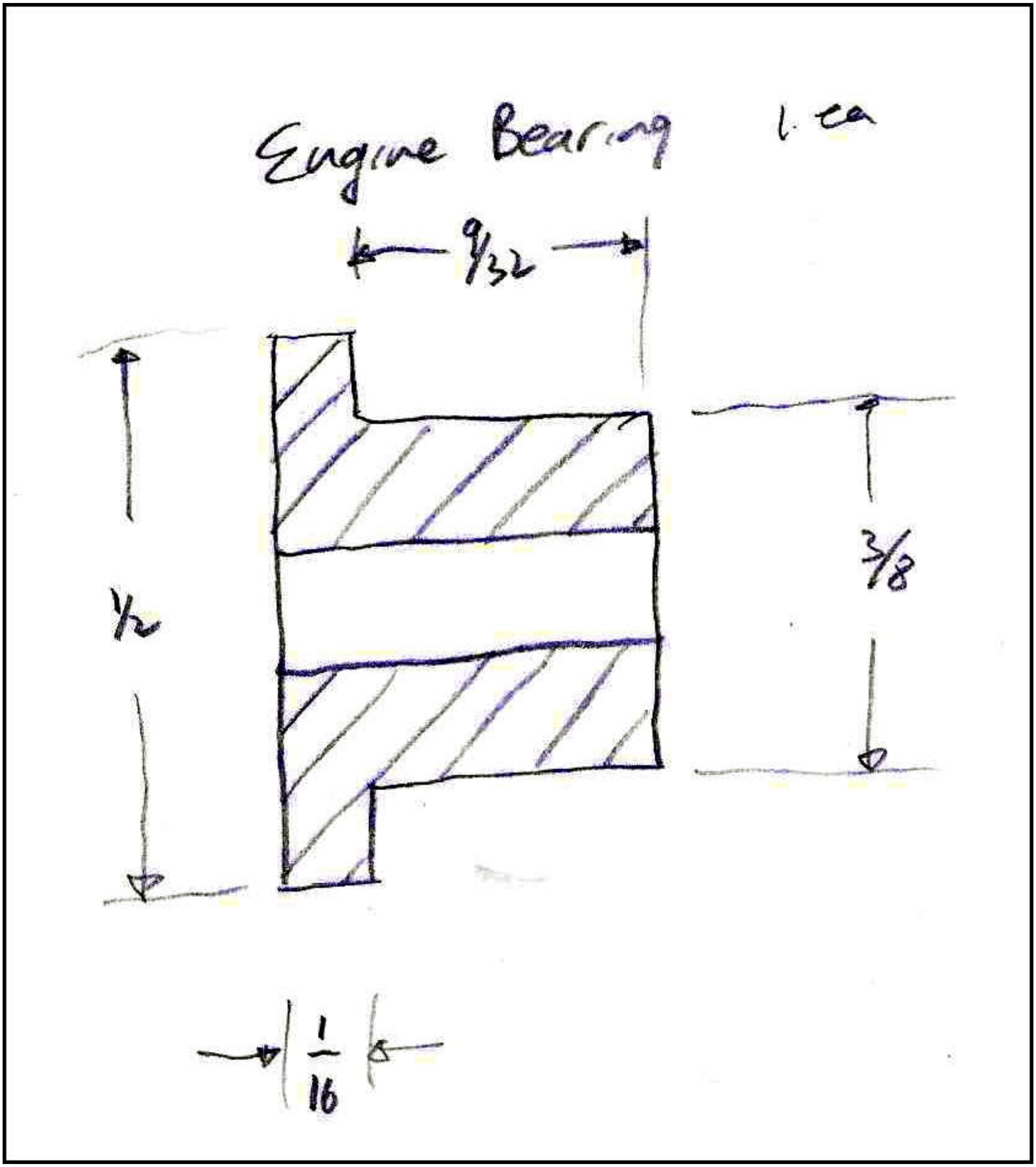


Figure 4: Engine Bearing (1)

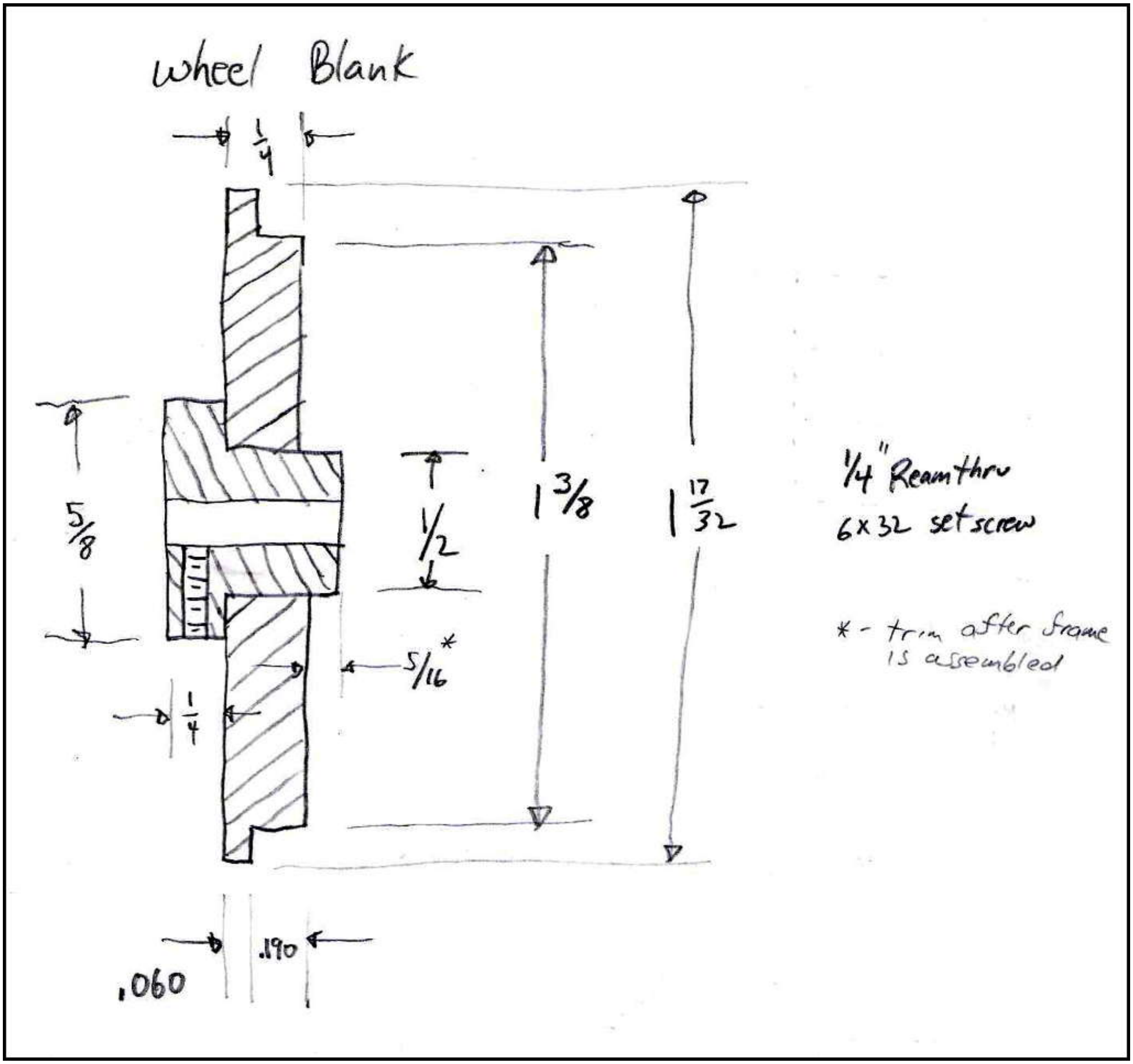


Figure 5: Wheel Drawing For The Nina

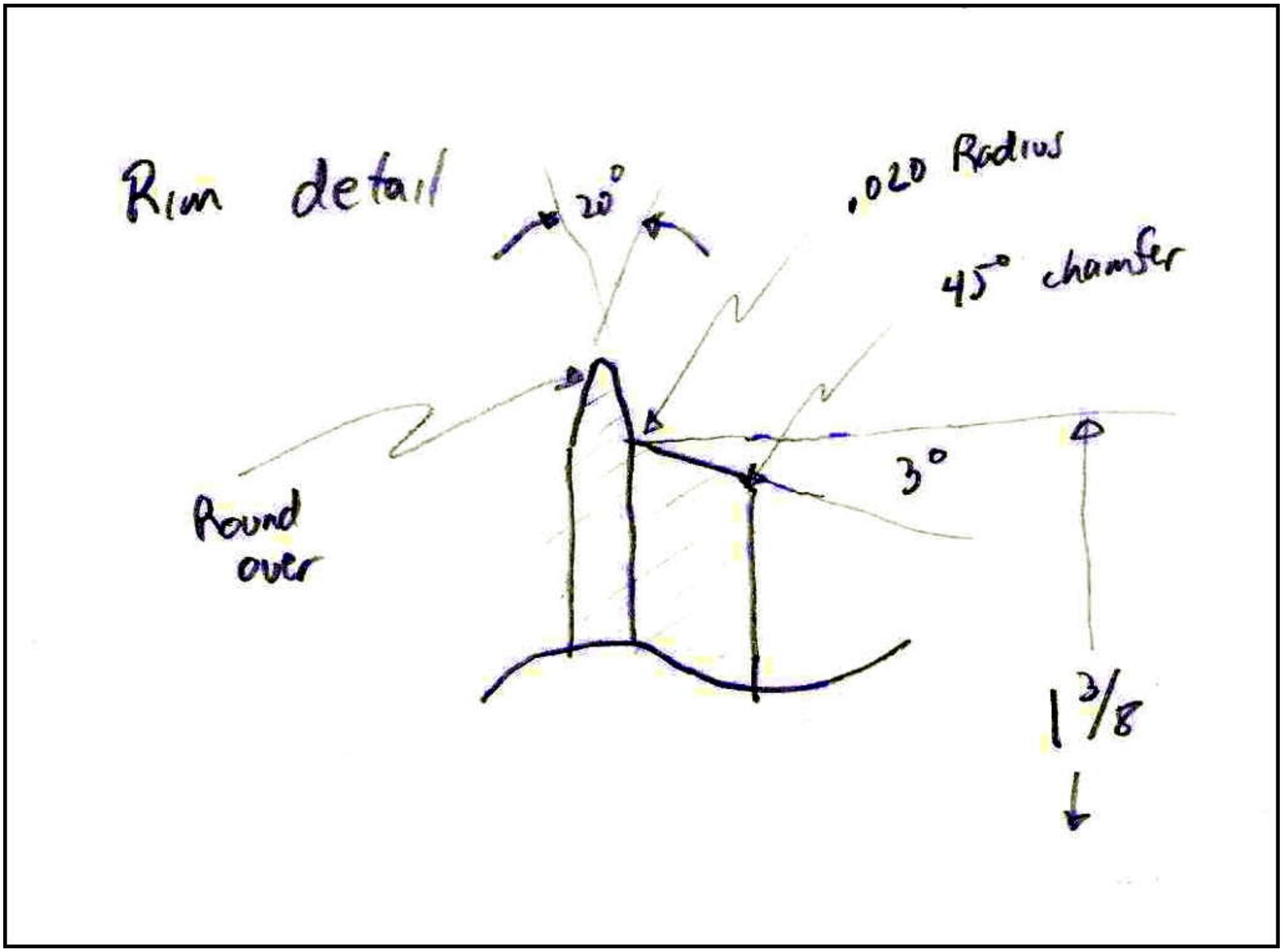


Figure 6: Wheel - Tread & Flange Detail

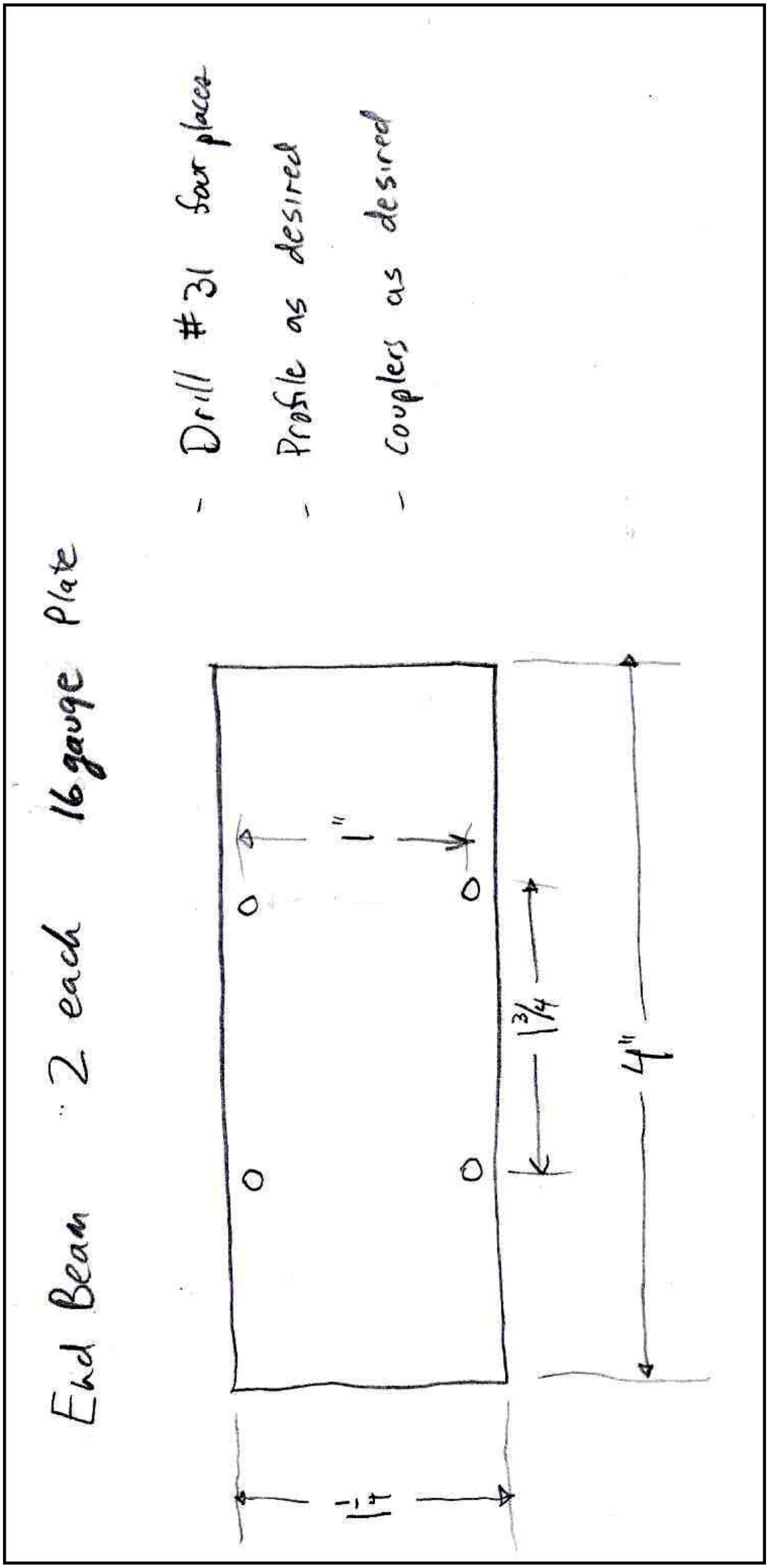


Figure 7: End Beam Sketch

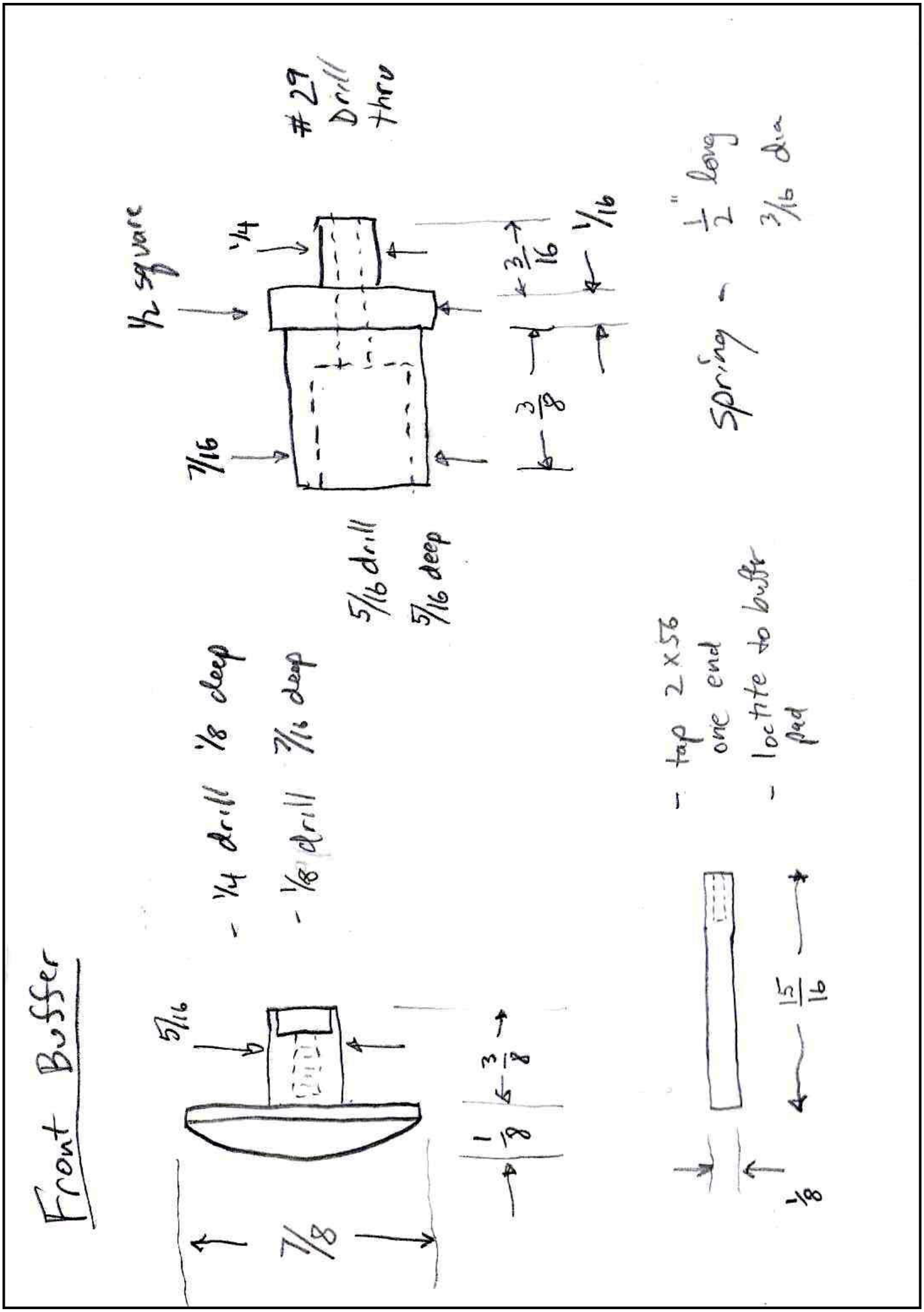


Figure 8: Front Buffer Sketch

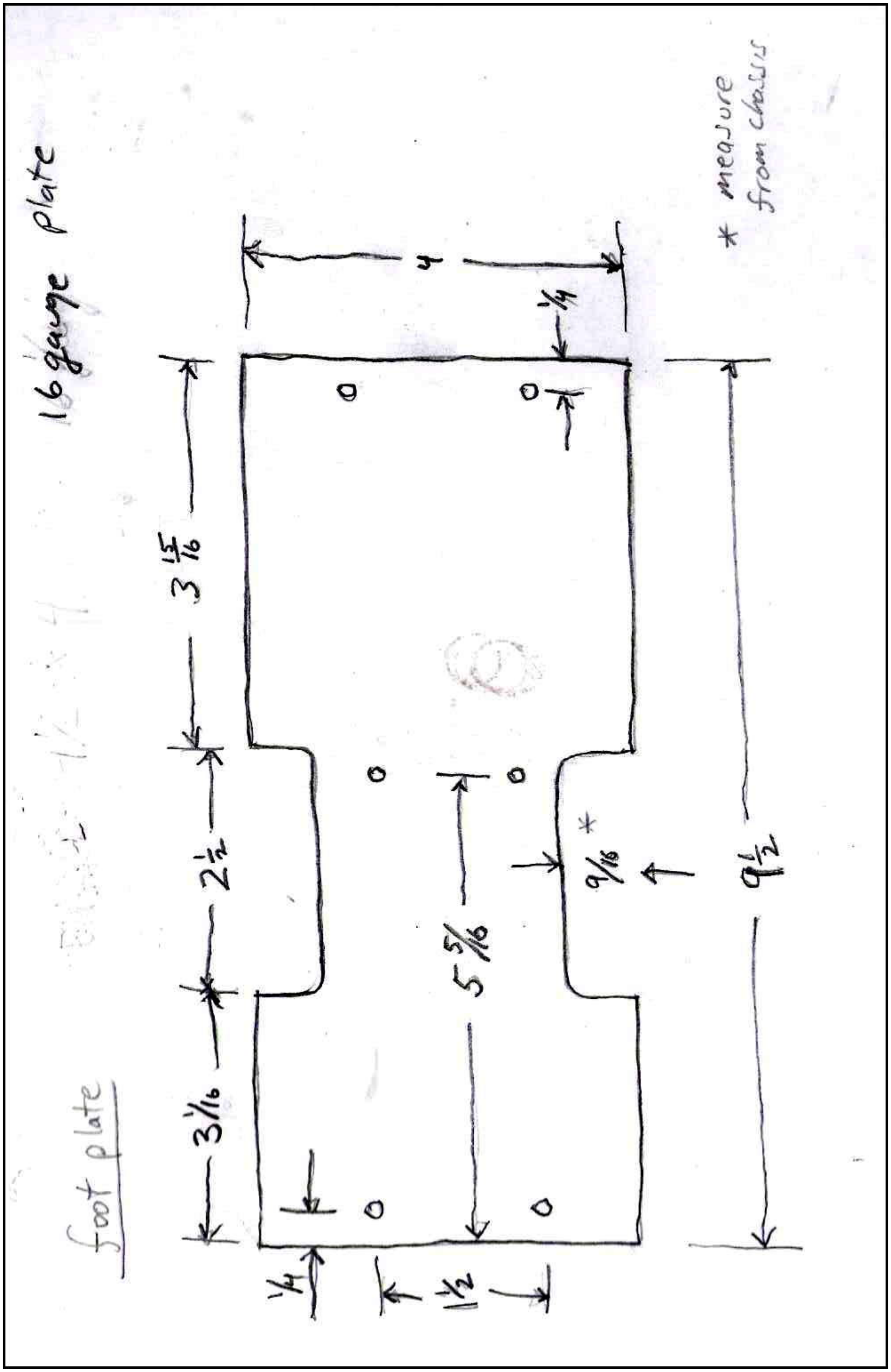


Figure 9: Footplate Sketch

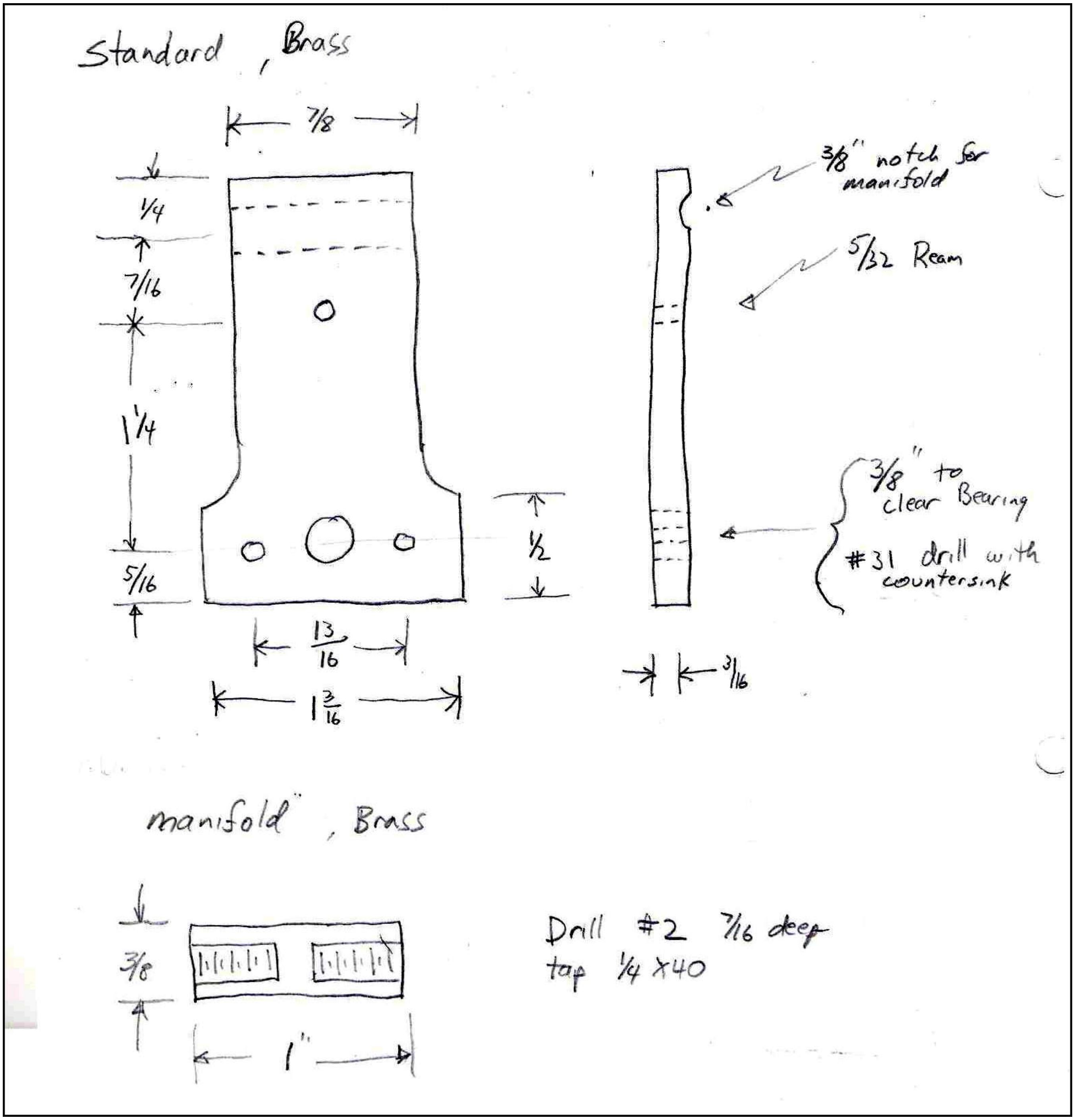


Figure 10: Engine Standard

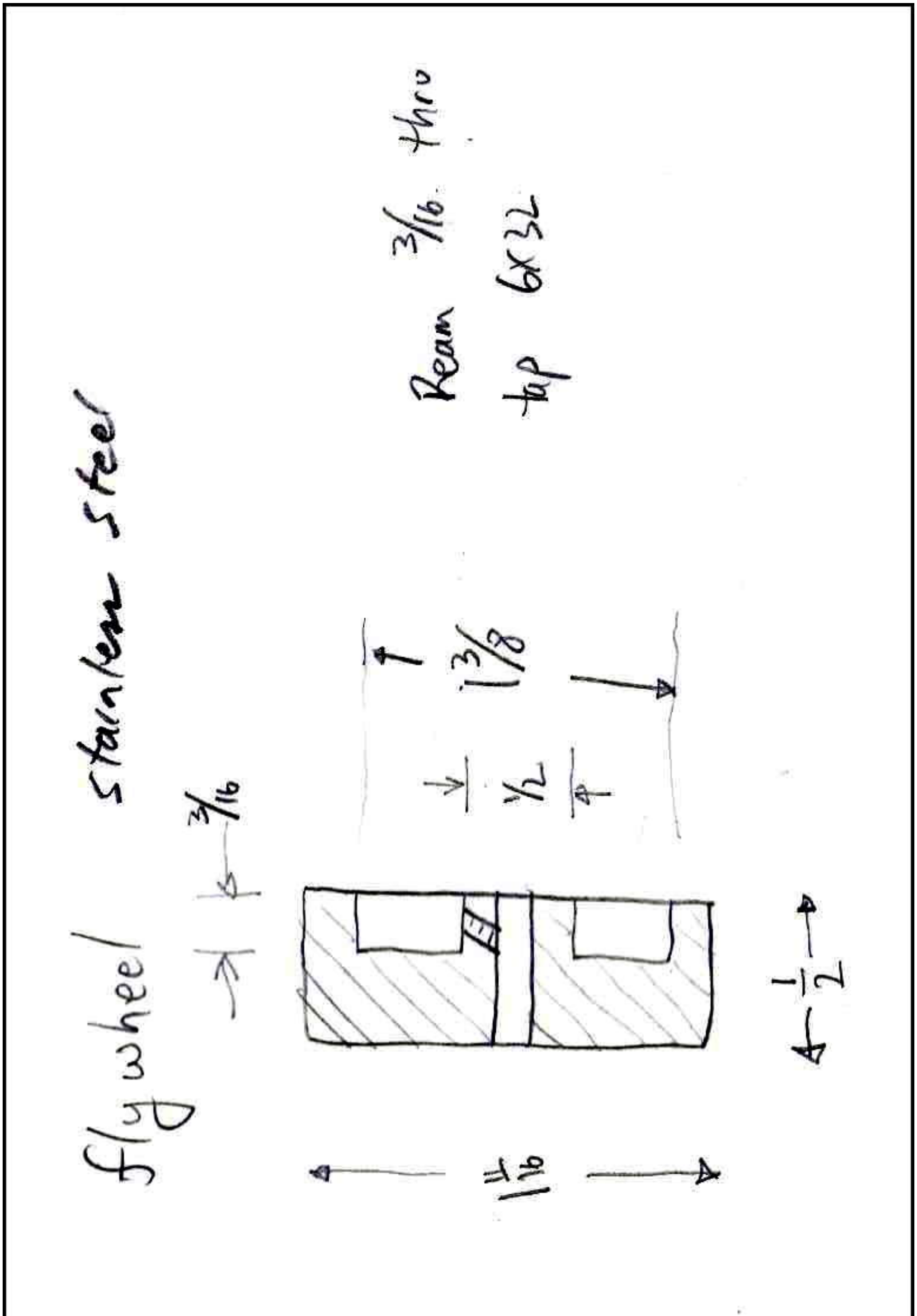


Figure 11: Flywheel Option A

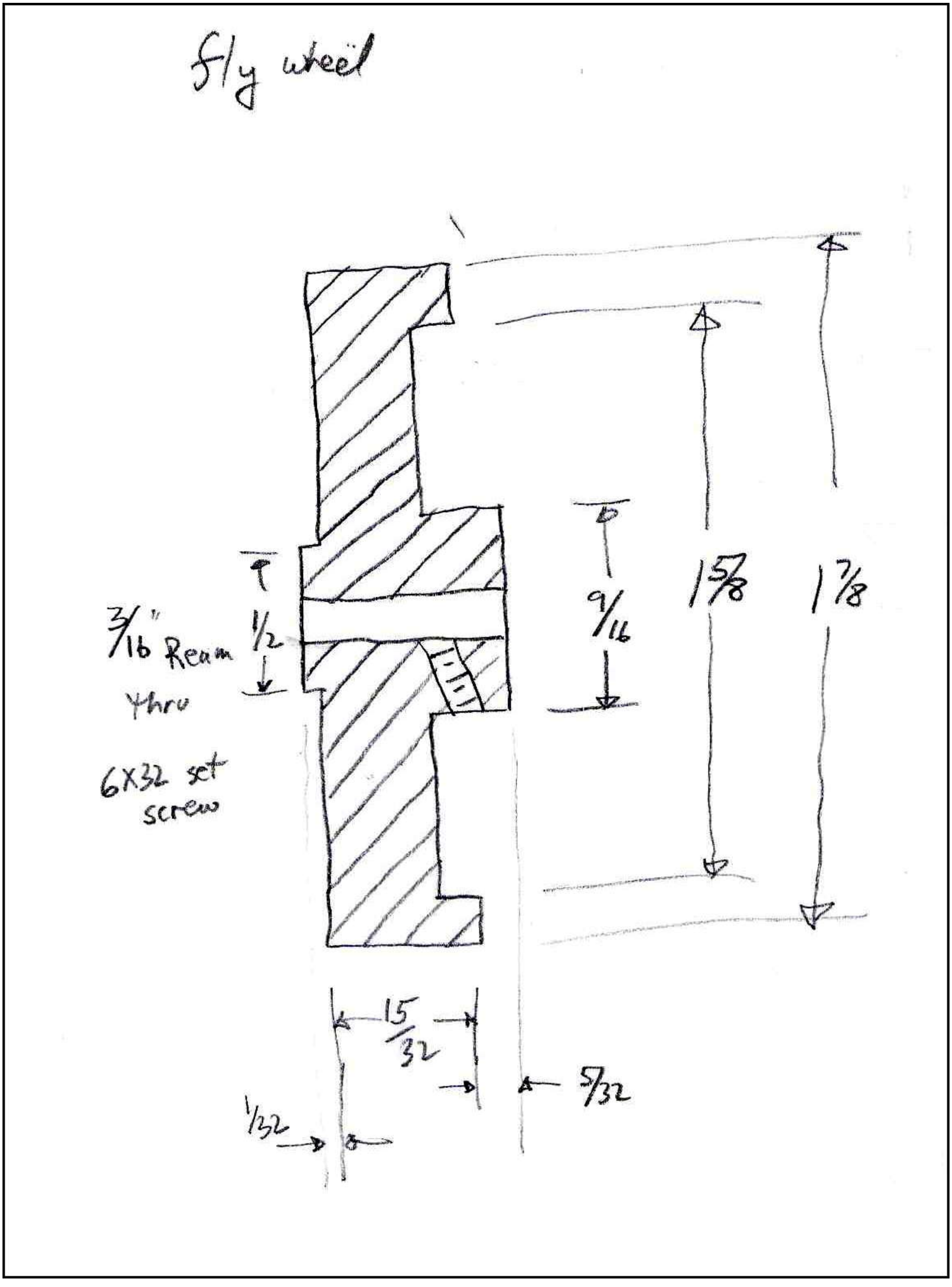


Figure 12: Flywheel Option B

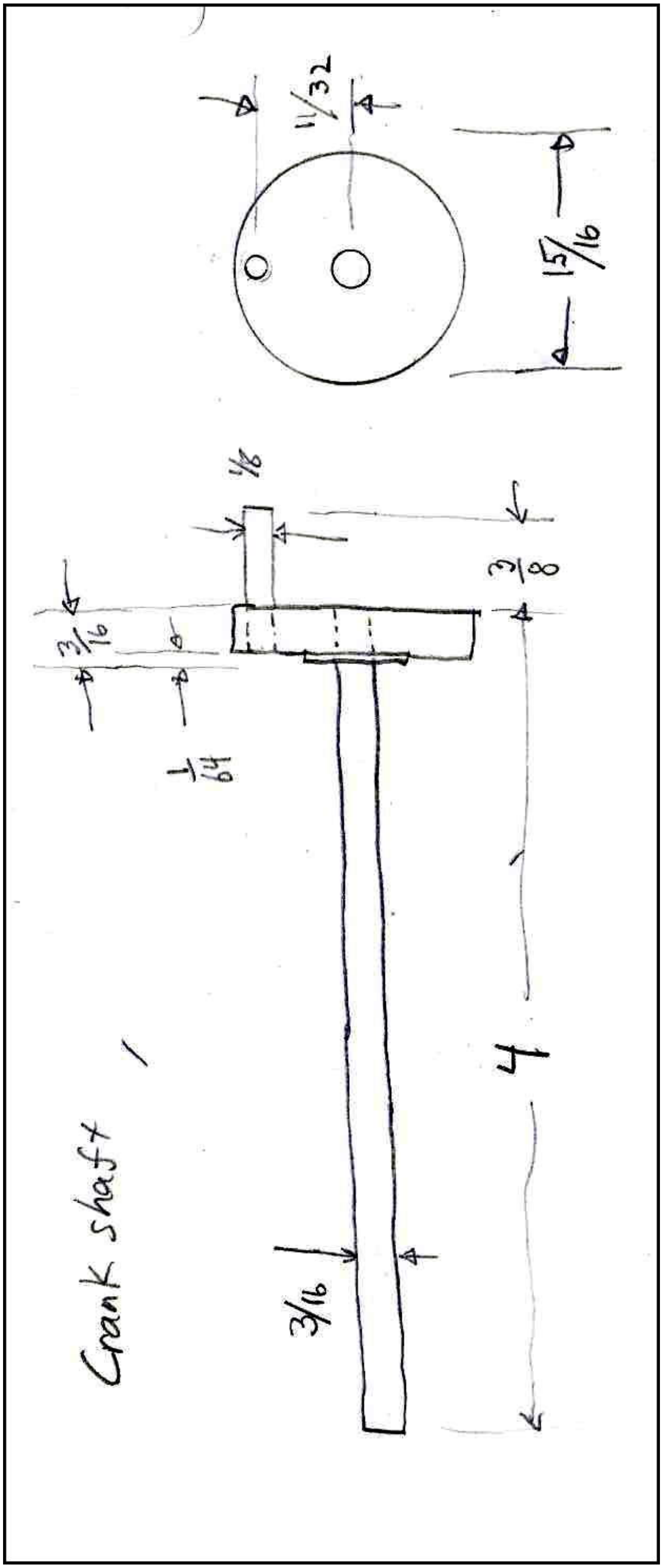


Figure 13: Crankshaft

A VERY SIMPLE WOBBLER

New Zealand reader D. S. Cruickshank describes how to make a very useful tool

Some time ago there appeared an article which gave a very good description on the uses of a wobbler. Now if you have a wobbler and were unsure exactly how to use it, then the article must have been most helpful. However, for those of you who didn't have this useful workshop device the article may have prompted you to try and make one. Although this device looks very simple and operates on a simple principle, it is not quite so simple to build. Most designs involve some form of spherical pivot. In order to make this pivot a special form tool will be required. To make this tool is not a simple job for the beginner or anyone else for that matter.

Design

I often have need for a wobbler but have been put off making one because of the time involved. I prefer to press on with whatever it is I am making rather than spend more time than is absolutely necessary on tools, jigs and such. To this end I came up with a design for a simple wobbler that can be built in under twenty minutes. These sort of claims are often made by very skilled people who can make even the most complicated task look simple. Let me assure you I am not highly skilled and am not an organised worker. This is all to show you that if I can make one in twenty minutes most people will be able to do it better in ten minutes.

The essential simplification in my design is the lack of a complex pivot arrangement. Just think about car design for a few minutes. Look at the steering and suspension joints. Many of these now use rubber inserts rather than metal bushes and pins. If it is good enough for the motor industry, why not for a wobbler. A rather soft rubber is required and the sort I used came from a draught excluder. However, I see no reason why a piece from an "O" ring of suitable cross section should not be used provided it is flexible enough. The rubber used needs to be about a quarter of an inch diameter. I have said rubber, but any synthetic equivalent would probably do the trick.

Construction

Well, having give a brief description of the design let's get on and make one. I've made a drawing of the one I constructed. The measurements fit well with my lathe which is a ML7 but none of the measurements are that critical, so feel free to improvise. A quick hunt through the scrap box should provide a suitable length of rectangular mild steel bar. The length is not critical. The pin of a wobbler does not have to be on lathe centre height but it helps if it is. It also makes the whole thing easier to construct.

The first step is to clamp our length of rectangular bar in the lathe tool post. It must be set at 90 deg. to the lathe axis. This is simply achieved by setting it parallel to the chuck face. Open the jaws a little and place a steel rule horizontal across the diameter of the chuck. Now bring the tool post up to the chuck and set the rectangular bar parallel to the outer edge of the steel rule. Clamp the bar tight in the tool post. Now to actually do a bit of machine work. Put a small centre drill in the chuck and adjust the cross slide so the centre drill will enter the rectangular bar about a quarter of an inch in from the end.

Start the lathe on a fast speed and centre drill the rectangular bar. Don't put too much pressure on or the drill may break, and don't forget to wear safety glasses. Don't alter the position of the cross slide. Remove the centre drill from the chuck and replace it with a $\frac{1}{8}$ in. drill. Drill a $\frac{1}{8}$ in. hole right through the bar. Now remove the drill and replace it with one the same diameter as the outside diameter of the rubber you wish to use. Drill into the bar but stop $\frac{1}{16}$ in. from the end of the hole so as to leave a shoulder. This shoulder will stop the rubber going right through.

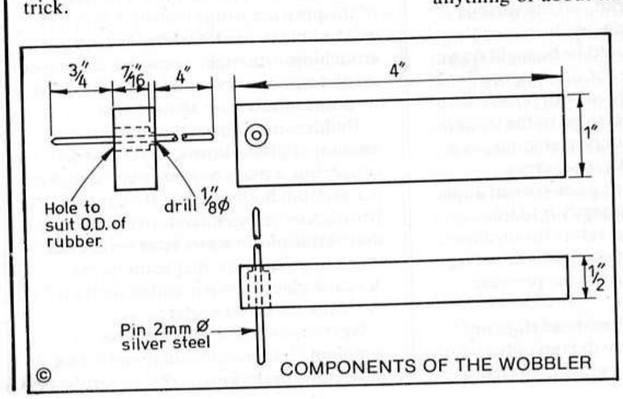
Don't move the cross slide yet. Take the drill out of the chuck. Now to make the pointer. I used an old bike spoke but anything of about that diameter would be suitable. Grind a point on each end of the pointer rod. I did this on a bench grinder. I don't suppose it matters too much if the points are not quite true. We are now at the hardest point of the whole project. Cut off a short length of the rubber, about $\frac{3}{8}$ in. should be plenty. Push this piece of rubber into the hole in the rectangular bar. Now grip the pointer rod in the chuck with about half an inch left sticking out. Move the saddle toward the chuck and force the pointer rod through the rubber. Release the chuck and repeat the operation until the pointer is the correct distance through the rubber. Don't have the lathe running for this operation or you will just screw the rubber up. Well there we go, it is finished.

Use

You want to test it. Well why not. Get a short offcut of round bar and put a punch mark where you think the centre is. Put this in the chuck and enter the point of the wobbler into the centre punch mark. Turn the chuck by hand and observe the far end of the wobbler. How good was your guess at centre? Remember, this particular wobbler will multiply your errors by a factor of about five. Wind the cross slide to clear the wobbler and with a centre drill in the tailstock chuck must put a shallow centre in the offcut which is still in the chuck. Now stop the lathe and test this with the wobbler. The far end of the pointer should be steady. You will also notice the wobbler still works even if it is not exactly on centre.

On the wobbler I made I didn't have to glue the rubber in place. The act of forcing the pointer through it caused it to expand and grip, in the hole. If you are not as lucky, a spot of glue may be required. *(I used a dab of superglue – Ed.)*

I was so impressed when I read the article that this one was made for use in my own workshop. Rubber used was from a lorry tyre, a tread section collected at the side of the motorway! – Ed.



COMPONENTS OF THE WOBBLER

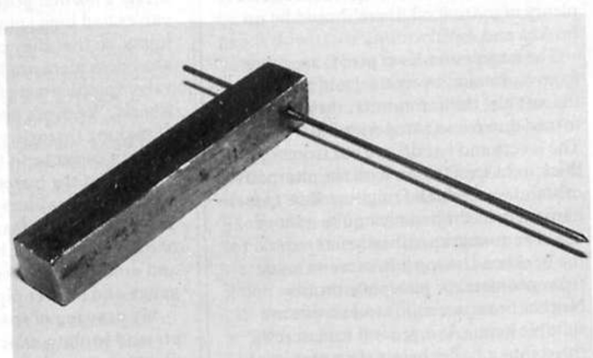


Figure 14: Making a Wobbler

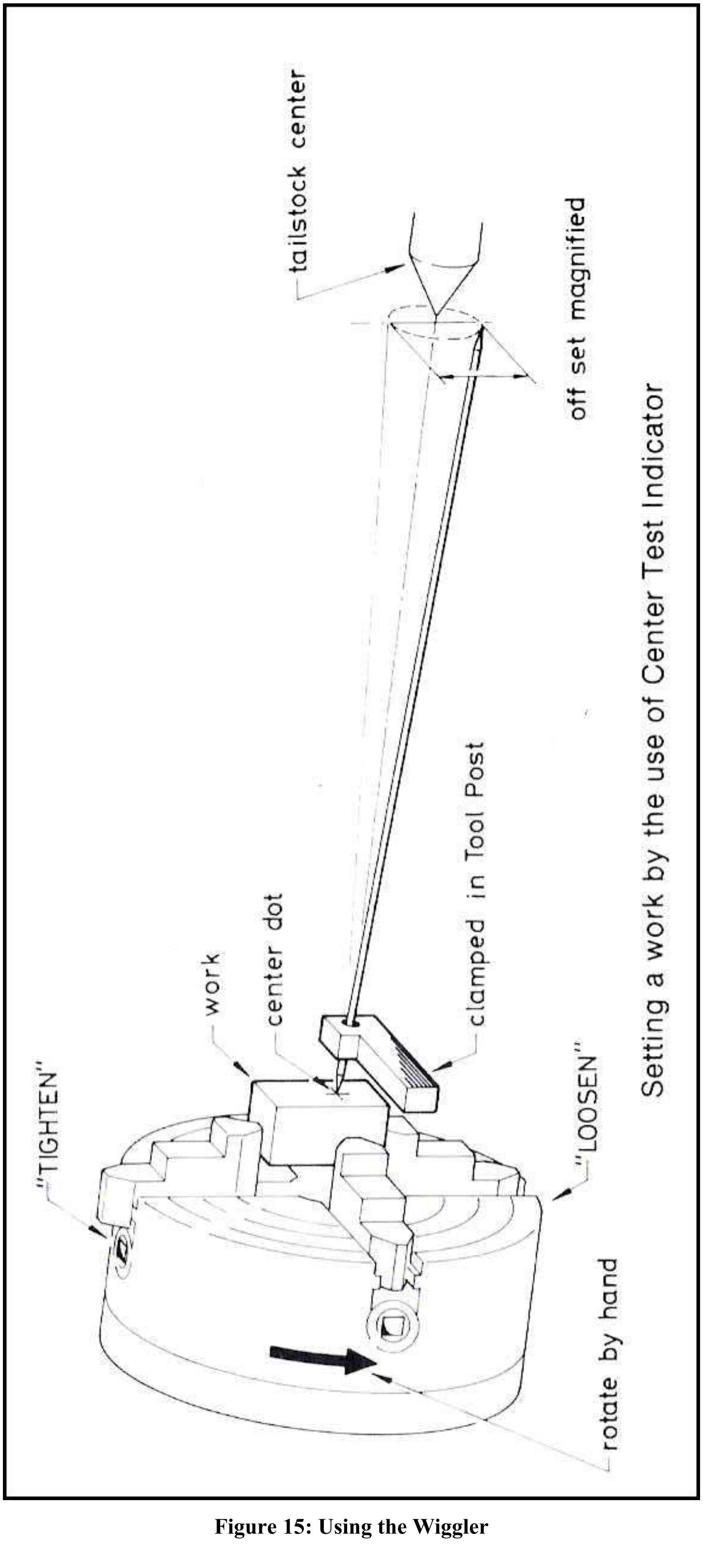


Figure 15: Using the Wiggler

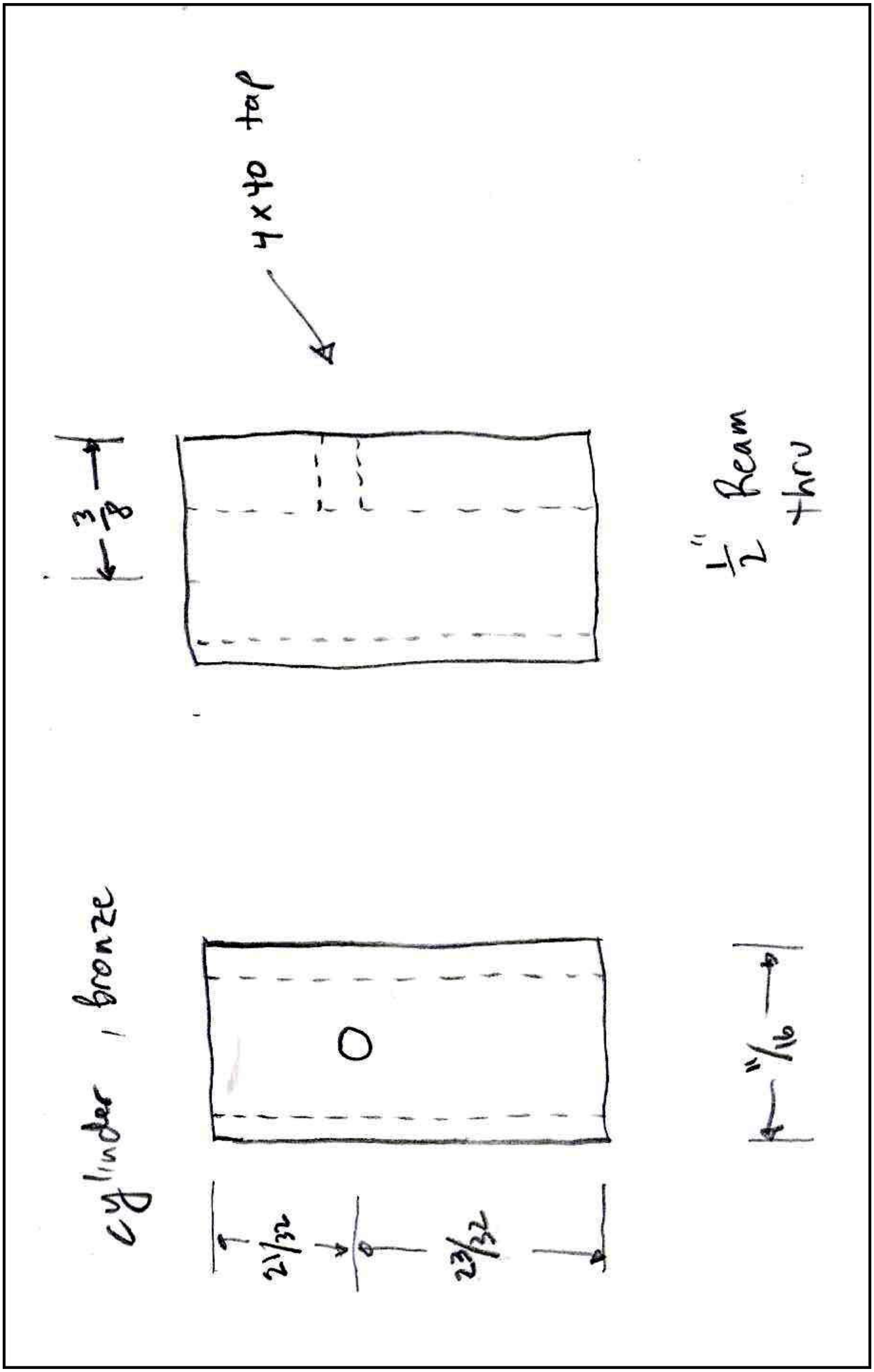


Figure 16: Cylinder Drawing

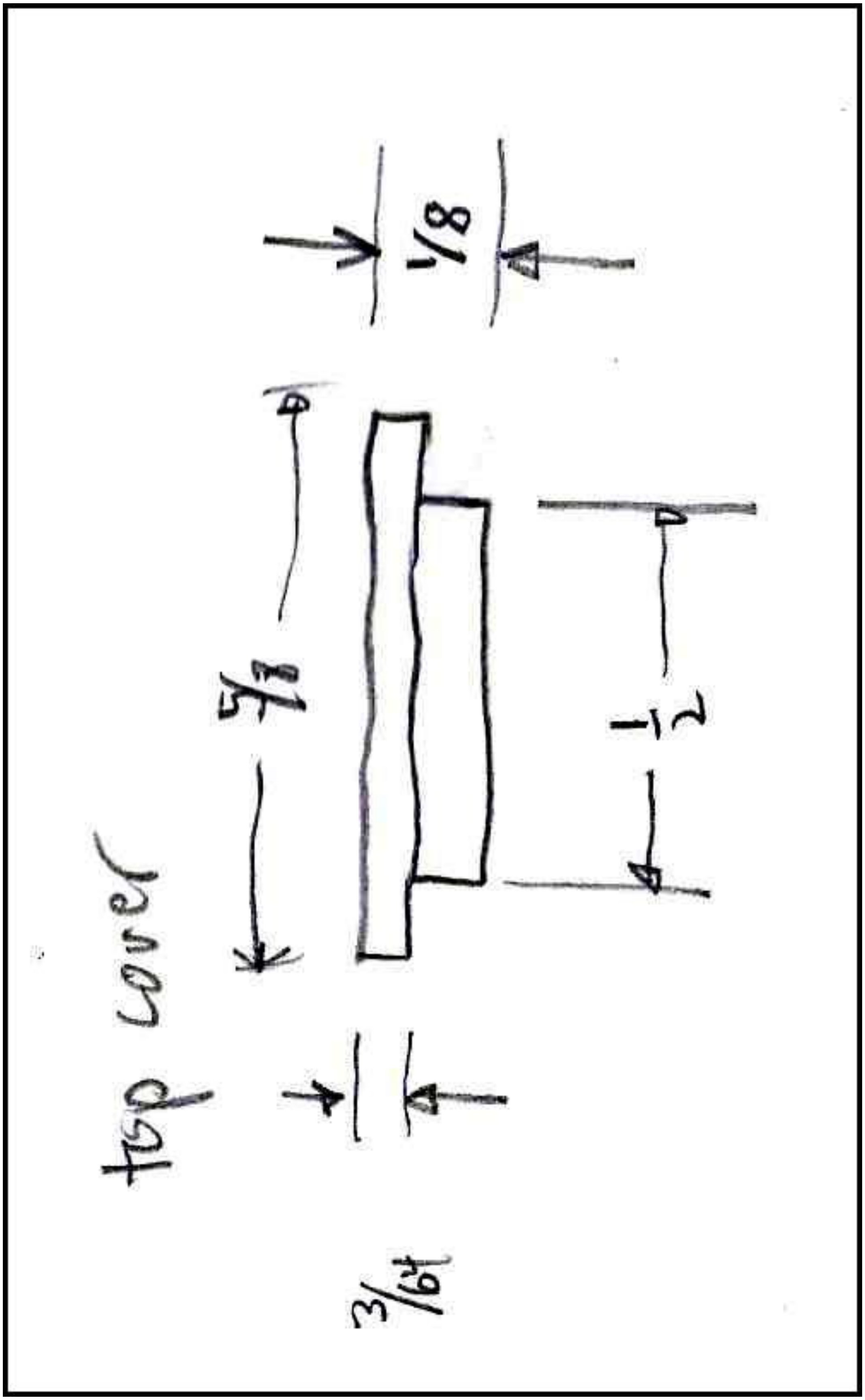


Figure 17: Cylinder Top Cover

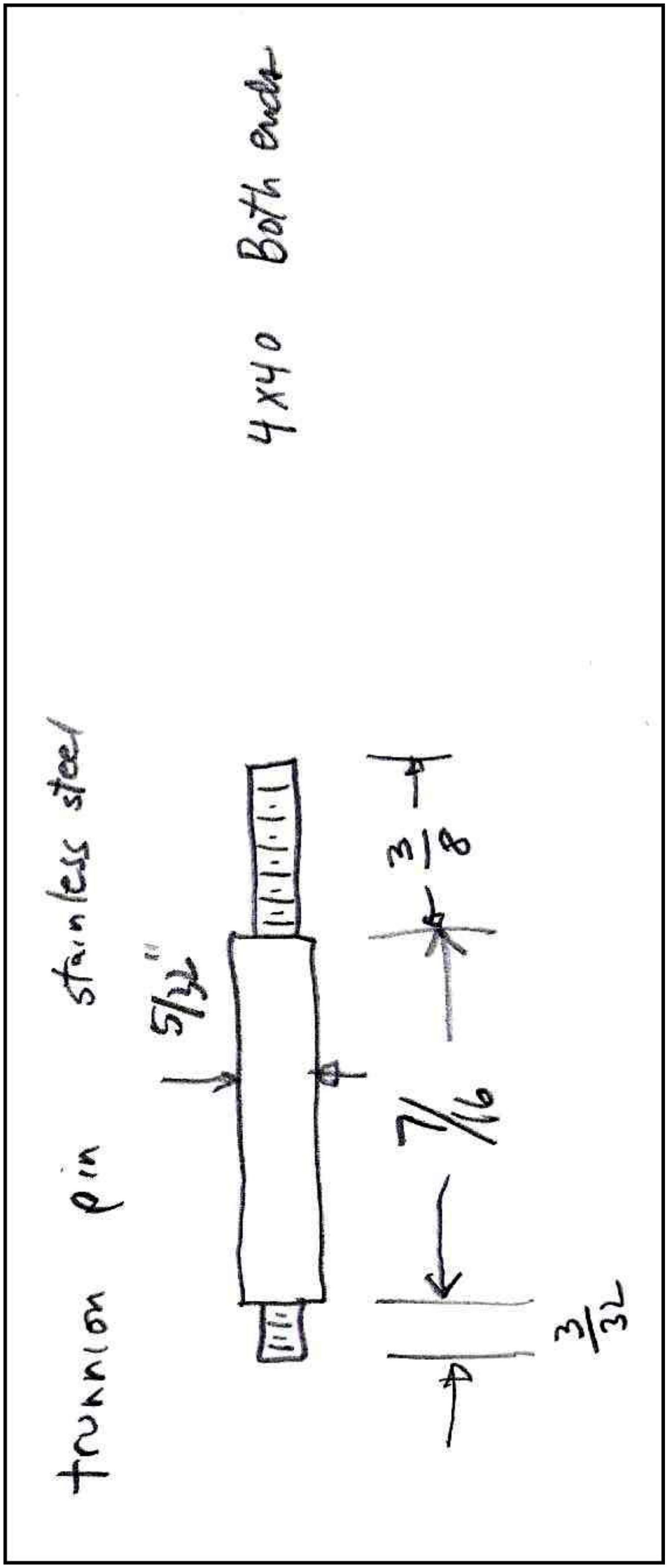


Figure 18: Steam Cylinder Trunnion Pin

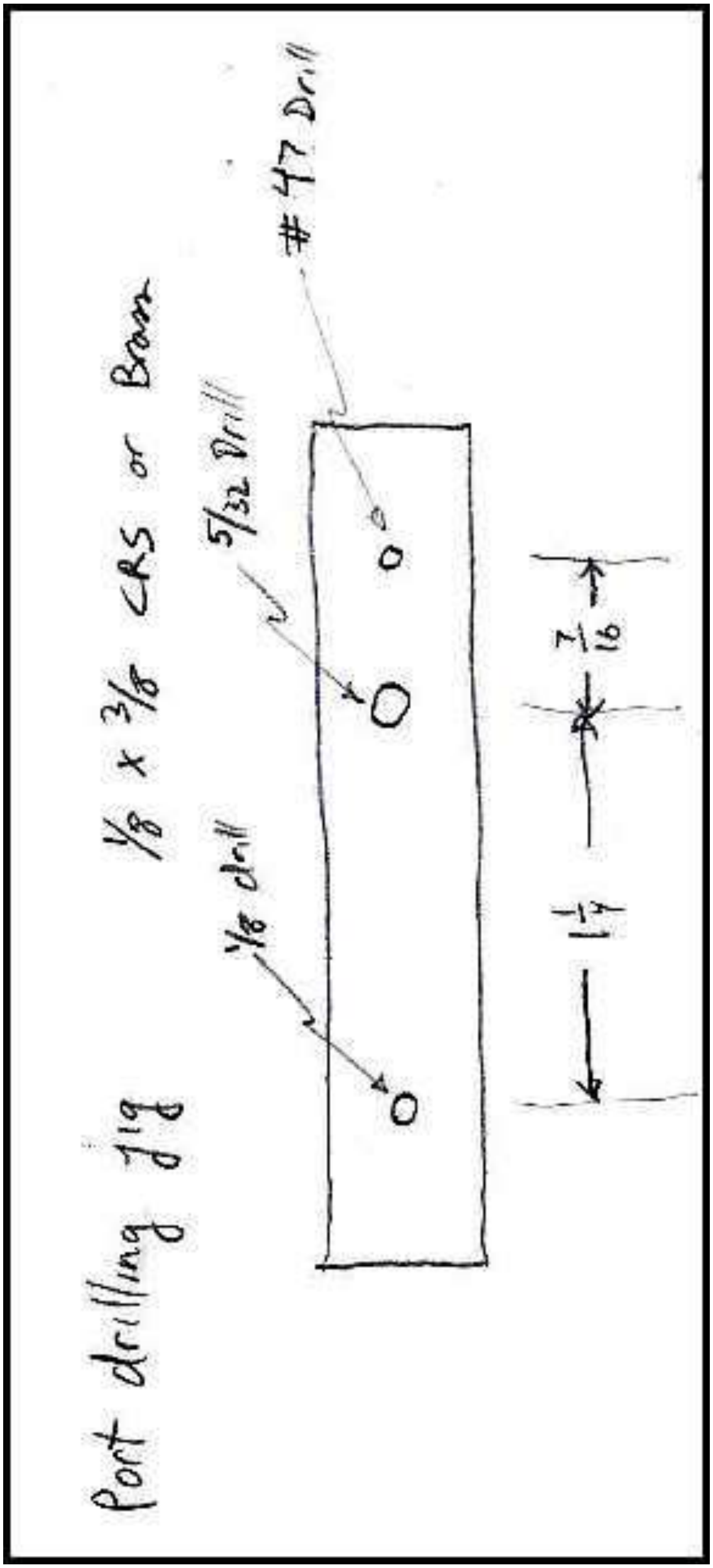


Figure 19: Steam & Exhaust Port - Drilling Jig

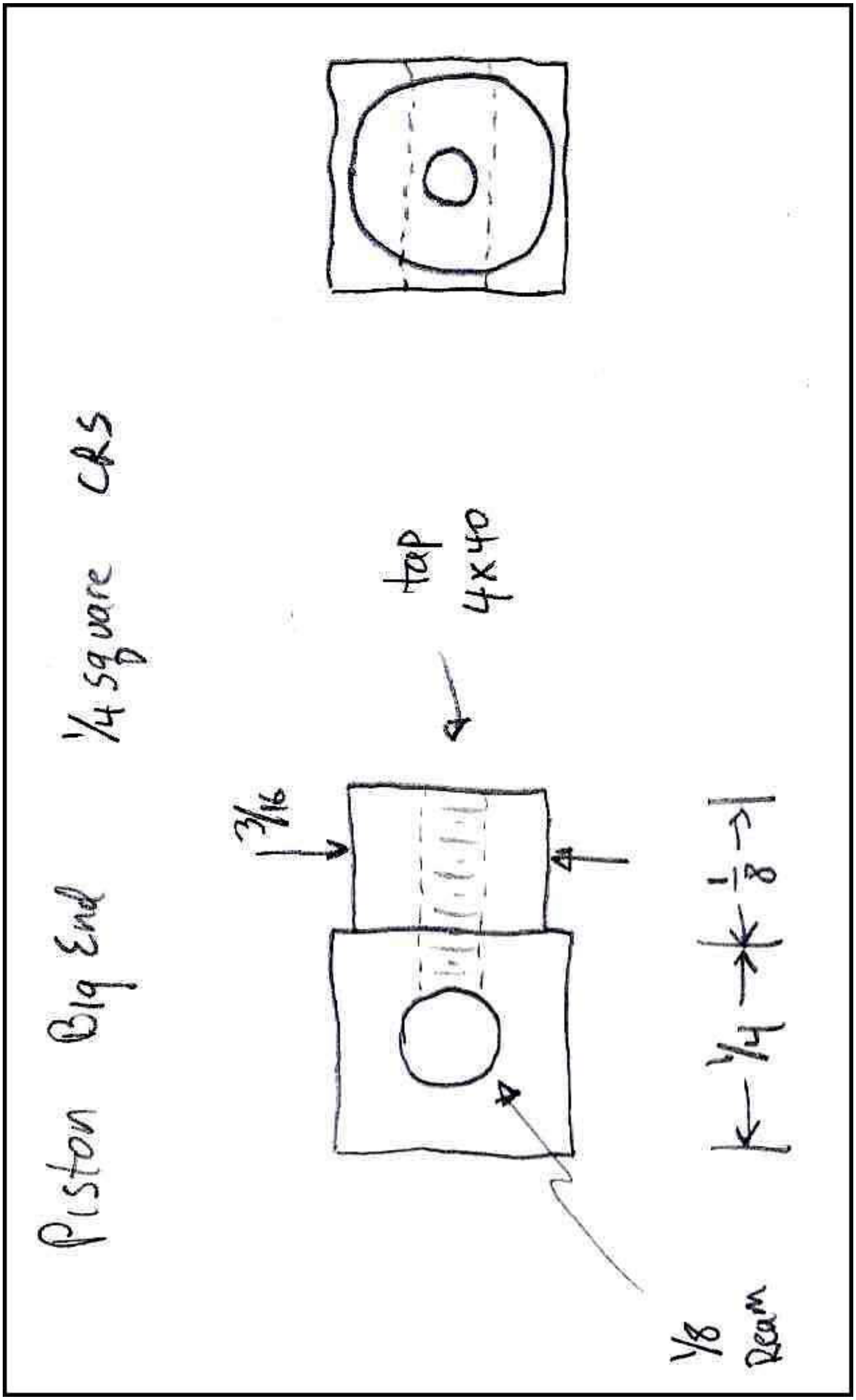


Figure 20: Steam Piston - Big End

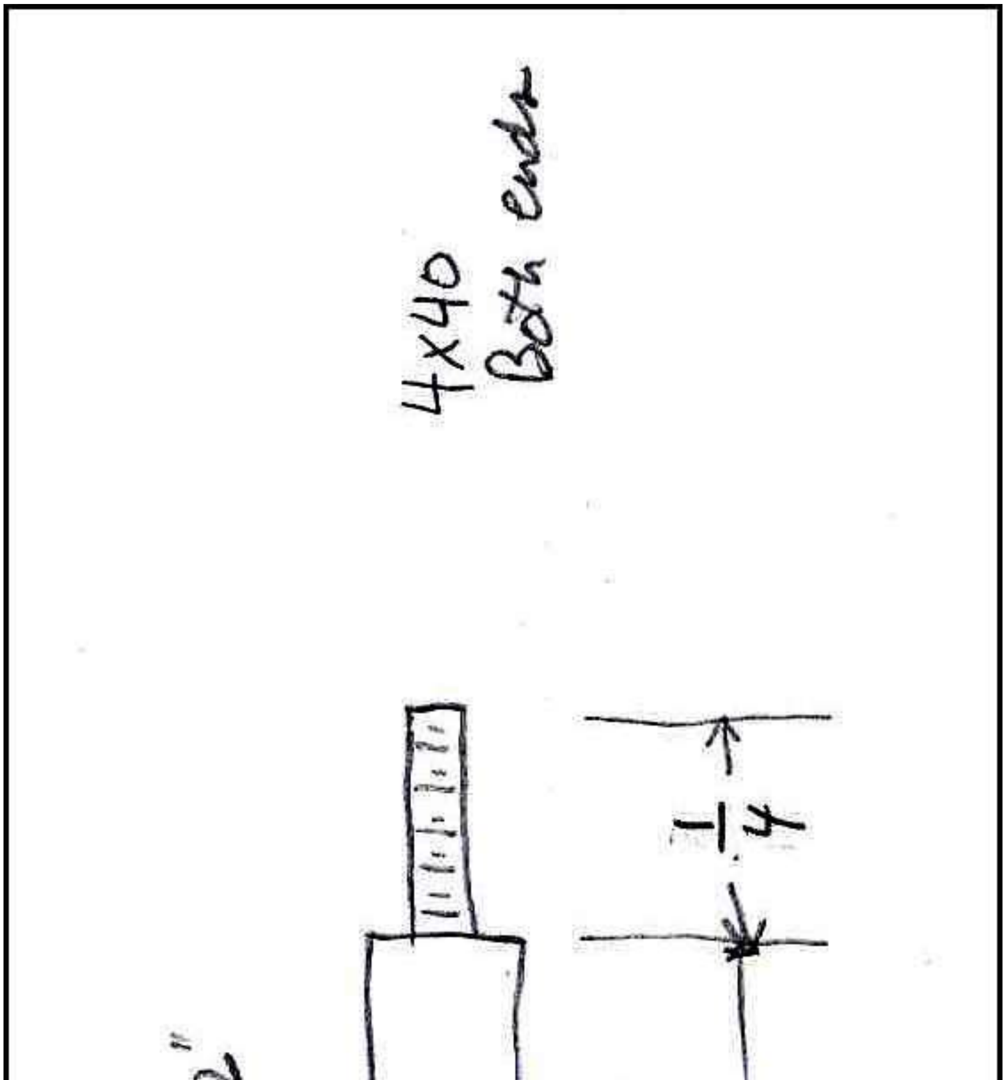


Figure 21: Piston Rod

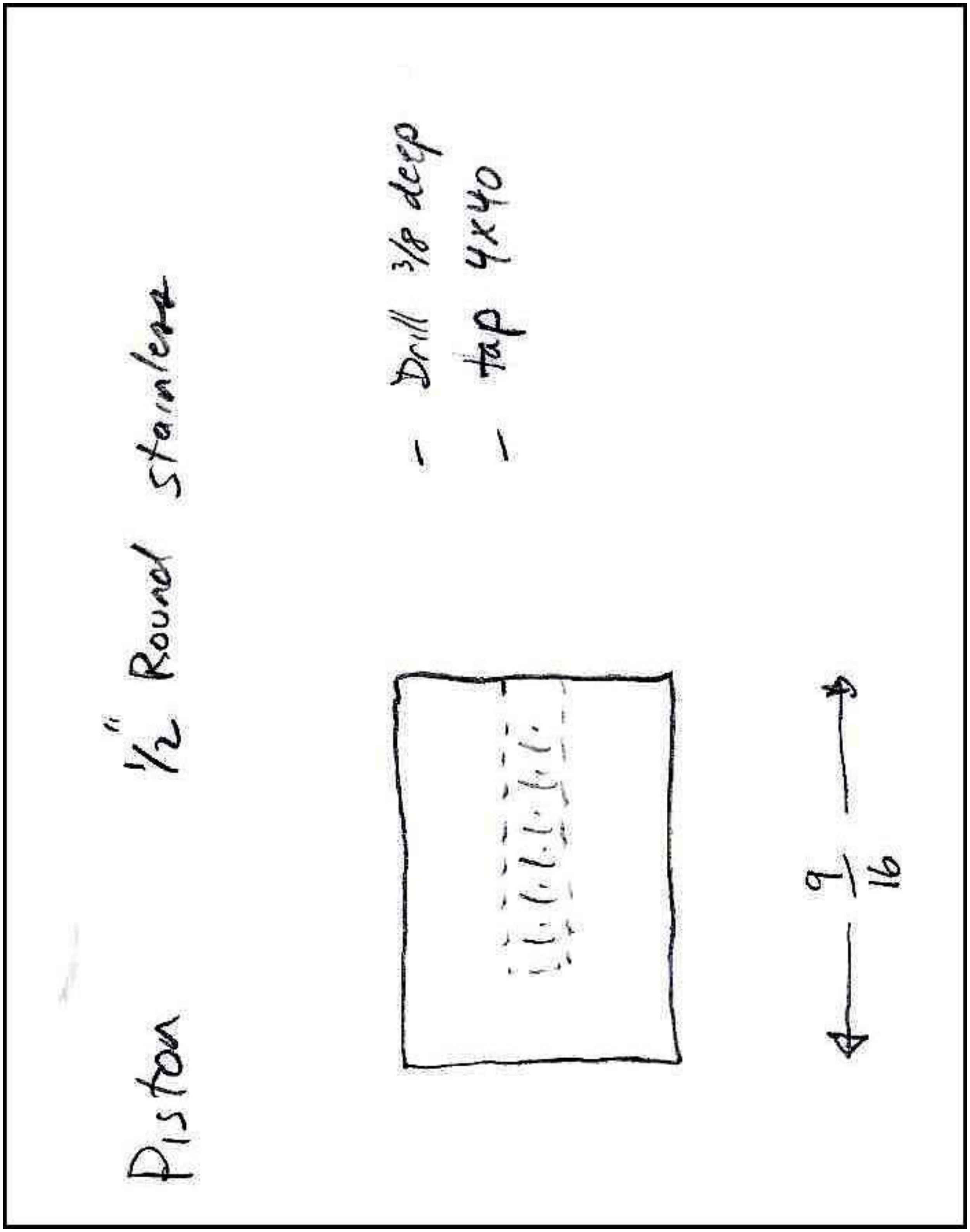


Figure 22: Steam Piston

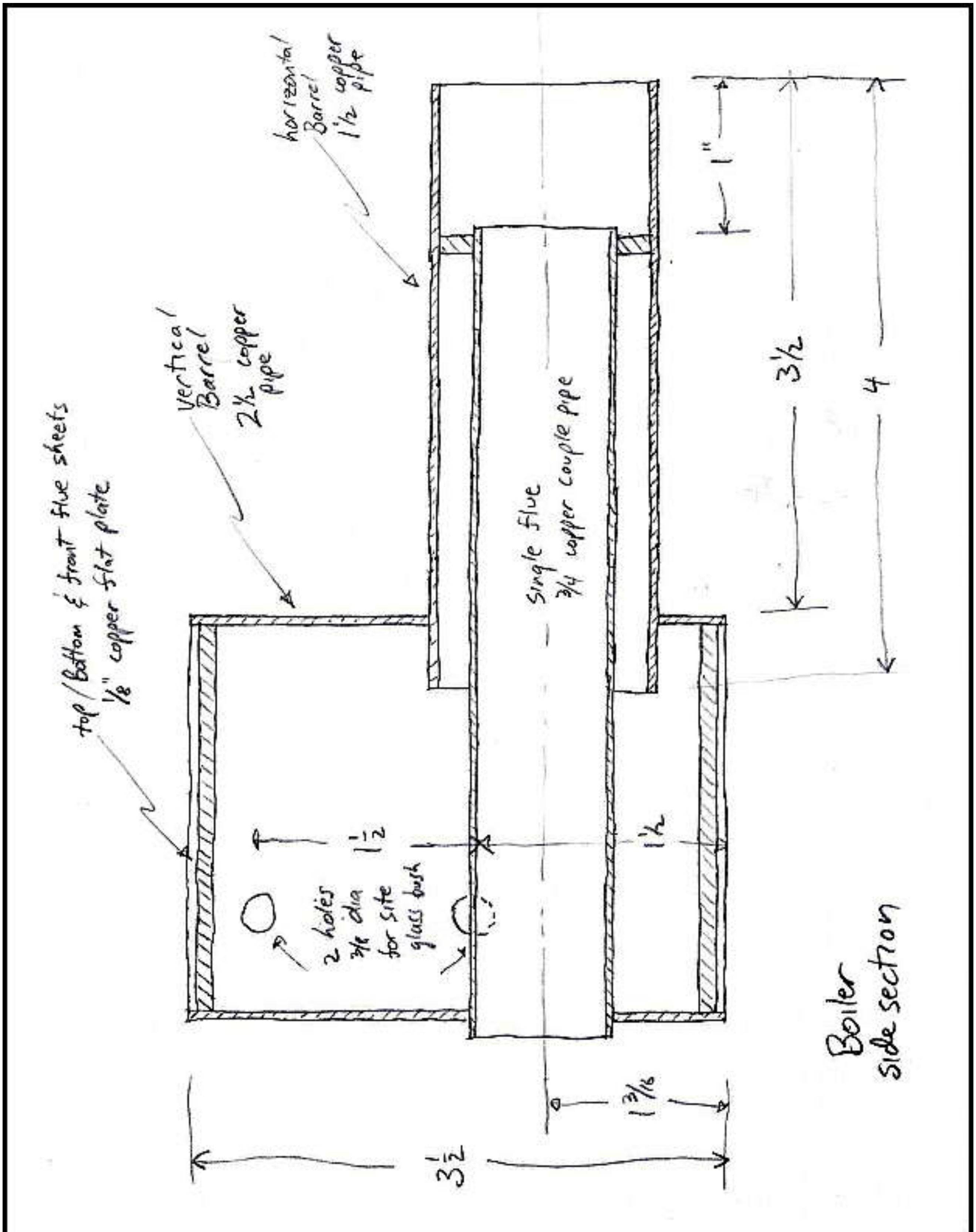


Figure 23: Boiler Page 1

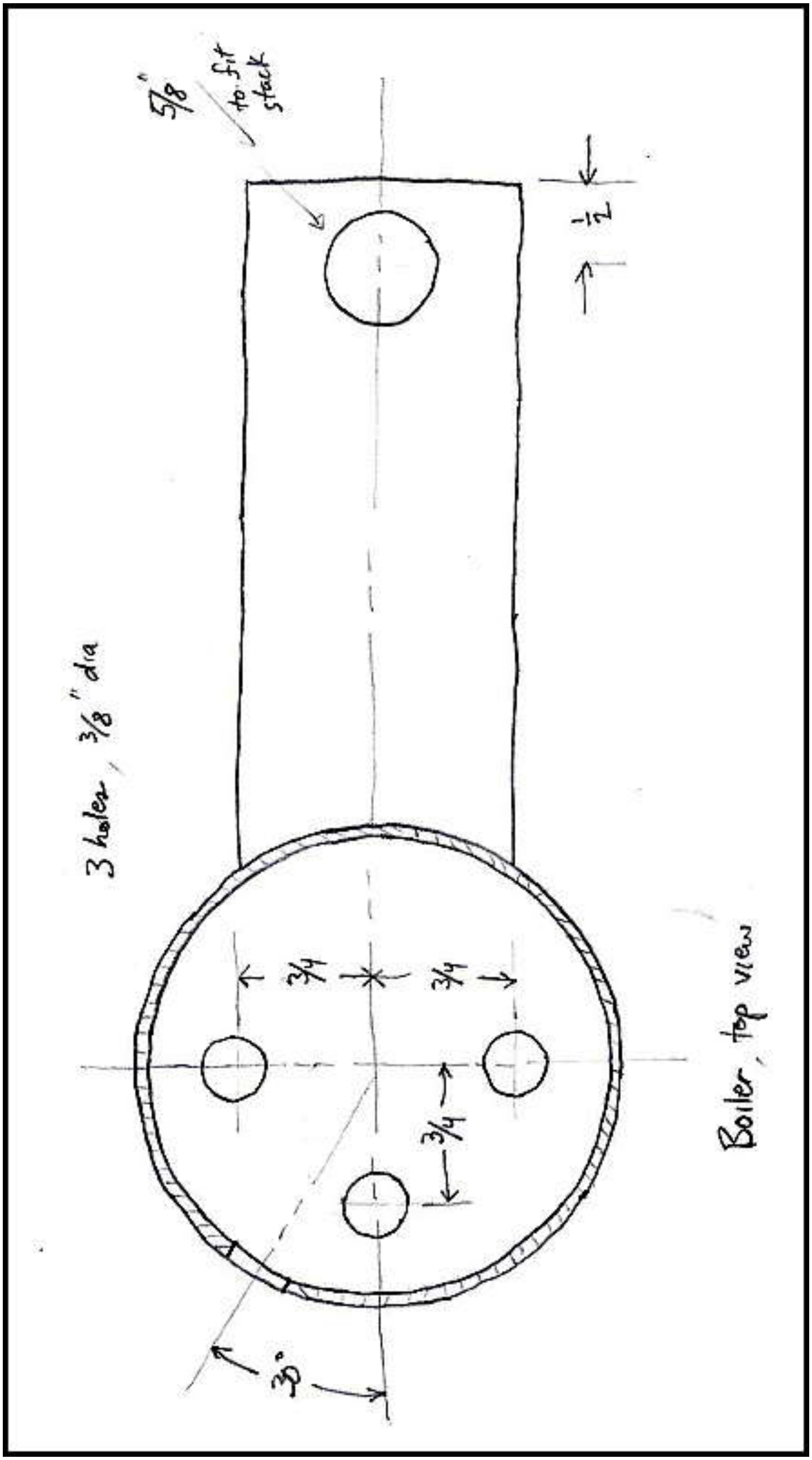


Figure 24: Boiler Page 2

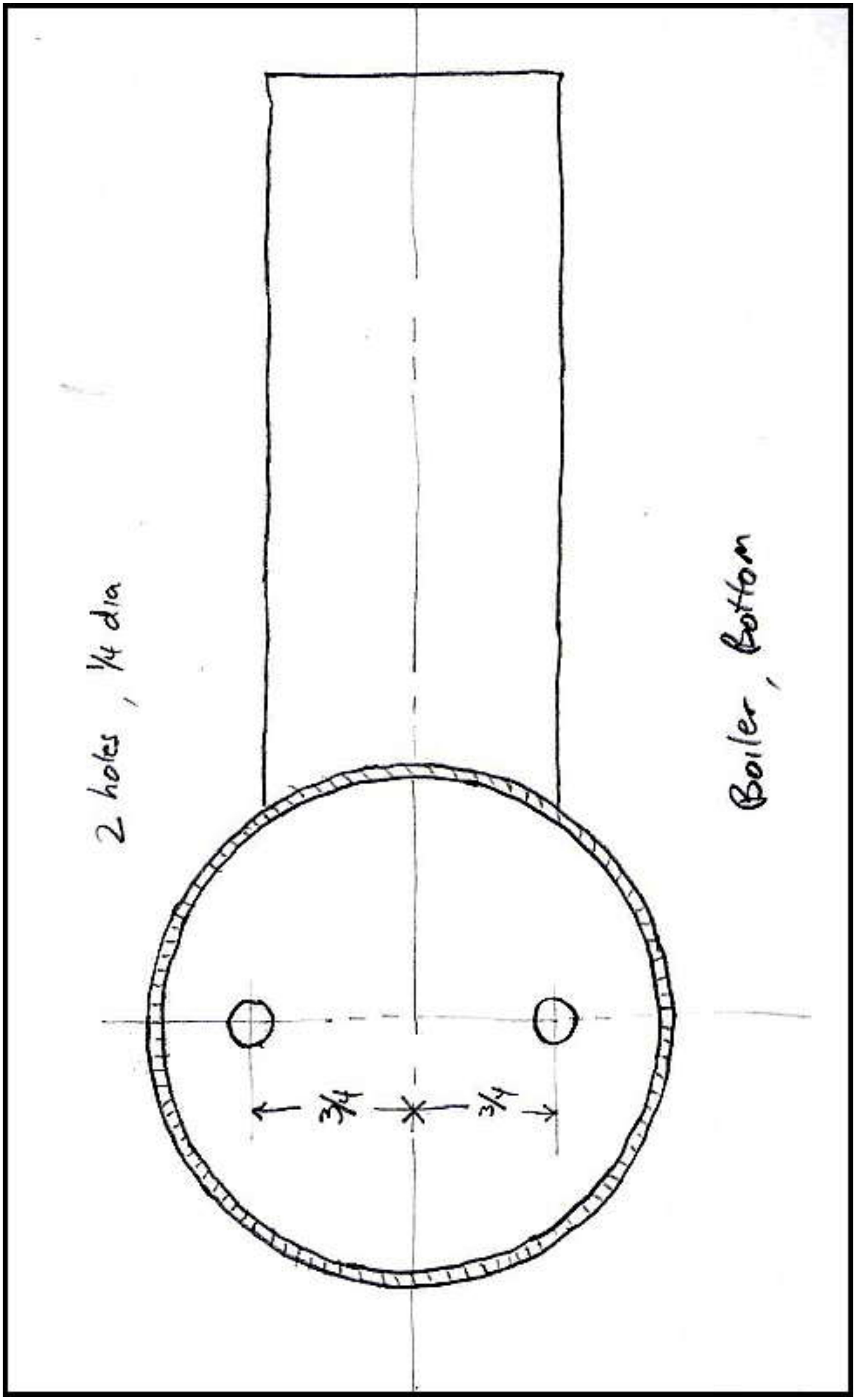


Figure 25: Boiler Page 3

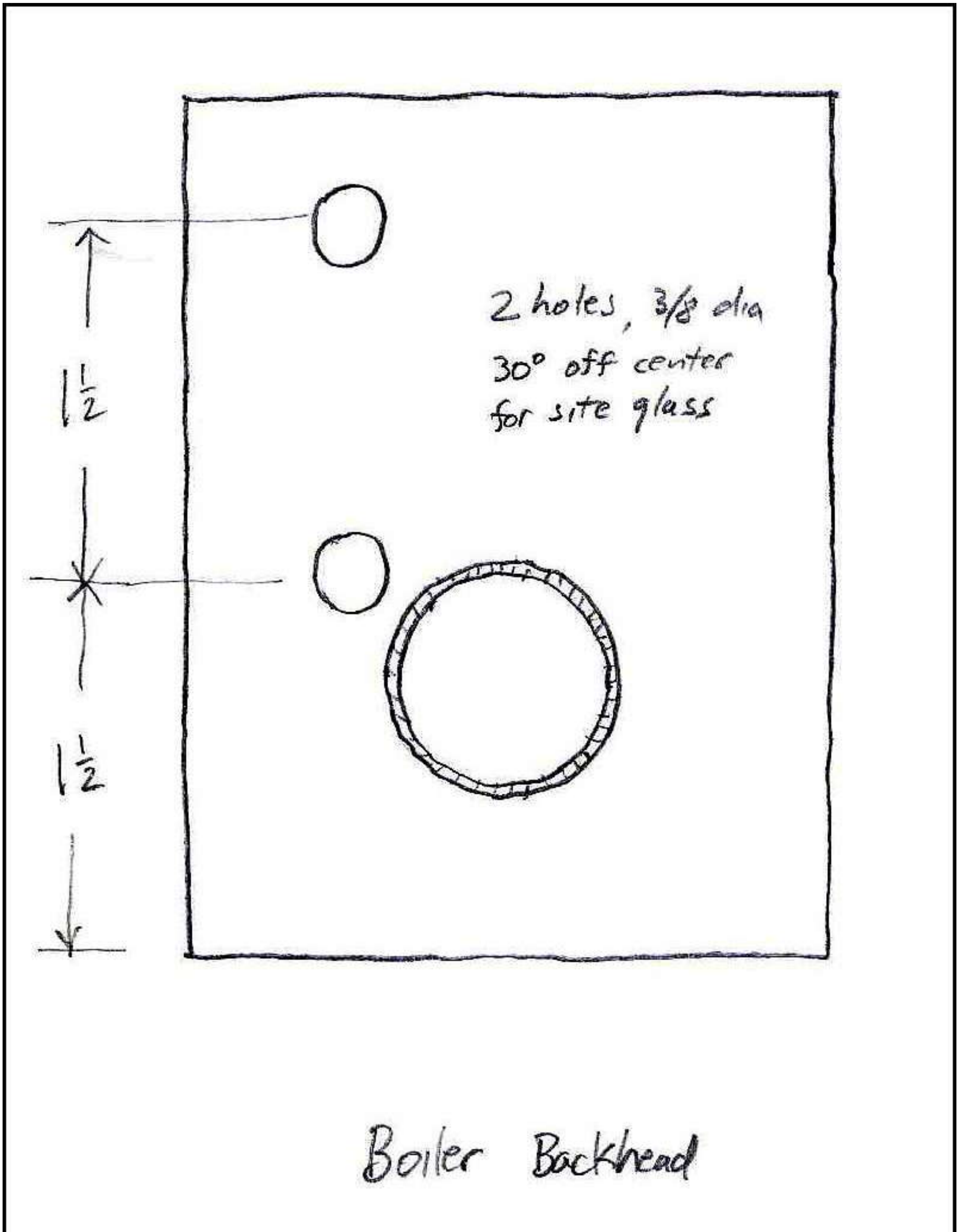


Figure 26: Boiler Page 4

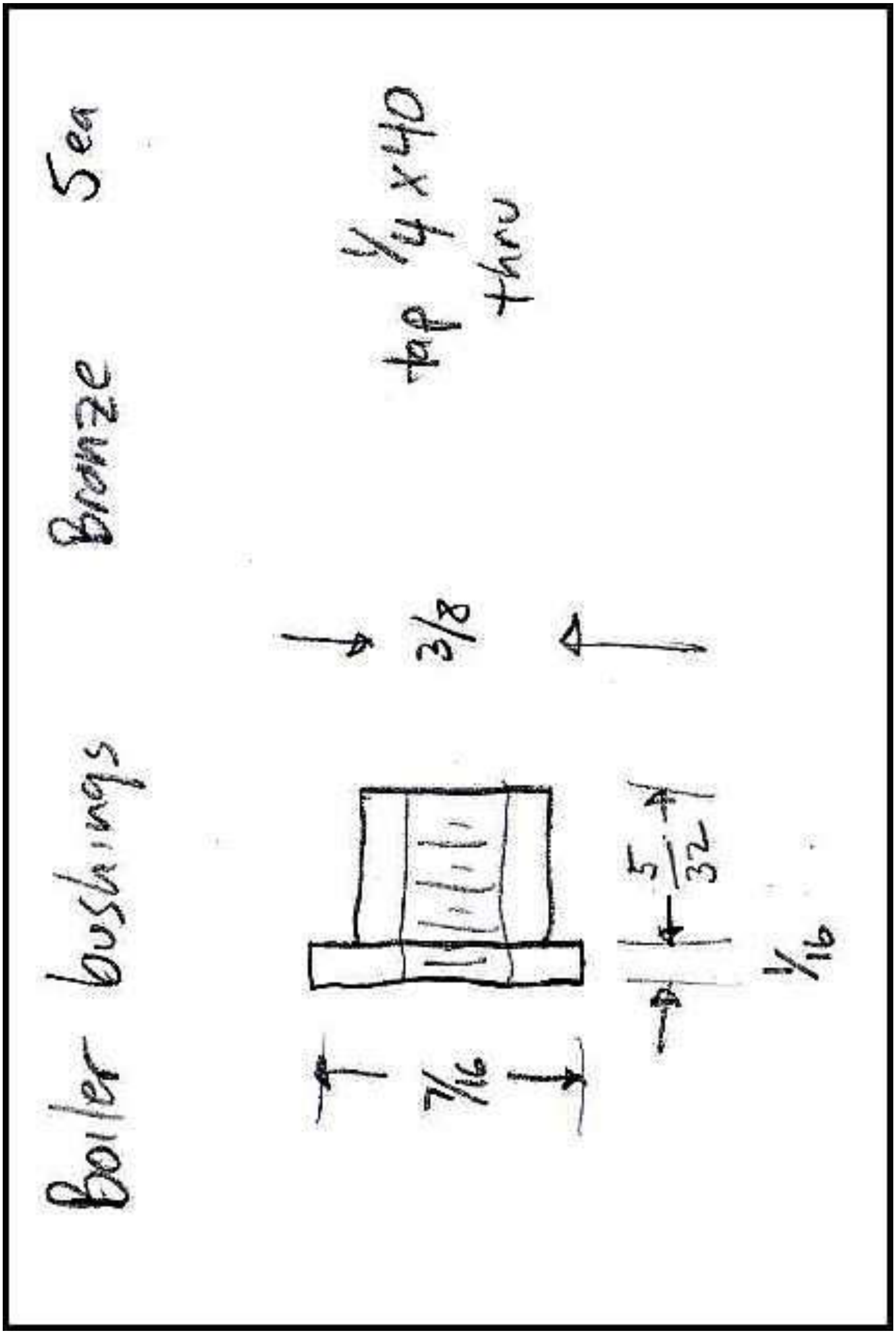


Figure 27: Boiler Bushing - 1

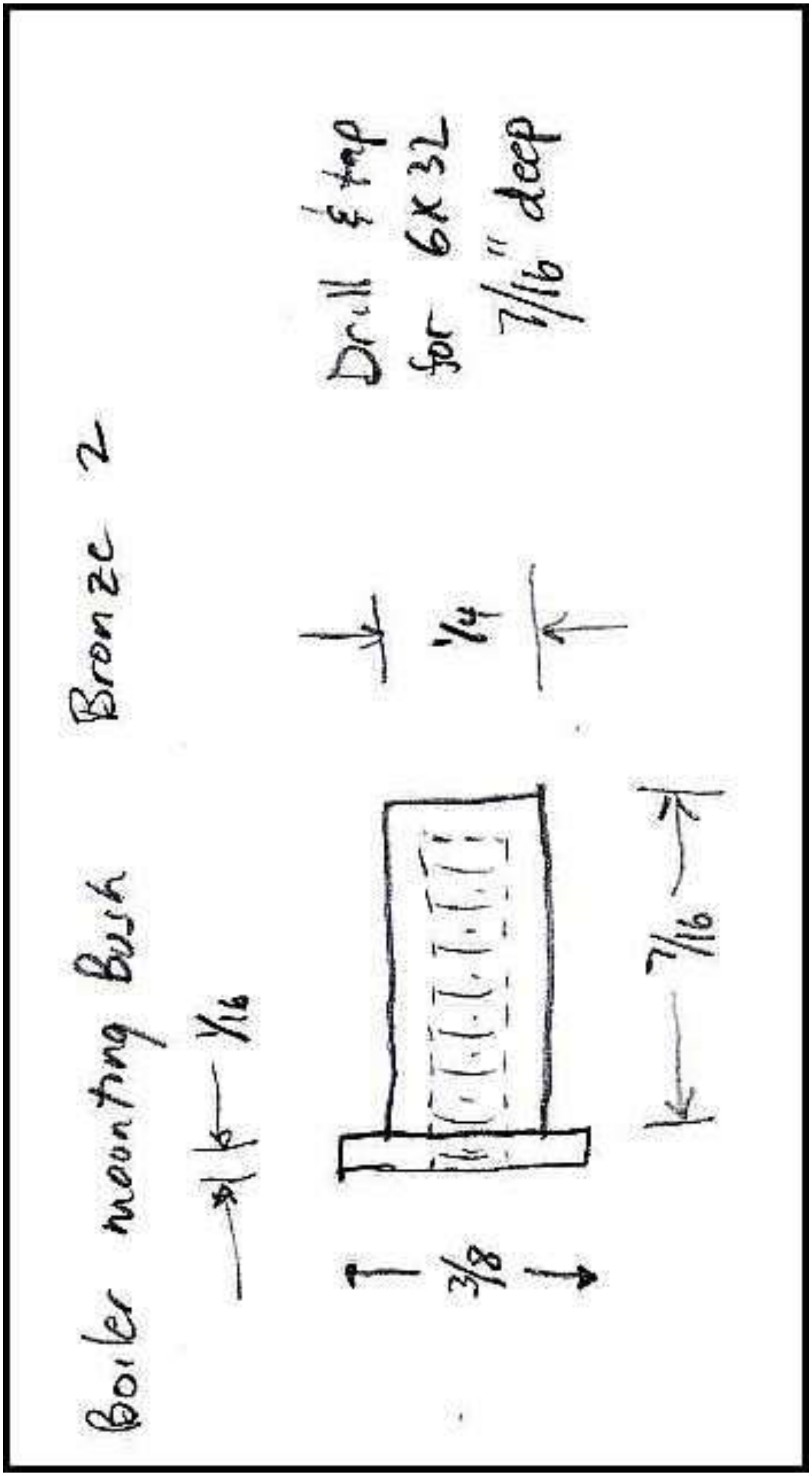


Figure 28: Boiler Bushing - 2

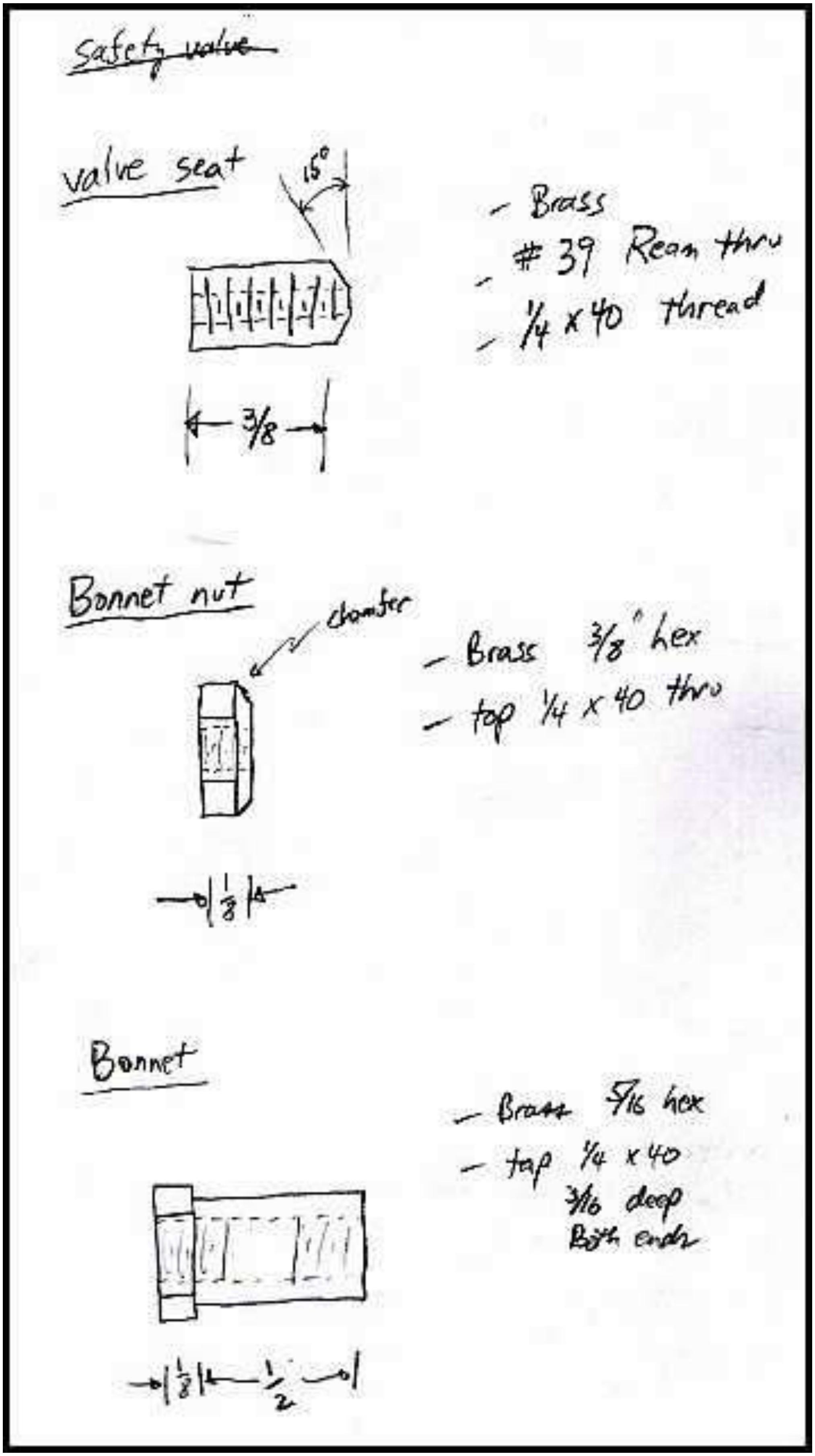


Figure 29: Safety Valve - 1

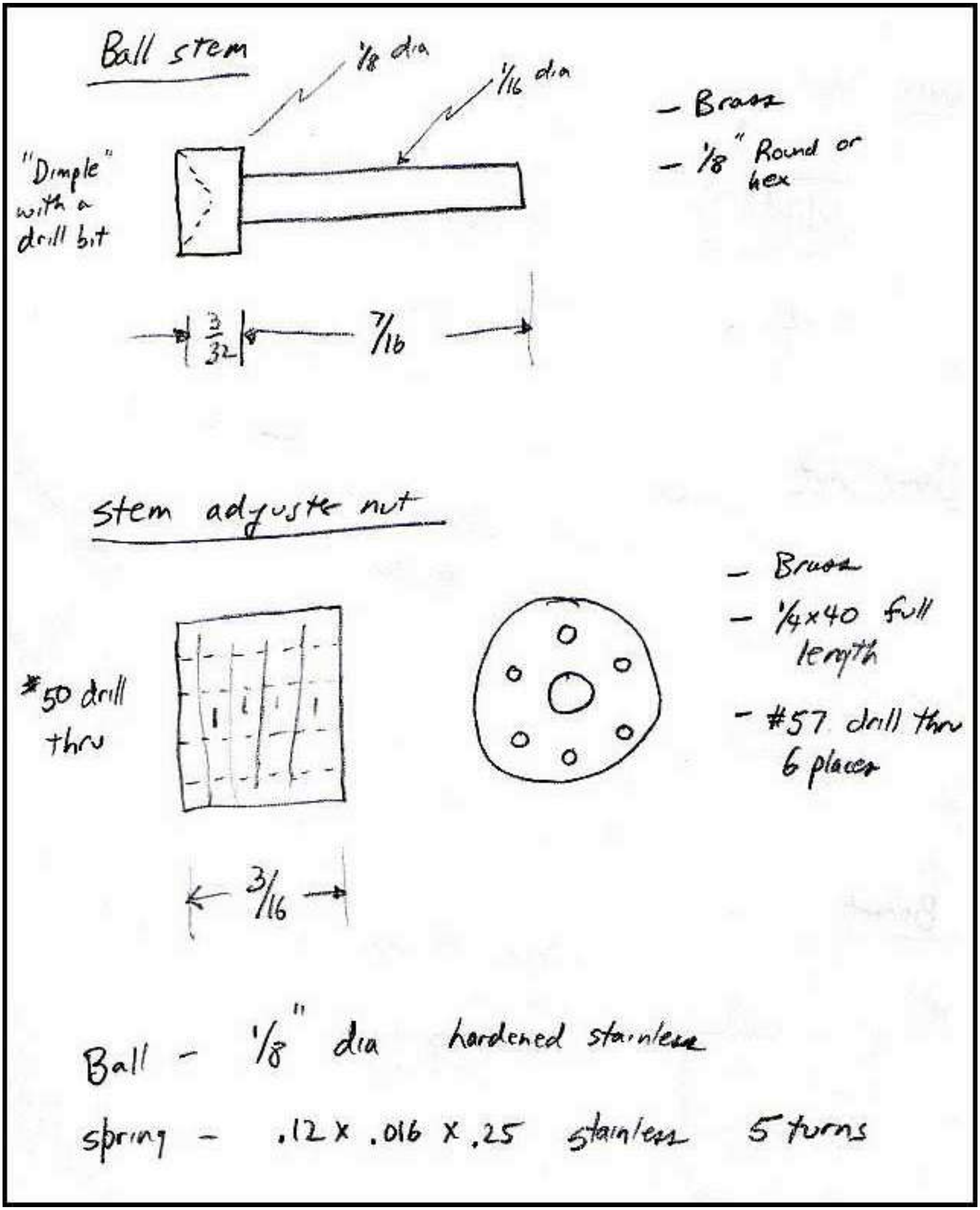


Figure 30: Safety Valve - 2

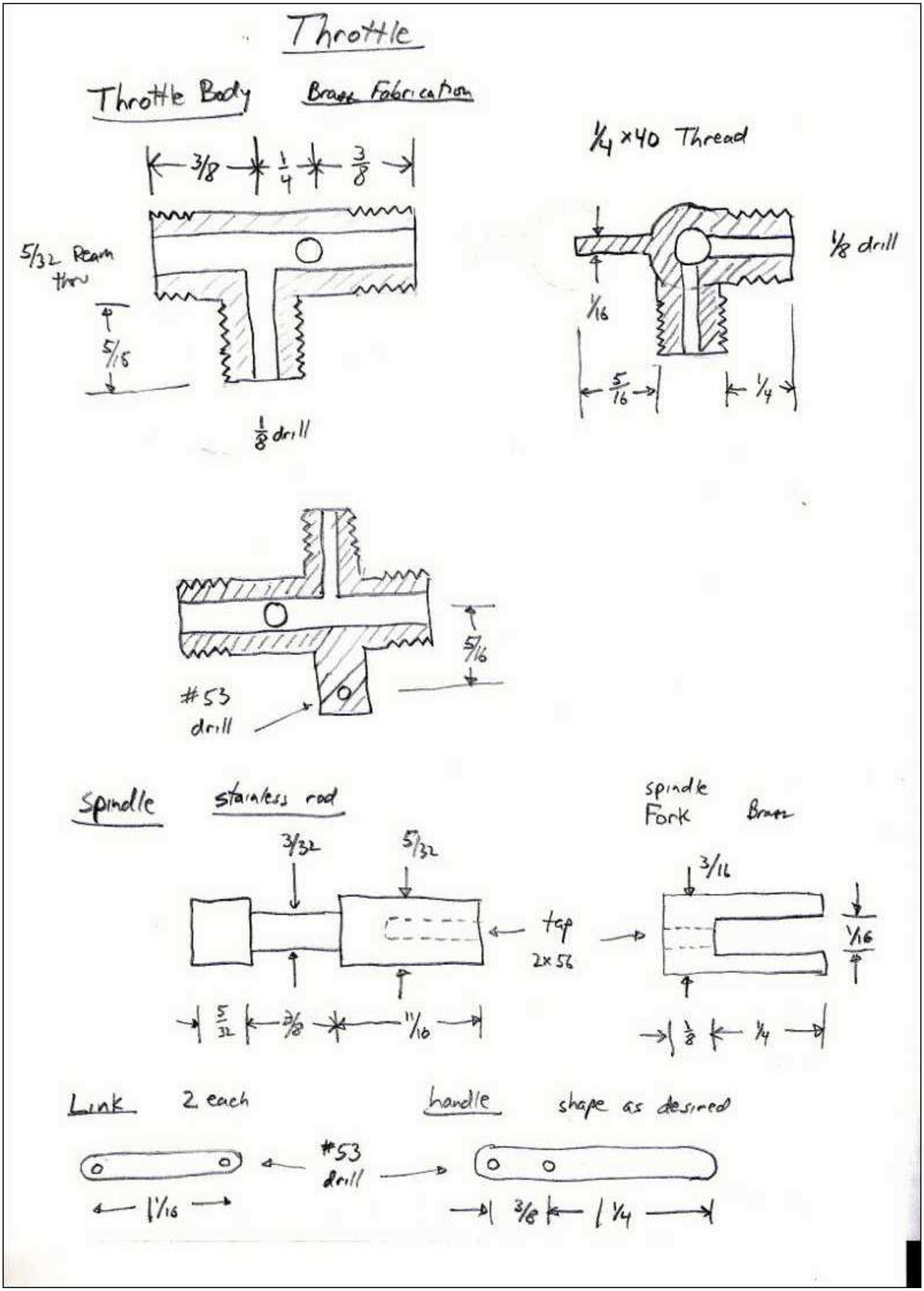


Figure 31: Throttle Piston Type

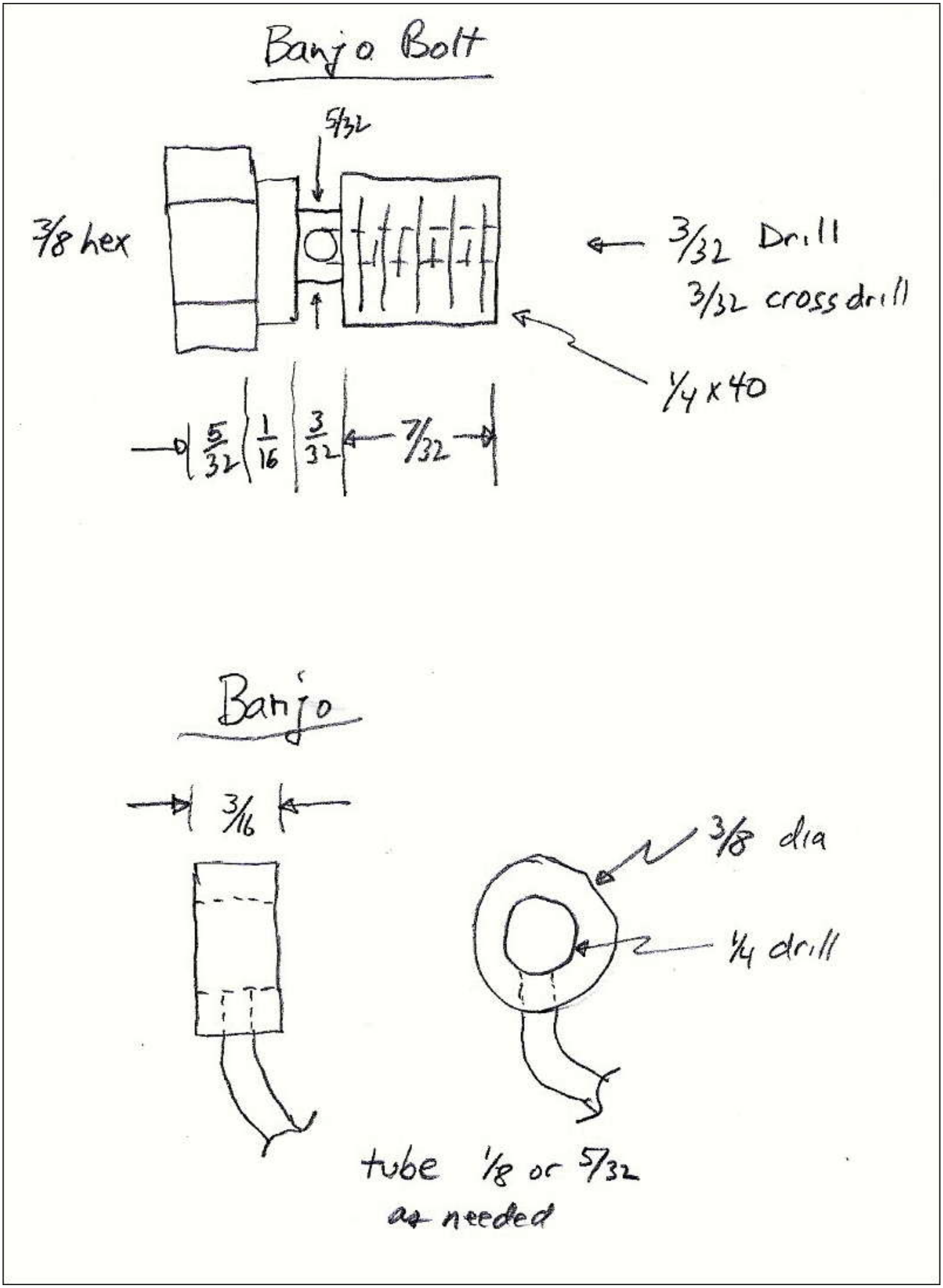


Figure 32: Banjo Bolt Shop Drawing

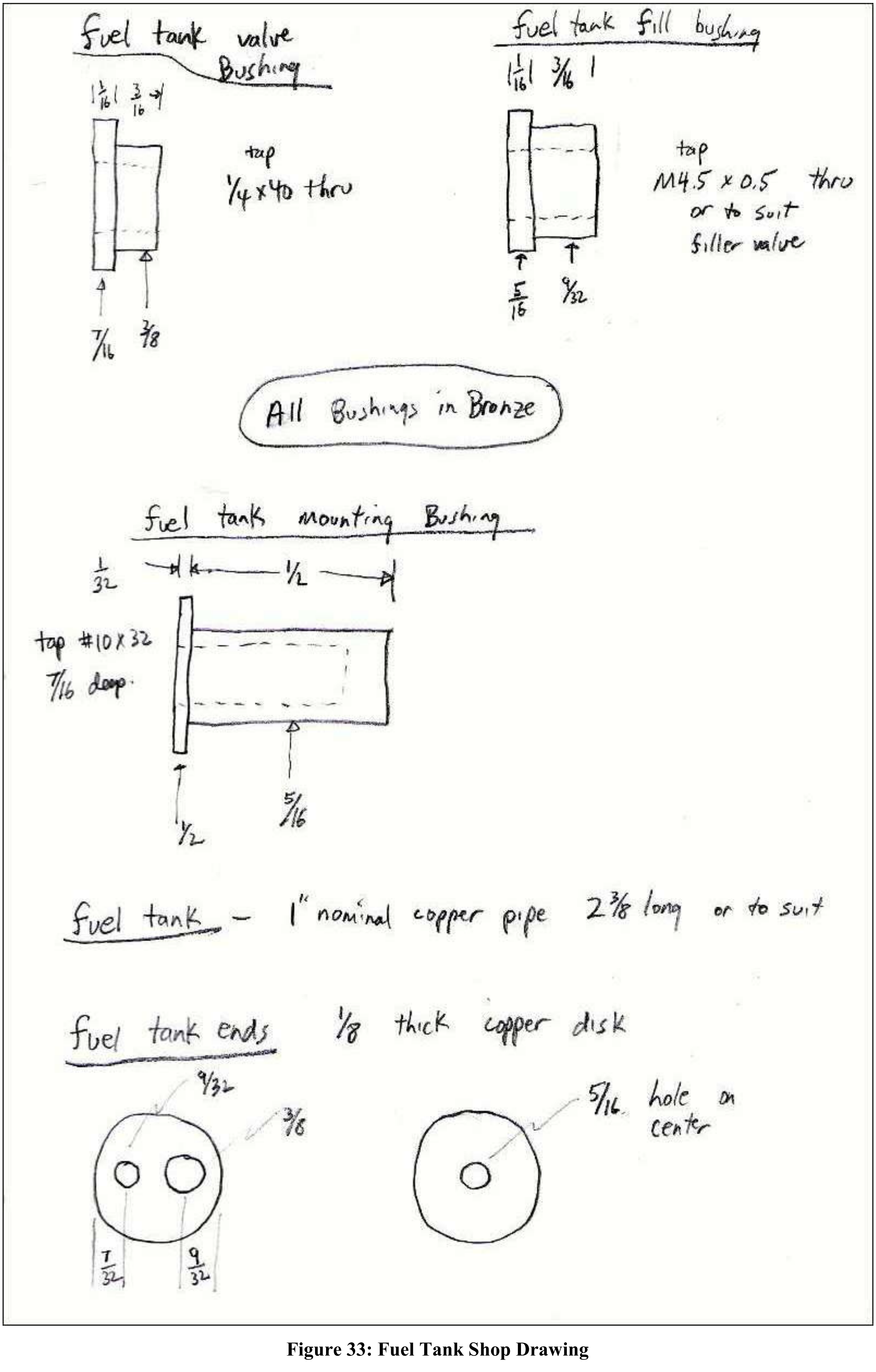


Figure 33: Fuel Tank Shop Drawing

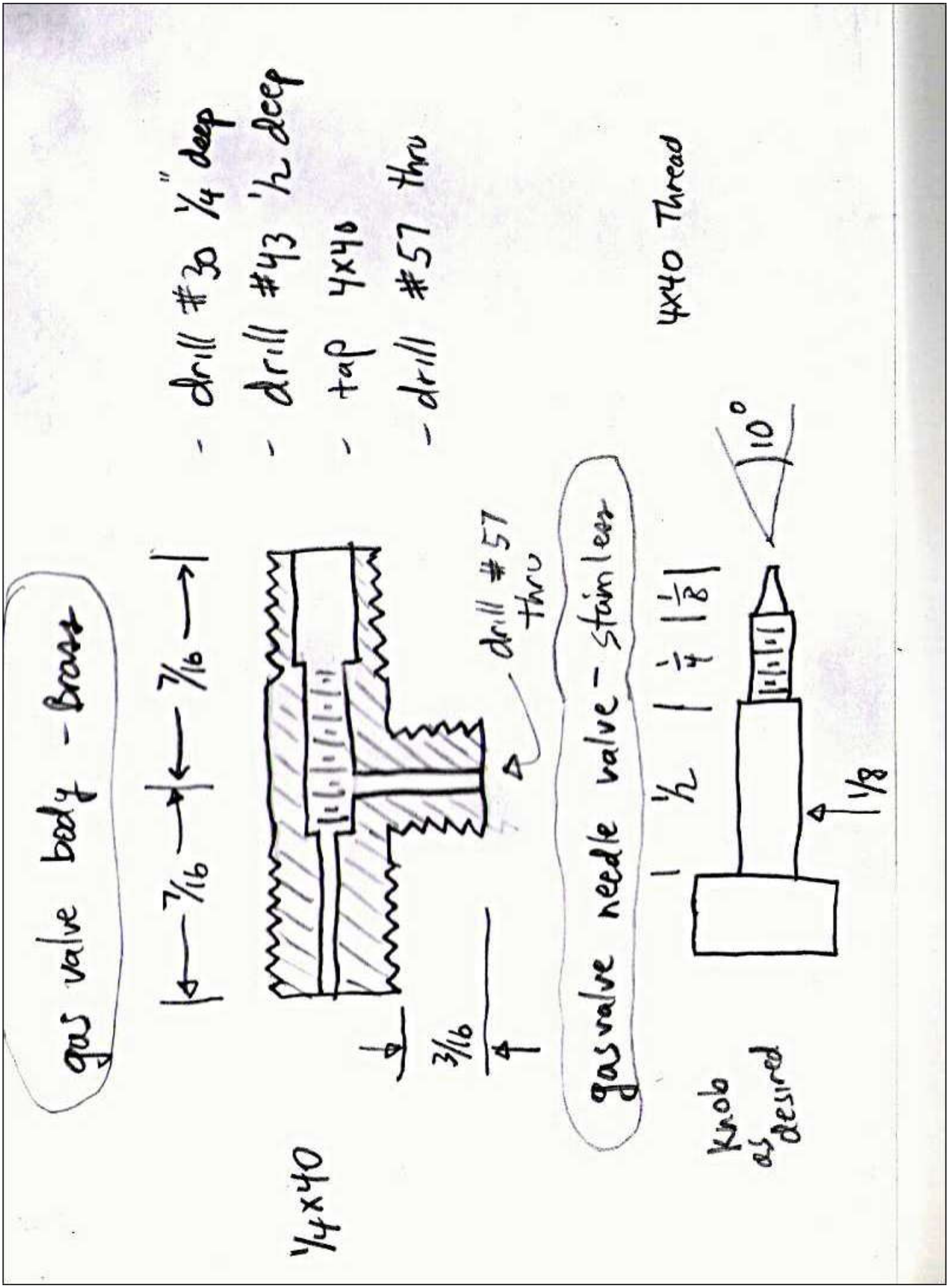


Figure 34: Fuel Valve Shop Drawing

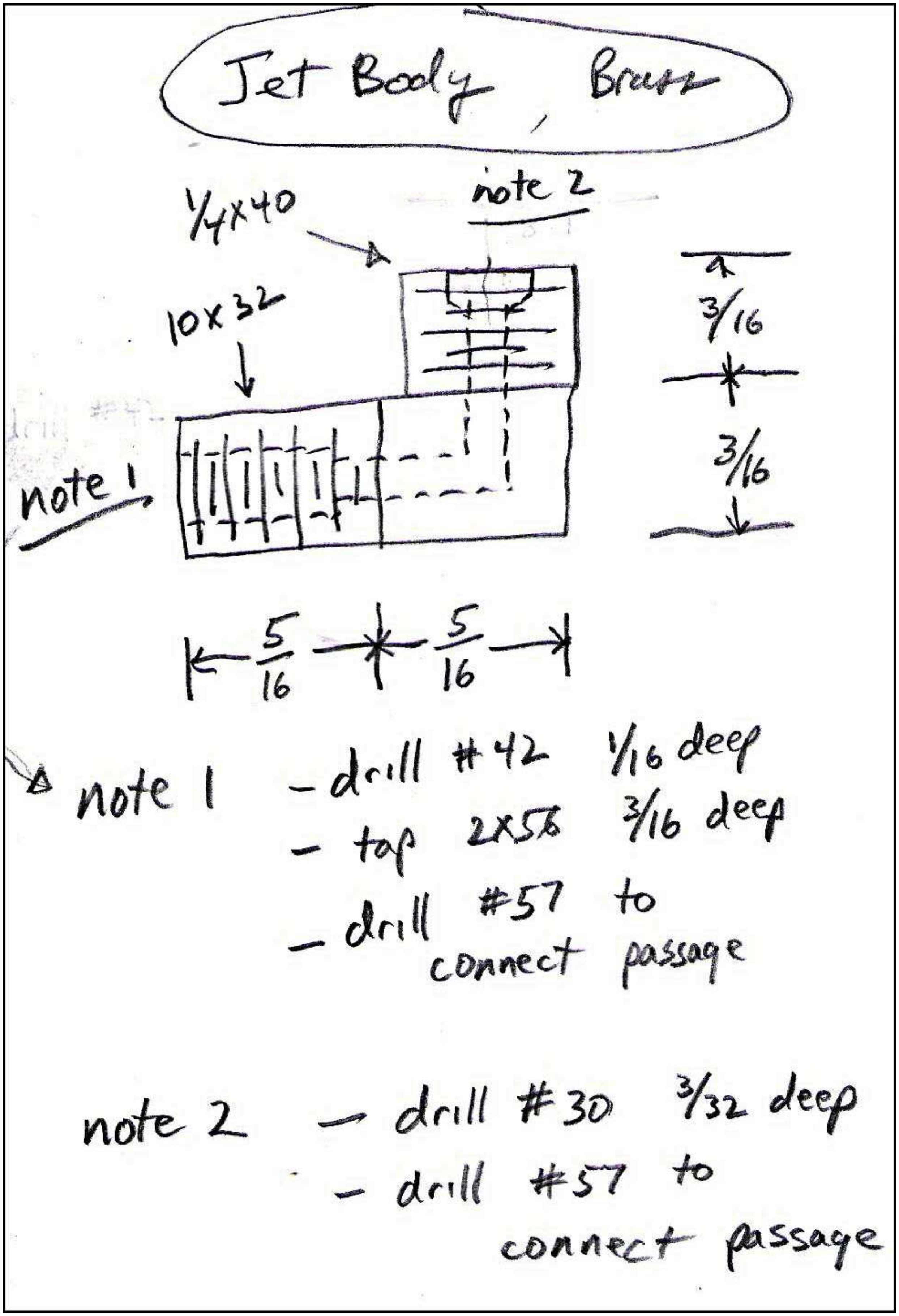


Figure 35: Gas Jet Body

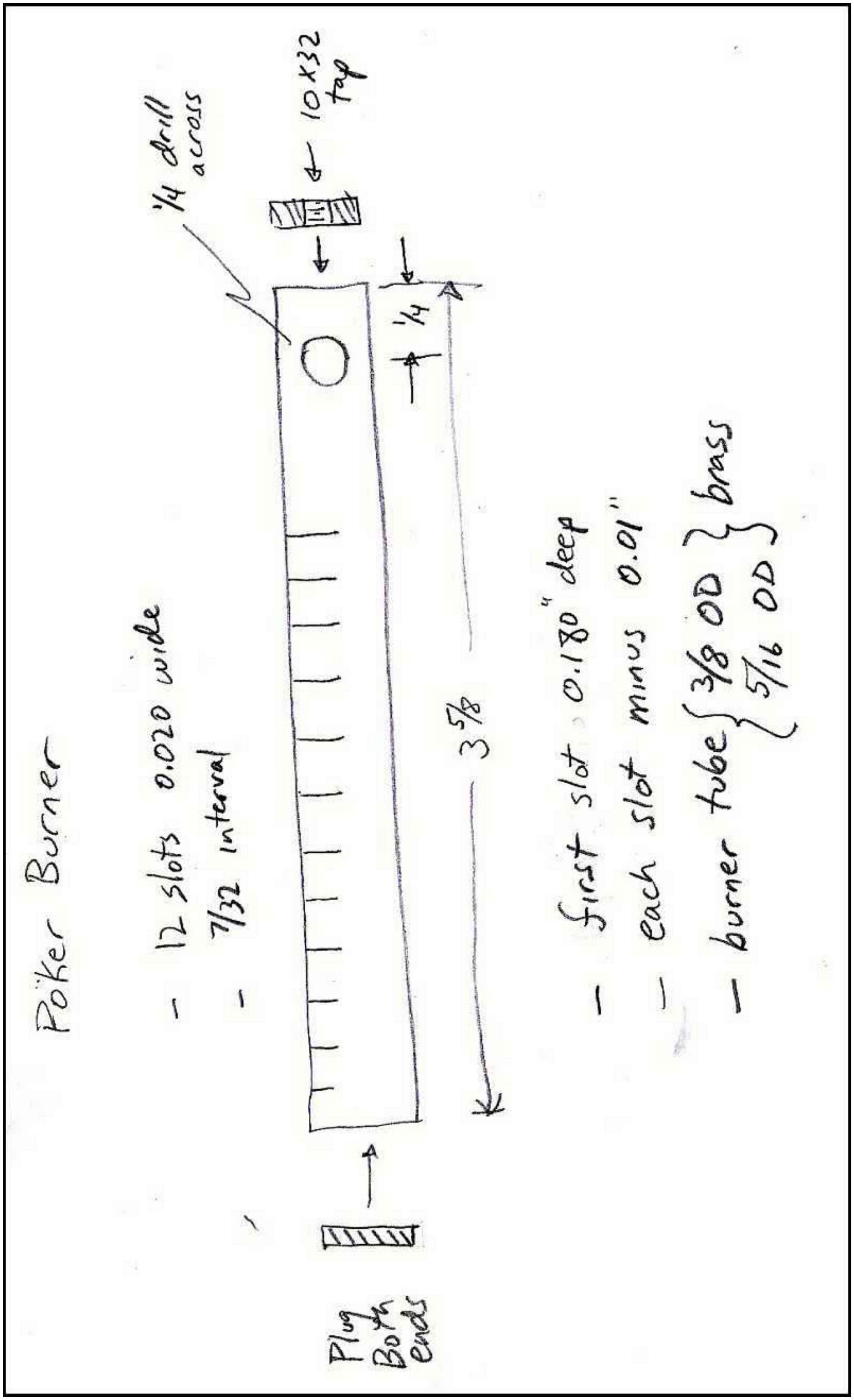


Figure 36: Burner - Poker Style

Gauge 1 Locomotive
Fuel Tank Pressure Research
Butane – Propane Gas
(Live Steam Forum/Topic: Fuel Pressure in Gauge 1 Loco's -- Test Results)

During recent construction of a Gauge 1 live steam locomotive, I fabricated my first butane fuel tank. Since butane containers are pressure vessels, I decided to pressure test the fuel tank the same as a copper boiler by pressurizing to twice the maximum operating pressure. I found two charts on the Internet that show the vapor pressures of butane-propane mixes based on temperature. From these I could determine the test pressure for the fuel tank.

The first chart comes from EngineeringToolBox.com. The second comes from Algas-SDI Comapny in Seattle, makers of natural gas equipment for utilities.

The data shows that a mix of 70% butane/30% propane, which is common camp stove fuel, produces 93 PSI pressure at 110 degrees F. I used a pressure of 200 PSI to test the fabricated tank. The test was successful.

To verify the scientific data I did an experiment with the fuel tank to measure the actual pressure in the tank. I conducted the experiment with two different fuels: Coleman brand camp stove fuel and Ronson brand "Ultra Butane", both off-the-shelf from Walmart.

This is the test set-up.

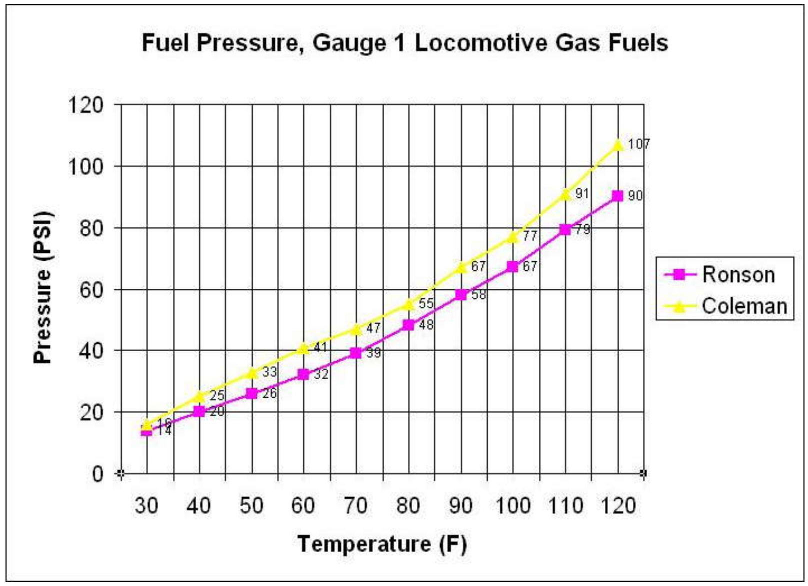
The fuel tank is a three-inch length of medium wall copper plumbing pipe, one-inch nominal diameter (1.125" OD, 1.025" ID). The end plates are 1/8" thick copper plate. Bushings for the fill adapter and gas valve are bronze, with silver-solder construction throughout. The tank's capacity is 35ml. The pressure gauge is 0-160 PSI. The valve to the left of the gauge is to release fuel after the test is over.

The test started by chilling the tank in ice water and filling with fuel in the usual fashion. The test set-up was placed in a pan of ice water and into the freezer for the first measurement at 30 degrees F. Thereafter, ice was removed from the pan and replaced with warm water. Pressure readings were taken at 10 degree F intervals to 120 degrees F. Each temperature was maintained for 15 minutes before reading the pressure to ensure the fuel was chilled/warmed throughout.

These are the pressure gauge readings:

Temperature (F)	Ronson Pressure (PSI)	Coleman Pressure (PSI)
30	14	16
40	20	25
50	26	33
60	32	41
70	39	47
80	48	55
90	58	67
100	67	77
110	79	91
120	90	107

And here is how the pressures charted out:



Conclusion: The measurements I took are very consistent with the scientific data. A test pressure of 200 PSI on a fabricated fuel tank would be sufficient for operating temperatures up to 110 degrees F.

I always thought that Ronson/Zippo lighter fuel was pure butane. It does not appear to be. The test showed it might be a mix of 80% butane and 20% propane. Coleman fuel appears to be 70% butane and 30% propane as advertised.

I also did a very abbreviated test on these two brands of fuel I got at a "Chinatown" grocery store.

The pressures indicate they are probably 70/30 mix as well.