Shay Tanks
Part I - Background & Fuel Tank

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Initial: 7/11/03 Last Revised: 12/27/2008

Two tanks are used on the Shay, a water tank and a fuel tank. I'm planning to burn oil so both tanks are functional. My experience working with sheet metal has been mostly bad so I was not anxious to build the tanks. In fact there were many interesting things to work on such as the water pumps, brake cylinder, etc. However, the tanks were beginning to loom over my head so though it best to get to it. Once started, it turned out not so bad ---- in other words, a tank fabrication process that made it difficult to screw them up was developed.

Research: The first step was to decide on how to piece the sides and the rivet detail. Kenneth fabricated the rounded corners and then riveted the four sides to the corners. That's a lot of rivets but it also insures the sides are square with the corners. That's a photo of Ken's tanks on the right.

The tender tanks on the Cass shays had been photographed on previous visits in anticipation of building tanks. None of the tanks on the Cass Shays are the same. Also, probably none are original, so one has a lot of latitude here. The tank on Shay No 5 has no rivets, it's welded construction. All of the Cass Shays burn coal so all have coal bunkers instead of fuel tanks.

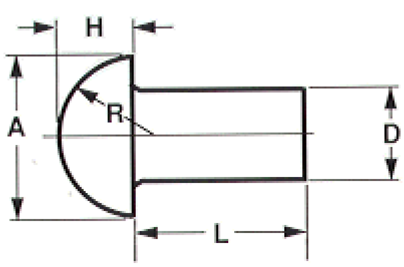
The photos on right show the tender tank on Cass Shay No 6. One piece of steel is used on the sides and back. There has to be a seam in the front but I failed the photograph that seam. There is a close spaced row of rivets at upper and lower edges to attach sides to the top and bottom. There are also staggered vertical rows of rivets that attach internal supports.

On Cass No 2., the tank sides and rounded corners are single pieces with the flat ends riveted to the sides. This has the same close spaced rows of rivets to attach the top and bottom as Shay No 6. The rivets attaching the internal braces are in a straight vertical row rather a staggered row as on Shay 6. There is also a close spaced row of rivets around the outer edge of the top ---- I think they're hidden by dust and dirt on the top.

I decided to make my tanks like Cass No 2 tanks. For the water tank, will use four pieces: two sides with the corner bends and two ends. There will be four internal vertical braces on each side and one on each end. For the fuel tank I decided to make the front, two sides and four corners from one piece and the back from a second piece. There will be one vertical brace on each side and the rear and two braces in the front.

Rivets: The rivet heads on Cass Shay No 6 are 0.95 inches diameter. The rivets in the rows along the top and bottom are spaced on 1.6 inch centers. For 1/8 scale, this scales to a 0.119 inch head and 0.2 inch spacing. It was soon learned that you buy rivets based on shank diameter, shank length and head style --- sort of like machine screws. However, the head diameter was most important so went to Internet and found the following specification for small round head rivets (jay-cee sales & rivets, inc --- www.rivetsinstock.com).

Round Head Rivets



Normal Size or Basic Shank Diameter		D Shank Diameter		A Head Diameter		H Head Height		R Head Radius
		Max	Min	Max	Min	Max	Min	Approx
1/16	0.062	0.064	0.059	0.122	0.102	0.052	0.042	0.055
3/32	0.094	0.096	0.090	0.182	0.162	0.077	0.065	0.084
1/8	0.125	0.127	0.121	0.235	0.215	0.100	0.088	0.111
5/32	0.156	0.158	0.152	0.290	0.268	0.124	0.110	0.138
3/16	0.188	0.191	0.182	0.348	0.322	0.147	0.133	0.166

Notes: approx. proportions
A=1.750xD
B=0.750xD

R=0.885xD
Length tolerance for rivets shall be + or - 0.016 in.

This says 1/16 inch shank diameter rivets are required. None of my normal suppliers carried 1/16" diameter rivets. The smallest Coles lists is 3/32" diameter. Ken Schroeder told me to use copper rivets; the brass rivets are too hard to bend over. jay-cee sales had 1/16" brass rivets, but no 1/16" copper rivets. (I tried some of the brass rivets and Ken is right, they're too hard. Reminds me of something a female colleague once said: 1 in 20 men will listen to good advice, the other 19 will go ahead and pee on an electric fence.) Found one place with 1/16" diameter 1/4" length copper rivets at $20/500. That seemed high. Finally used search engine www.dogpile.com to find Hanson Rivet (www.hansonrivet.com/). They carry 1/16" diameter 1/8" long copper round head rivets for $34/pound. A pound has over 4,000 rivets so that looked like the best deal. The sales person was very nice.... suspect he normally sells in lots of tens or hundreds of pounds but was happy to sell me a pound and accepted payment via credit card.

Tank Material & Construction: Kenneth suggests using brass or galvanized steel for the tanks--- 22 gauge for the sides and bottom and 18 gauge steel for the top. He also suggests bending some 1/2" X 1/2" angles from the side material to rivet to sides and ends to support top and bottom. After digesting this I sent a list of questions to Kenneth. As to the material, he said he's used both brass and steel and been happy with both. He did note that the water tank is subject to corrosion so if steel is used, it should be galvanized and it would probably be a good idea to paint the inside with one of the epoxy paints made to seal water tanks. I also questioned whether the water tank would support a fat (180 pound) engineer. He said he's had a much bigger engineer than that on his shay and no problem. As for the soft soldering, he uses acid core solder, an acid flux and a large electric soldering iron.

Bending Tool: I then reviewed several of Kozo Hiraoka's books (Building the Shay, Building the Heisler and Building the Climax) for tank construction techniques. For his 3/4" scale Heisler tank he used 1/16" (16 gauge) brass for the sides so maybe I should go a little heavier than the 22 gauge Ken suggested. Hiraoka suggests a really neat tool to make the corner bends ---- this was a breakthrough for me. Ken suggested forming the corners around a piece of 1/2" pipe but I couldn't see how to do that with any precision. Hiraoka's technique was to use a couple bolts to draw a piece of angle against the round forming piece with the sheet metal in between

Here's my crude version of Hiraoka's --- that's 1/2" (0.825" OD) pipe, 1"X 1/8" angle and 1/4" bolts. I tested it on both 22 gauge steel (pictured here) and also on 18 gauge steel with excellent results on both.

(Note the corrosion on the steel. This was after I returned from a few weeks volunteer work in Africa. When I was gone the spouse decided that it was a good time to clean up the workshop so she scrubbed and painted the floor. Apparently she also used a damp cloth to remove the dust from the sheet steel. Wait till she goes away for a few days --- I'm going to clean up her sewing room for her ---- using the sand blaster!)

The bolts were later welded to the angle to make it easier to use. As we'll see, these bolts will need some additional attention.

After making a few test bends I realized that the round corners are very forgiving --- the corner can actually be moved slightly if necessary.   This capability led me to the basic construction technique ---

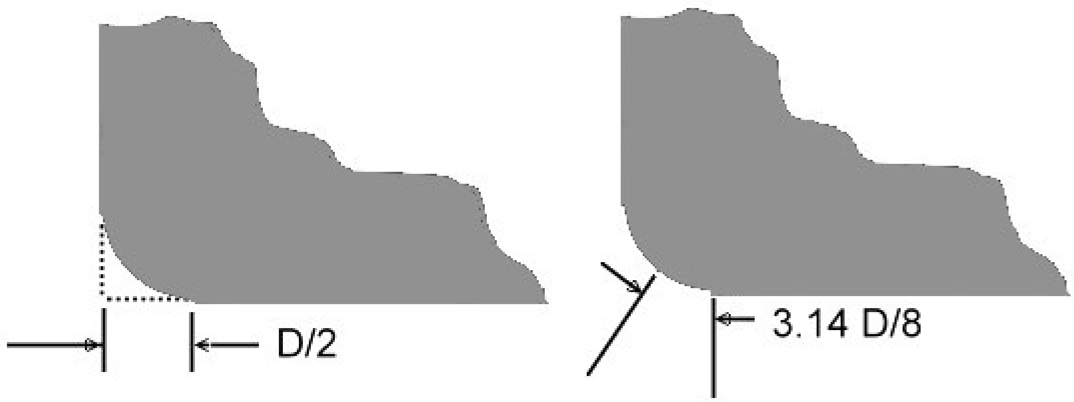
1. Drill all the holes for the rivets and install rivets (except near the bends).
2. Install internal braces.
3. Make bends.
4. Join sides and ends to form a band.
5. Cut top and bottom just fit into the band--- making sure pieces and hence sides are square.
6. Solder the inner top and bottom into place.

The plan is to use two tops. The inner top is soldered into place to provide rigidity. This inner top has a large hole in the center to provide access to the inside of the tank. The second or outer top is slightly smaller, sets over the inner top and is held into place by a few button head screws (fake rivets). The outer top provides the seal and has the finished appearance.

OK, what about all the rivets? The rivets that join the ends of the sides and the end pieces will actually function as rivets. The same for the rivets that go into the vertical reinforcement angles. The rest of the rivets, specifically the rows along the top and bottom of the sides are there for decoration only --- I'll solder them to hold them in place and also seal the holes.   The rivets around around the outside edge of the removable top are also for decoration.

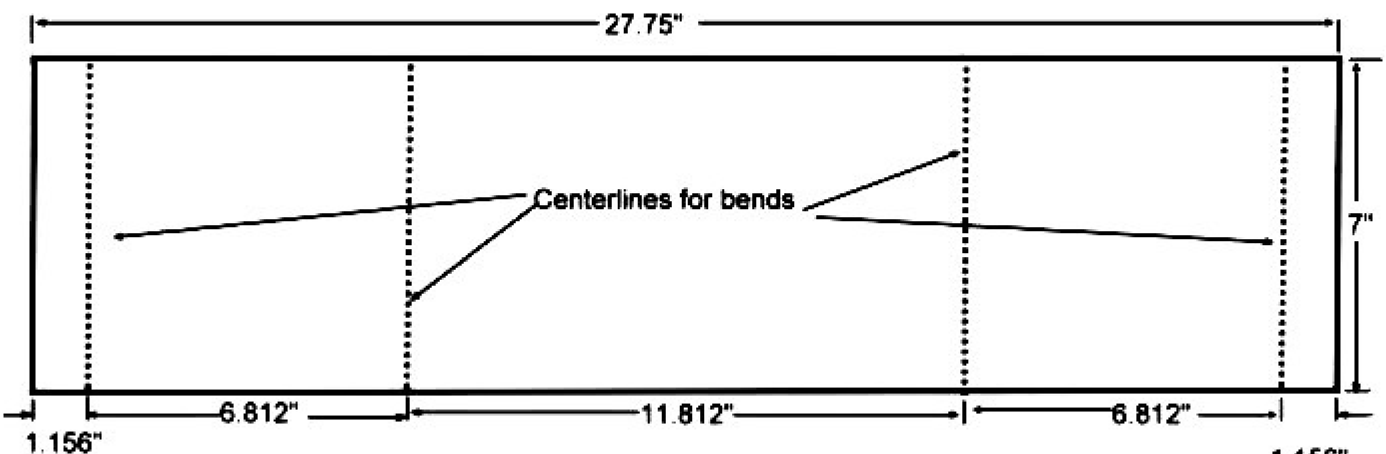
Geometry: One of the first tasks is to determine the dimensions of each piece. The rounded corners complicate things a bit as shown in diagram below. The curved section starts a distance of one half the diameter of the curvature back from the corner as shown on left   I think of each side or end piece ending at the center of the rounder corner because that is where I need to place a mark to line up the bending fixture.   The distance from the start of the curve to the center of the rounded part is one eighth the circumference of the round form or π D/8 or 3.14 D/8.   This means that the length of the side is reduced by the factor [D/2 - 3.14 D/8] at each end.

This factor can be rewritten as 0.107 D. I'm using 1/2" pipe for the curved form. The diameter of my pipe is 0.825 inches so the factor 0.107D is 0.88". I rounder that up to 3/32" which will make the tank slightly smaller (and also increase the probably that the base will be a tight fit or have to be cut down).



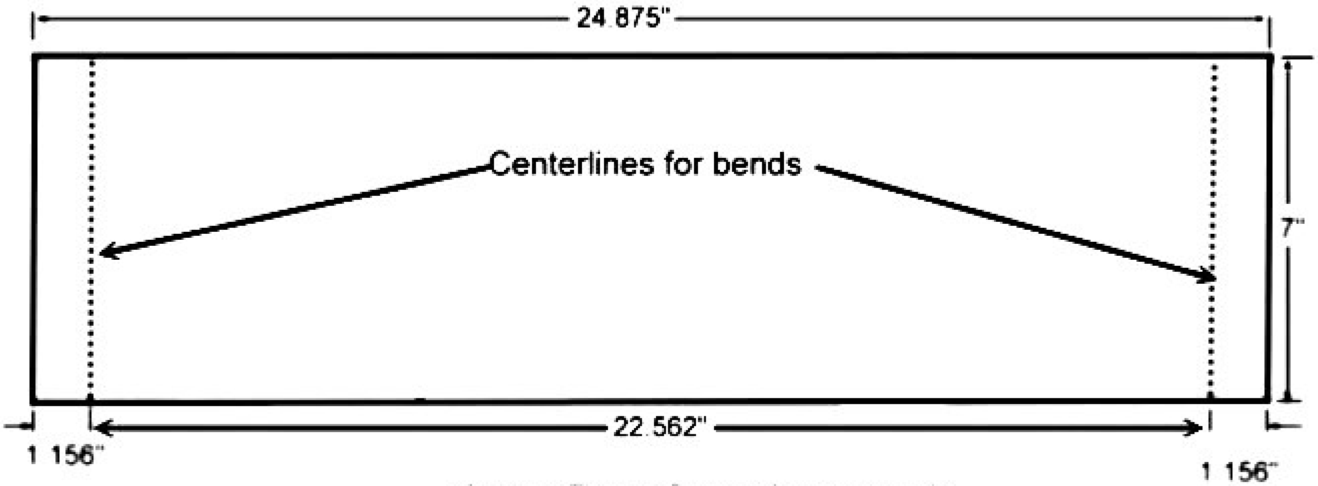
The tanks are 7" high and 12.125"" wide. They mount on floors that are 12.375" wide so there's only 0.125" margin on each side --- not much room for error ---and I'd already cut the floors. Then I started to wonder whether I should take into account the thickness of the material. To be safe I decided to use a width dimension of 12" and assume it's the inside dimension of the tank. I was less concerned with the length of the tanks (22.5" for the water tank and 7" for the fuel tank) since there is plenty of margin in that direction.

Marking off the fuel tank sides & ends: Kenneth suggests that the seams for the end pieces be about 1" from the corners. The tanks are 12" wide so I decided to make the end pieces 10" long, hence the end pieces are 7" X 10" pieces. The fuel tank is 12" wide and 7" long. Recall that I decided to make only one end piece --- at the back. The total distance around the tank if the corners were square would be 38". Because of the rounding, each end of the sides and ends are shortened by 3/32" inch or a total of 8 times 3/32 inches or 3/4" making the total distance around the tank 37.25". I decided to lap each joint by 1/4" so there requires an additional 1/2" for the two laps. The end is 10" wide so the other piece must be 37.25" - 10"(for the end piece) + .5"(for the laps) = 27.75" The layout for that piece is shown below.



Fuel Tank Front & Sides

Marking off the water tank sides: The water tank is 22.75" long, 12" wide and 7" high, the same width and height as the fuel tank. The end pieces are 7" X 10", the same as the back piece of the fuel tank. I used a technique similar to that for the fuel tank above to compute the length of the sides with corners to be 24.875" The layout for the sides is shown below.



Water Tank Side (2 required)

Sheet Metal List: After all these computations I was able to make up the material list for the steel store. Kenneth had suggested 22 gauge for the sides and bottom and 16 gauge for the top. I decided to use galvanized steel and make things a bit heavier: 20 gauge for the sides and ends and 14 gauge for the top and bottom. The complete list is:

20 Gauge galvanize:
- 3 pieces 7" X 10" (the ends)
- 1 piece 7" X 27.75" (fuel tank sides and end)
- 2 pieces 7" X 24.875" (water tank sides) (These dimensions were corrected 12/27/08)
- ~10 linear feet of 1/2"X1/2" angle bent from this same material (for internal reinforcing)

14 gauge galvanized steel:
- 3 pieces 12.125" X 7" (fuel tank bottom and tops - slightly oversize)
- 3 pieces 12.125" X 22.75" (water tank bottom and tops - slightly oversize)

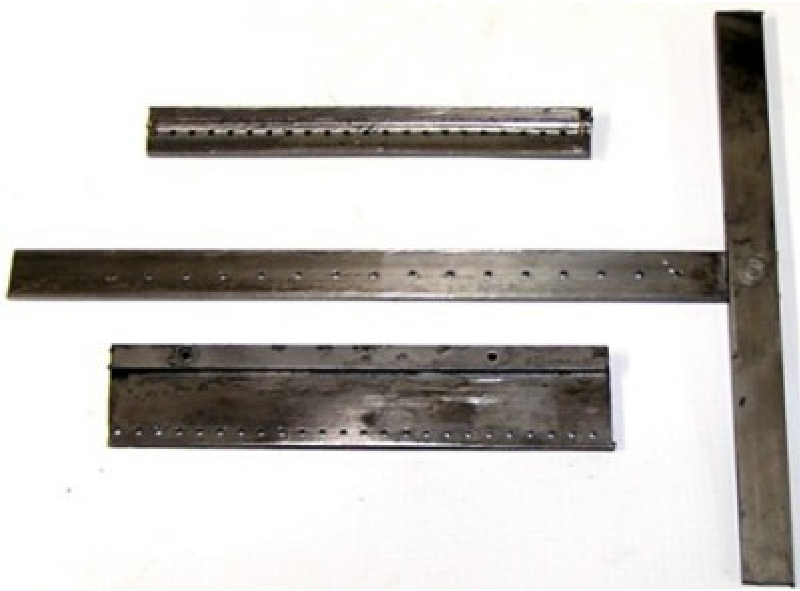
I faxed the order to steel store in the morning and then visited Mill Creek Central RR to learn about track work. Spent most the day learning about cutting ties and stopped by steel store on way home. They were just about to start the cutting. Man do they have a big shear --- hydraulically operated --- can handle a 13 foot cut of 1/2" thickness ---- if I only had more room my shop.......

They cut everything as ordered; the pieces were to the correct dimensions and square. One difference from the order -- they didn't have the 20 gauge so they used a larger gauge. When I got home I found the sides and ends were 0.56" thick. That's 17 gauge --- but maybe it's 18 gauge with 3 or 4 thousands of galvanize coating on each side. Wow --- I forgot about the thickness of the galvanize; sure glad I decided to make that 1/8" reduction in the width of the tanks!

Rivet Hole Templates: There are about 700 rivets in the fuel tank and about 1300 in the water tank so I'm not about to try marking off and center punching that many holes ----- after the first few, there'd be a staggered row. The solution of course is to make a set of drilling templates using the indexing capability of the mill table. Three templates are needed as follows:

1. Holes centered 0.125" from the edge for the lower row on the sides and ends and the edges of the lap joints. The hole spacing for this template is 0.2" (5 per inch).
2. Holes centered 0.625" from the edge for the upper row on the sides and ends. The hole spacing for this template is also 0.2" (5 per inch).
3. Holes in a row perpendicular to the edge starting at 0.5" from the edge and ending 6.125" from the edge for the vertical reinforcing braces. The hole spacing for this template is 0.375"

The three drilling templates are shown on the right. To drill the holes, the template is held firmly against the edge and the end hole is drilled. A #0 screw with nut is installed in the hole to hold one end of the template. A hole is then drilled in the other end and a second screw and nut installed. The screws hold the template in place so the holes in between can be drilled very quickly. The screws are then removed and the template is then slid down the sheet and one end secured with a screw through the last hole drilled so that proper spacing is maintained. Works slick!



Before starting on the actual tanks I made several test runs using the drilling templates and the bending fixture on scraps that I collected at the steel store. The piece on the right is the end cut of one of the side pieces ---- it's 18 gauge galvanized. I soldered the rivets in place using paste flux and acid core solder and the very fine tip on the Sievert propane torch. The solder flowed very well on the galvanize. I'll have to also try an electric iron as Kenneth suggested. The paint is from an old partially used aerosol can of engine paint. This sample looked good to me so it was time to do the real thing.

Fuel Tank Construction: I started with the fuel tank. I drilled all the holes in the rear end piece first as shown on the right. (The piece is actually square, the distortion is due to camera angle.) After confirming that the hole pattern was correct, I used this plate as a pattern to drill an identical hole pattern in the front and rear end pieces for the water tank.

The next step was to use the end as a pattern to drill mating holes in the large piece that will become the front and sides. The two pieces were clamped together and two holes drilled and #0 screws inserted to hold the pieces in position. An additional set of holes were then drilled at the other end of the long piece.

I next put rivets in the top and bottom of the rear end piece. These rivets were temporarily held in place by masking tape over the heads and then soldered in place using Ruby Flux and 50/50 acid core solder. That's an old 200 watt soldering iron I bought for $5 at a garage sale some 20 years ago. (The tips cost more than $5 now and I got at least 6 tips with it.)

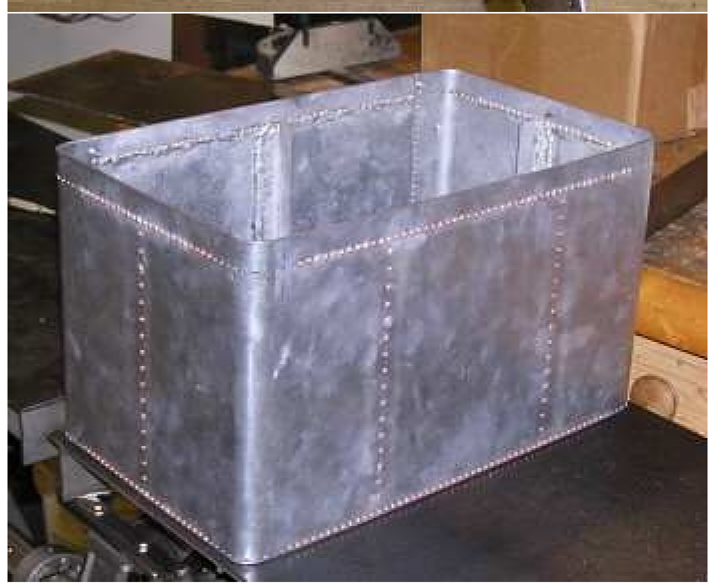
After the rivets were soldered the ends were flattened against a piece of tool steel (lathe bit) as shown in the photo. The head of the rivets were driven with a punch made from 1/4" drill rod. The end has a recess made with a # 3 center drill (~ 7/64") that matches the rivet head. That's the lower row of rivets on the side/front piece.

The next step was to rivet the stiffeners into position. First the stiffeners were clamped to the side or end pieces and the rivet holes used as a pattern to drill through the stiffener. I drilled a couple holes and put in a couple #0 screws to hold them in position while the rest of the holes were drilled. Rivets were then installed and the ends flattened. As shown on the right, the punch for the head is held in the vise and the end flattened with a flat end punch --- or just use a hammer and forget the flat end punch.

After the stiffeners were riveted in place the seams and rivets were sealed with solder. The iron worked really well. The photo shows the long piece that will be come the sides and front. Note that some rivets are missing. That's the area of the bends for the corners. The heads would interfere with the angle part of of the bending tool. Another point, one side of each end of the stiffening angle is notched so that it doesn't interfere with the top and bottom rows of rivets.

This photo shows positioning the bending tool in preparation to making the first bend. The position of the side of the pipe was carefully calculated and measured. (The earlier drawings show the position of the bends relative to the edges. The side of the pipe is of course half the diameter of the pipe from the centerline of the bend.

Everything started well and then one of the bolts broke. And, that red stuff ain't paint ------ too late to caution about the sharp edges. The original bolts were poor quality carriage bolts. Replaced them with a couple fine thread grade 8 bolts. No more problems.



Success!!! I was really worried about whether I would get vertical bends in the correct position. It looked good and then I fastened the rear end to the bent piece with four #0 screws and nuts. This is the front side.

This is the rear side, Still have a lot of rivets to install. Before proceeding I smoothed all sharp edges with a file.

This shows the first three rivets between the rear end and the sides. Note that the seam is much narrower under the rivets. All the remaining rivets were installed, the rivet ends were flattened and the seams and rivets sealed with solder.

Next the inner top was cut to fit and soldered in place. (I want a liquid tight seal around the inner top so the fuel oil doesn't seep out the top. I plan to use a gasket between the inner top and the the outer top to complete the seal.) The bottom was then cut to fit and soldered. I initially soldered the top and bottom seams with the iron. The easiest way I found was hold the tank at a 45 degree angle with the seam at the bottom, cut a piece of solder the length of the seam and lay it in the seam, flux the seam and then run the iron along the seam. The resulting seam was liquid tight but not uniform so I applied Ruby Flux along the seam again and then used the propane torch to carefully heat the seam until the solder flowed creating a more uniform fillet as shown on the right. After this step the solder appeared to have flowed uniformly into the seam making a strong seal.

This is the back with top and bottom in place. The white stuff on the side is soap residue.

The front of the tank. The smudges are soap residue. The difference in the tank color between this photo and the one above is due to the flash in the previous photo and no flash in this photo.

The fuel tank at this point is a success. The galvanized steel worked great; glad I used it rather than brass. The soldering went much easier than expected with the solder adhering very well if the joint is fluxed. The Ruby Flux tends to not wet the surface very well when cold but when heated it flows and coats the surface. The 50/50 solder (50% tin/50% lead) worked very well too. (With the use of lead in the solder it's probably wise to not drink the water from the water tank --- same goes for the oil in the fuel tank.) The steel does solder differently than brass or copper because it's a poorer conductor --- it's easier to get a small point of solder to flow and more difficult to get a large section like a few inches of a seam to flow all at once.

Update-Mounting: The fuel tank had been finished for some time when I got around to worrying about the mounting arrangement. The water tank mount was made first using screws into the tender floor with the heads inside of the tank.. Rubber washers were used under the heads to make a water tight seal. However, when the screws are removed any water leaks out the holes.

It was decided that the fuel tank should be removable without draining the fuel and without leaking fuel. Tank removal will be necessary to access plumbing under the cab floor.

The mounting fixtures shown in the photo above were fabricated from 5/16" brass rods. (The height of about 1" was overkill; 1/2" would have been more than adequate.) The fixtures were soft soldered to each side of the floor of the tank.

Update-Drain: A drain was installed in the right side. The valve is a common hardware 1/8" pipe valve connected to a street elbow. There is a stainless steel washer and rubber sealing washer between the elbow and the bottom of the tank. There is a 1/8" NTP nut on the inside of the tank screwed onto the male end of the street elbow. The output pipe is 1/4" tubing soft soldered into the end of the valve. A length of 1/4" ID hose will be slipped over the end of the tube when the tank is drained.

This is a good point to end this section. Still need to make the outer top with the hatch. Will do that as well as show the construction of the water tank in the next part. The control valve and output to the burner will be shown in the burner page.

Shay Home
NLW Home