Welcome, and thanks for your interest in building **PYRTE** (stands for **P**ull **Y**ou **R**ound **T**raction **E**ngine by the way) with the revised edition covering the latest (2012) steam regulations allowing this machine to be used in a public place (providing a boiler certificate is obtained first along with the appropriate insurance).

The good news is…

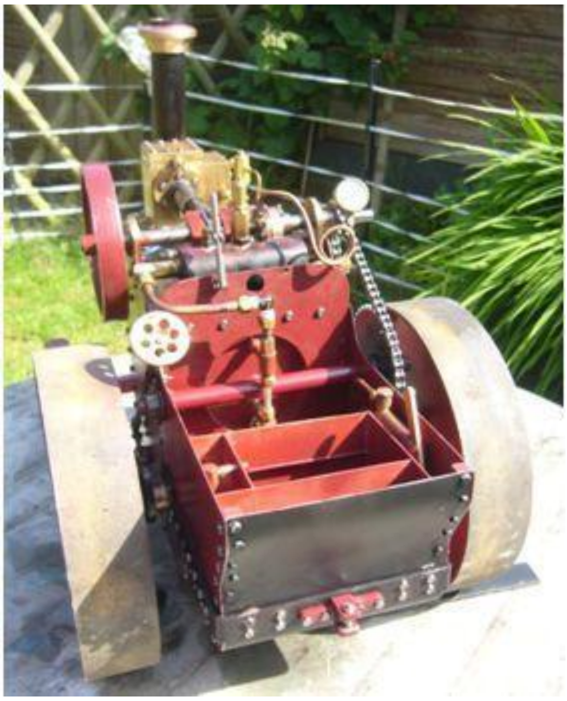
Here you have the chance to learn how to construct this easy build traction engine in a step by step manner, from start to finish, with everything explained along the way.

You've taken the first step to owning your own live-steam traction engine and with just a little persistence it will not be long before you are driving your own live-steam engine, built with your own hands, being pulled around easily as you watch the crankshaft and flywheel spinning almost silently right in front of your eyes as you trundle along.

And just so we all know what we are talking about with thread sizes, there are basically two thread types here, the BA threads and the ME (Model Engineer) threads. The BA's come in specific sizes and teeth numbers per inch or mm. The ME's have overall thread diameters in inches although there are versions with different numbers of teeth per inch so please watch out for this, all available from model engineering suppliers here in the UK. They are not the confusing American threads as some have thought, and also so far there appears to be no metric threads for add-on steam fittings as required.

So let's push on with the build…

BUILDING PYRTE



Building the Boiler

And just so that we will all be reading from the same script, and you will not be confused (myself as well) with regards to the metric measurement system, I shall give the imperial sizes (followed by the metric size in mm – if I remember).

And for the pictures and the drawing, for those people not too familiar with computers, if you want to enlarge the pictures, simply have them on your screen and press the control button and at the same time press the + or – button to alter the size so that you can see it comfortably for yourself.

Building the boiler for this live-steam traction engine **P Y R T E** is very straightforward and requires no professional skills at all, just a little common sense and care, although many of these pictures are from the original model (pre steam regulation upgrade requirements) and should be used only as a guide.

Everything is covered below.

Tooling requirements to build the boiler for P Y R T E:

- Use of a lathe
- Use of a blow torch
- Use of a battery powered drill – preferably with a low torque setting (*this is purely for tightening the nuts and bolts to save your finger ends*).
- A set of small sockets.
- A bench drill with stand – A hand drill can be used, but the bench drill is a little more accurate.
- One 3.6mm drill *(tight clearance size for 4BA bolts).*
- One 4BA nut spinner *(a bit like a box spanner that fits into a 10mm (⅜) drill, just to save your finger ends).*
- One 5BA nut spinner.

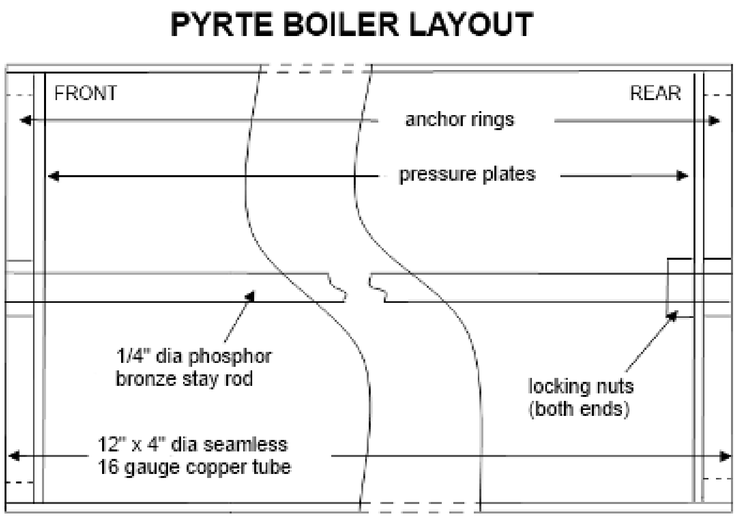
The 4BA bolts usually have 5BA heads, just to make things more confusing, but the 4BA nut spinner has the correct sized cavity for the 4BA nuts and the 5BA nut spinner is the correct size for the 4BA bolt heads.

- 4, steel hex head 4BA bolts X ¾ inch (19mm) length.
- 8, steel 4BA nuts.
- 8, brass hex head 4BA bolts X 1 inch (25mm) or brass 4BA studding. *(Countersunk screws can be used just the same, and if you are using studding, then 16 of the 4BA steel nuts are needed).*
- Taps and die to produce the threads on the stay @ ¼ inch x 40 (6mm x 1).

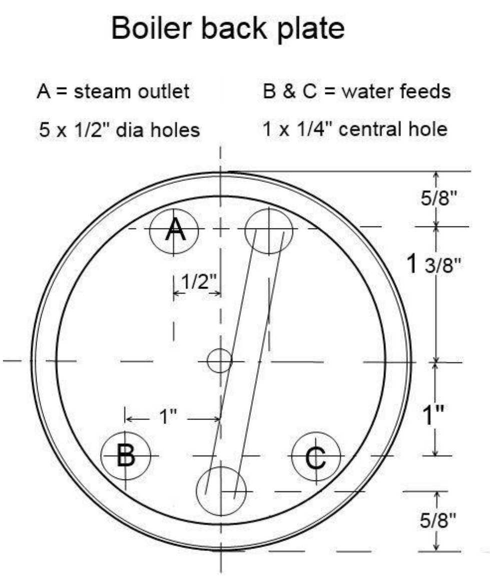
Materials required to build the boiler for PYRTE

- 1 length of 12 inches (300mm) of 4 inch (100mm) diameter 16 gauge thick ($^{1}/_{16}$ inch or 1.5mm) seamless copper tube *(for the boiler barrel).*
- 1 copper plate, 12 inches (300mm) square of 13gauge (around $^{3}/_{32}$ inch or 2.5mm) - *(for the two boiler end plates – you can use 2 x 4” squares if that is more convenient for now, but you will be needing more as the build progresses).*

- 2 lengths of 12 inches (300mm) X ¼ inch (6mm) square copper rod *(for the external anchor rings).*
- 1 length of 12 inches (300mm) x ¼ inch (6mm) diameter phosphor bronze rod *(the central boiler stay)*.
- 1 length of 1½ inches (38mm) of ⅜ inch (10mm) hexagonal phosphor bronze rod *(to make the 3 nuts for the stay)*.
- 2" length of ½ inch diameter phosphor bronze round (the 5 bushes on the rear boiler plate).
- Silver solder and flux.
- A couple of pieces of 4 inch + square plywood and a 12 inch + length of ⅜ inch/10mm studding with nuts and washers (*to act as a carrier for the boiler in the lathe*).



The original total time to produce this simple boiler for **PYRTE** is just under 3 hours in experienced hands – compared to a conventional boiler of this size at around 30 + hours, (going onwards to 60 hours or more) assuming no leaks are found with the complicated boiler.



To get you started off with building this very simple boiler for your live steam traction engine, you need a seamless 16-gauge copper tube (that is approximately 1.5mm walled thickness – (*16 gauge is ¹⁄₁₆ of an inch or around 1.6mm*) as the barrel for your boiler, being 4 inches (100mm) in outside diameter and 12 inches (300mm) long and squared at both ends.

The 4 inch (100mm) size is readily available here in the UK, whereas the original dimension of 4½ inches is not, now that we are all going over to the metric sizes, so by reducing the diameter a little, the water will boil a little sooner, although it means being more aware of the water level in the boiler and needs a little more frequent, but lesser action on the pump to keep it topped up to the central height.

You will need two lengths of ¼ inch (6mm) square copper rod, long enough to fit tightly inside the circumference of the copper tube. These lengths are just less than 12 inches (300mm) each for the above diameter.

You will also need two circles of 13-gauge (approximately 2.5mm) copper plate to act as the ends of the boiler, one at each end, and they must be a very close fit to the inside of the barrel.

Plus you will need (*and this is purely for safety's sake*) a 12 inch (300mm) length of ¼ inch (6mm) diameter phosphor bronze rod, centre drilled at both ends for later tail-stock support, and threaded at each end with ¼ x 40 tpi (6mm by 1.0 threads per mm) to a length of ¾ inch (20mm), to act as a brace (*commonly called a stay*) between the centres of the two end plates, along with three ¼ inch (6mm) deep nuts made from ⅜ inch (10mm) hex bronze, all threaded ¼ x 40 tpi (teeth per inch)(6mm x 1.0mm).

One point here is that if you are thinking of scaling this engine up to 1.5:1 or running it at a higher pressure of say 75lbs/sq", then doing it at 1.5:1 is about the most you can get with a copper boiler owing to the linear strength of copper, plus at the larger size, using a 6" diameter copper tube, the end plates would need more stays, another 4 spread out evenly over the plate area with 1 sitting centrally. 6 would be even better for higher pressures as well.

You could use metric taps and dies if you wish, but the ones I have are really inferior quality, as, if I cut a nut at 6mm from one set of taps and then cut a bolt, again at 6mm from another set I have, the two will not even thread together despite them supposedly being the same size and thread pitch.

I think they were produced in different parts of the world by different manufacturers, so it was asking for trouble. For that reason I tend to stick with the old imperial sizes for taps and dies as they produce a far better result.

The pressure you should be running at with **PYRTE** *would not normally need this additional stay, but if you decide to run the engine at more than 50 lbs/sq. inch or accidentally go over-pressure (safety valves do stick sometimes) then this will allow you time to remove the heat and let off some steam with a good safety margin.*

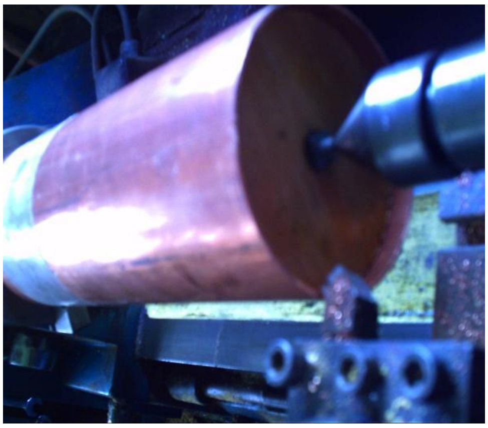
THE BOILER BARREL

So starting at the beginning, the boiler barrel of **PYRTE**, your soon-to-be Traction Engine, the basic frame that everything is attached to on the usual traction engine or roller, needs both ends cleaning up of burrs and a carrier inserting to support it in the lathe while the ends are squared and a few marks put on it to make life easier a little later on.

If you cut two pieces of half inch plywood, or whatever other scraps of wood you may have, (*ply is easiest as the crossed grain gives it better machining abilities and makes it sturdier*) to a little over 4 inches diameter, centre drill them to match the diameter of a piece of studding you have (*threaded bar*), 3/8inch (10mm) diameter is fine, which needs centre drilling at both ends so that it can be carried in a centre in your tailstock), and turn them down on your studding – nutted tight both sides of both pieces of timber – to a tight fit so they just fit inside your barrel.

The picture shows the 6mm studding I originally used, but this was not really sturdy enough. The white area on the copper tube is merely where the glue from the label was attached by the supplier and can be ignored.

With one piece of timber inserted in the tube at the chuck end, sitting close to the chuck so the jaws are not gripping inwardly on unsupported copper tube, and the other piece of timber sitting around 1/2inch (13mm) inside the tail-stock end of the barrel, with barely an inch of the studding protruding beyond the timber, and both pieces of timber nutted tightly both sides in place, you can support the tailstock end on the tailstock centre, as in the picture.



The tailstock end can now be skimmed, using a sharp tool, but be very gentle with your cutting, and cut toward the studding rather than away from it, and also heading towards the chuck, otherwise the tube will simply move towards your tailstock if it is not gripped tight enough by your timber inserts.

If you find the wooden inserts are a little too small and the cutting point digs in and stops the rotation rather than trimming the tube, it is possible to add extra width to the diameter by wrapping insulation tape/cellotape around the outside edge of the timber inserts – but make sure you apply it in single layers so there are no odd overlaps causing the tube to wobble.

Talking about wobbling, you will not get your tube to run perfectly true, as the manufacturing process does not demand perfection and concentricity, regardless of any handling problems the tube has endured, so you will have to try to get it wobbling as little as possible before you begin.

Skim the end near the tailstock, and then de-bur it and turn the whole lot round end to end, adjust the carrier positions, true it up and skim the other end. You are aiming for a foot in length, but building machinery in general calls for very slight modifications regarding measurements - this part is not critical, especially as it is your first attempt, providing at least one end (the rear end that everything else attaches to) is dead square.

In fact, my boiler barrel length ended up at ten and one quarter inches (it was just a tube I had available at the time). It looks a little stunted now she's built up, but a longer barrel will allow longer periods between top-ups of water and a better balanced power output, plus yours will look more like a proper engine.

While it is in the lathe it is best to place a few marks on your barrel, so attach a scriber to your tool post and gently scribe a line along the side of the barrel.

Providing you can see it, it is OK for now, as it will have a few light saw cut marks on it for ease of seeing, as this line will most certainly disappear from general eyesight with heat treatment during the building process.

Take a piece of foolscap paper (big enough to go right round the barrel – diagonally?) and wrap it tightly around the barrel, marking where the overlap point is. This gives an exact measurement for the outer circumference, so all you need to do is to fold that length in half and mark it on the paper again.

What this has done is to give two positions on the paper, which can be applied to the barrel, showing the exact top and bottom of the barrel. Now if you assume the already scribed line is the top, and hold the original overlap mark on this line, then the second mark is the bottom centre line as you go round the circumference of your barrel.

This point needs marking on you barrel, and with the scriber point aligned with this second mark, a second line can be lightly scribed along the length of your barrel, that way giving you a top and bottom line to work to.

If you wish, you can provide these same marks using a piece of angle iron by sitting the angle iron along the length of your boiler and scribing along one edge of the angle iron, that way a line can be drawn truly along its length.

Using the paper method the other side can be found and a second line marked in the same way.

Three more marks need to be added. These are around the circumference, ⅛ inch (3mm) in from each end (these are to give a guide for the centres of the anchor rings, which in this case are ¼ inch or 6mm wide). The third line denotes how far the smoke-box has to be pushed on the outside of the front end of the barrel, and therefore needs to be at $^5/_{16}$ of an inch (8mm) from the front edge.

You also need to mark, very lightly with a junior hacksaw, the position of the two long lines where they end at either end of the barrel, with the upper rear one being very faint on the end, but can be more pronounced on the outer face, say $^1/_{16}$ of an inch long (a couple of mm). These marks will be used for the setting out, so will need to be obvious, but not overly so.

All but one of these marks will be hidden and not on obvious show when the engine is completed, and will not be detrimental to the operation or appearance of your engine.

THE END PLATES AND ANCHOR RINGS

If you mark out your 4 inch (100mm) circles on the 13-gauge copper plate, also marking a straight line through the centre point on one (*this will be for the end nearest the driver - the rear*) to allow a guide for the water gauge fittings to be installed, incorporating a fitting for the steam take-off, plus the injection points for the water supply/drain for the boiler barrel.

These plates are slightly oversize for the inside circumference of the barrel and should the barrel not be perfectly round, as I have found many times since the building of other boilers, with a circle marked to match the inside of the barrel, the plates can be skimmed or filed down to fit closely inside the barrel.

The front plate needs a ¼ inch (6mm) hole boring in the centre for the stay to poke through when the rear plate is soldered in place.

This process is all in preparation for applying the silver solder to fix the plates to the ends of the barrel, but before this can proceed, the anchor rings (the two ¼ inch or 6mm rods) need to be shaped to a tight fit inside the barrel ends.

First these square rods have to be softened, and this is done by heating them to a dull red colour and quickly dunking them in cold water. To check they are soft, simply tap one with a screwdriver or something similar and the sound heard should be a very dull sound. If there is any ring to it, you have not got the metal hot enough (dull red is plenty) or you have taken too long to cool it down and it needs doing again.

Next you need a former to bend the rods around, and for this I used one of the pieces of half-inch plywood that was used as a carrier for the barrel, with a nut and bolt (*with a one inch washer either side to hold it straight being helpful, although not used here in my early engineering years*) through the centre.

The diameter was reduced in the lathe to a depth equal to the thickness of the anchor ring rod, (that was a ¼ inch in my case) along one half of the circumference, that way allowing some support of the timber carrier/former as the rod is gripped in your vice.

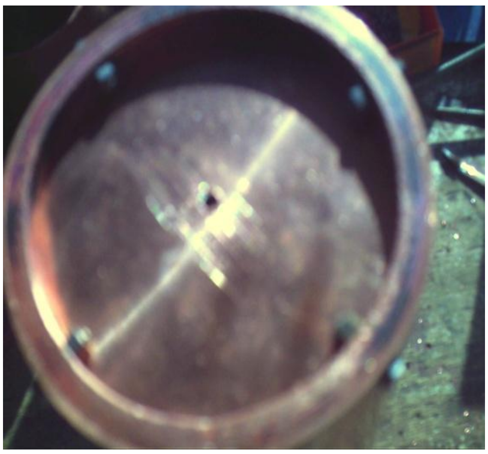
With the carrier/former held gently in your vice, with one end of a rod trapped between a jaw and the reduced size of the former, simply bend the rod round the shape of the former. I got mine a very close fit with the aid of a light rubber hammer.

The whole lot will need to be rotated in the vice, but this is very easy to do, until you find the last little bit is not going to fit, and that's where the rubber hammer comes in.

Try the shape of the newly formed pressure ring inside the barrel (for the front end only), gripping it with mole grips or something similar, but don't forget to use some padding on the outside so the jaws do not leave marks on the barrel, and get it to a good tight fit. You will have a little too much length to make a complete circle, so what you have to do is to bend it sideways and overlap it a little.

The more work you do (tap, bend, anything regarding the shaping) to the ring means it loses its softness and the harder the ring will become. The last thing you want is fractured or strained metal being used in the build, so if you need to re-soften the pressure ring, feel free to do so, as this makes the process that much easier.

Trim the length of the overlap so that a complete circle is formed inside the end of the barrel, with barely a gap between the two mating ends.



This pressure ring is firstly going to be temporarily bolted to fit inside the end of the barrel, making it a flush fit with the end of the barrel, as this pressure/anchor ring is the anchor point for the front plate (the circle of 13-gauge (2.5mm) copper plate - sitting to the rear of the pressure/anchor ring) and a strengthening point for the attachment of the smoke-box at the front.

This view (a bit blurred, I know – a poor quality camera from some years ago) is looking straight down on the front end with the pressure ring temporarily bolted in place with steel bolts, and sitting directly on top of the *supported front plate, just before the clean-up before soldering, although this one does not have the ¼ inch (6mm) central hole yet.*

Doing it this way saves all that fancy flanging of plates – the usual way of doing these joints – which leads to no end of leaks through poor fitting joints, and produces a far simpler and more robust joint altogether, and a much better anchoring point for the smoke-box.

This pressure/anchor ring needs to be silver soldered to the inside of the barrel, as soft solder would simply melt with any heat applied to it in normal running practice.

As an aside here, some builders have used two pieces of the ¼ inch (6mm) square copper ring in the front end as they have drilled slightly cock-eyed through the ring and punctured the boiler itself using the one ring, so that way using two rings rather than the one and bolting through the outer one allows a little leeway.

But first we have a few notes on silver soldering.

Silver solder, when applied to a really hot piece of unclean (metal) copper, brass or steel, will just form a blob and will not penetrate where it's needed, and when cold it is relatively easily removed.

It needs a certain amount of heat for it to run, and it's the running that is needed, and this heat must be in the metal itself - not the solder. The metal must be clean, shiny and scrubbed up, and it must also have flux applied where you want the solder to attach itself. What you are doing basically, with the shining and the flux, is removing any surface oxides from the metal.

The solder works by filling a gap, not as you would first imagine by encasing the two parts to be joined, and it is for this reason that the two mating parts should be a close fit.

There is a tolerance of between three and seven thousandths of an inch to play with.

Any less than three thou (0.08mm) and the solder will not penetrate; any more than seven thou (0.018mm) and the solder will just run through the joint and not form a seal.

OOhhhh.

I can see you cringing now as you've just read that, especially if it your first venture into silver soldering, but take heart, what follows is very easy to do……

Using your mark round the outside of your barrel at ⅛ inch (3mm) in from the front end, drill holes on this line at approximately ninety degree intervals around the outside – the positions are not critical, so long as they are on the marked line, but avoid using the points marking the top and bottom centre lines, as these will be needed later - with a clearance size drill for four small bolts.

(I used steel 4BA nuts and bolts initially to get it all lined up, but brass 4BA studding – I had no brass 4BA bolts at the time - with steel nuts for the actual soldering, and drilled it with a 3.6mm clearance drill, which suits the flowing ability of the solder).

Brass has been used simply because when the time comes to install the smoke-box, if a drill is used and catches one of these brass bolts or studding, it should be OK, but if steel ones are used, the drill may wander if it catches one, or even break and cause endless problems.

These nuts will be removed with a file in due course, as they would obstruct the smoke-box installation later on, but for now they can be left on.

The brass bolts or studding shafts themselves will come to no harm, as they are not in contact with any water in any way; they are under no pressure and are hidden by the smoke-box when complete, so they present no problem here.

Once the holes are de-burred inside the barrel it is time to insert the ring into the end of the barrel, keeping the front edge level with the front of the barrel.

The simplest way to do this is to insert the pressure ring almost far enough inside the barrel and then sit the barrel on its front end on a flat surface and push the barrel down to the flat surface.

The pressure ring now needs marking with the same drill as was used on the barrel in one place only, through one of the holes in the barrel, and make a point of starting your first hole around half an inch away from the cut ends of the pressure ring.

Once this is done, the ring is taken out of the barrel and drilled squarely through towards the centre of the circle, and with the burrs cleaned off the pressure ring, it can be re-inserted in the barrel and a 4ba bolt can be inserted and the nut tightened up just so that it nips the two mating surfaces together.

By making sure the pressure ring is sitting against the inside of the barrel and lined up with the front of the boiler once again, a second hole can be marked and drilled through the pressure ring.

Continue with each hole, cleaning off the burrs to make sure the ring is tight to the inside of the barrel before the next one is marked and drilled, either clockwise or counter-clockwise, making sure they are done and bolted tight, one at a time.

You may now find the ends of the pressure rings do not meet properly, but this is not a problem, as a small, brightly cleaned sliver of fluxed copper can be inserted in the gap and soldered at the same time as the main pressure/anchor ring is soldered, once the 13 gauge front plate is in place.

Remove the pressure/anchor ring from the cylinder and lightly chamfer the inner corner a little with a fine file along the inside edge where it touches the plate, and the front edge where it touches the inside of the barrel. This is to give a lead for the silver solder to run in.

The back (pressure plate side) of the pressure ring would benefit from rubbing on a flat sheet of emery cloth to flatten it out somewhat, as once the ring is bent in a circle, the edge nearest the plate will be mal-formed owing to compression at the inside and stretching at the outside diameter of the ring.

Clean it up with glass paper/emery cloth to a good brightness on the outer contacting surface where it butts up against the inside of the barrel. It also needs to be bright where the 13-gauge front plate butts up against it, along with the front outer ¼ inch (6mm) of that plate too.

The same cleaning/brightening of the inside of the tube needs to be done, allowing ½ inch (13mm) or more for the pressure ring and the plate, that way soldering the outside of the ring and the outside of the plate to the inside of the barrel, along with a small fillet of solder between the mating surfaces of the plate and rear of the ring.

In other words, all mating surfaces need to be clean and shiny.

An alternative would be to drill the pressure ring a smaller size and run a thread into it so the 4BA bolt could be used as a bolt, but because of the very small size of the 4BA tap, and the depth of the thread, along with the stickiness of the copper, you more than likely would have many taps broken. So drilling right through with a clearance size is the most practical option here.

Rinse off any dust particles with clean cold water and then gently heat the proposed joint to evaporate any moisture. (By not doing this rinsing and then evaporating the water off before applying the flux, many failures from poor running of the solder have occurred in the past, as silver soldering is best done in one go, rather than having to go back to reheat the joint and releasing other soldered joints through stress because of heat distortion and gravity).

Once it is cool comes the application of the flux, which comes in a white powder form. A small quantity is mixed with a few drops of clean water and stirred. The consistency should be like dairy cream and can be applied with a child's paintbrush where it is needed on the bright metal, once the parts are separated, and then assemble them together.

It can be noted here that to do any form of soldering, the metal must be clean and bright, especially for silver solder, but it can also be noted that the grease provided by fingers touching the bright work, providing they are not oily, will be removed by the flux. Anything else will need to be removed by scrubbing, filing or wire wool.

Do not forget to coat the brass threads on the studding or bolts you are using to hold the pressure ring in place with flux. Any nuts do not need this treatment!

When heat is applied to the fluxed metal, the water boils off and the flux forms a white residue, which you may think needs removing. Do not remove it, as when the metal gets hot enough, the residue turns to a clear liquid and a little after that, with the heat still in use, then is the time to begin applying your solder.

Too much heating can cause the silver solder to run through the joint, possibly because of expansion, so it is imperative that the joint is close together before heating commences, that way allowing the silver solder to just fill the gap and no more.

Regarding having a soldering hearth or something of that nature, I found that a few Thermolite breeze blocks – the ones designed for insulation purposes for house building from the builders yard (Celcon is another brand name for the same product, and there are perhaps others – but not the ones containing polystyrene) – serve the purpose admirably and can be cut to shape with an old hand saw easily.

I shaved the end of one block to a relatively tight fit for the inside of the barrel (like a piston) and used that as a support for the front plate, that way pushing it up against the bolted pressure plate/anchor ring.

The weight of the barrel with the anchor ring bolted (finger tight) in place, sat on top of the front 13-gauge plate, supported on top of the end of the piston (shaved block) held the front plate in place and allowed ample space in the joints to be available for the silver solder to be applied easily. Plus you have the added benefit of the insulation from the block, that way needing less heat to do the job.

I placed a few blocks around the upright barrel to retain the heat and began the soldering process after applying flux to all cleaned parts to be joined as it was assembled.

If there are any small gaps in your metalwork, then caulk them up with slivers of shiny copper, soaked in flux, and solder away.

One point here is that copper has a habit of radiating heat away from where it is needed, so be prepared to have a second blowlamp handy if your flux appears to remain as powder.

The heat is applied and although there is quite a mass of metal to be heated, because of the insulation, it took me around ten minutes to get the flux to run, as I made a point of directing the flame on the centre of the pressure ring in a general manner, warming up a large area of copper before I turned the gas up and concentrated it on the pressure ring on the top until I saw liquefaction of the flux, and less than a minute later I touched the silver solder to the joint.

A blob fell onto the joint and sat there, meaning the metal was not hot enough, so while I played the flame around and onto that blob of solder, I dipped the hot end of the silver solder into the powdered flux. The dry flux attached itself to the tip of the silver solder rod ready to be applied once the blob softened and ran through the joint.

After a little while the blob started to lose its volume – it was running in between the joints, so I then applied the tip of the silver solder to the same place and saw it run after a few seconds. It was just a case of re-dipping the hot tip of the rod in the dry solder and to continue working the flame and solder round the inside at the joint between the plate and the pressure ring until a complete ring was evident.

If you find the solder does not run too readily, you can use a piece of steel wire as a dragging rod to move the solder along.

If your solder is applied and it forms a pool around the joint and you see bubbles rising, then what you are seeing is the solder displacing any air within the voids caused by largish gaps in the joint(s), so keep applying the heat until the bubbles cease, regardless of how hot it feels, unless of course, you feel your solder is just running through the joint, but if this was the case, there would be no bubbles showing. This is a sure sign that you did not get your joints a close fit and the joints will need caulking with some small slivers of fluxed copper!

A seam of silver colour could be seen between the inside of the barrel and the front (uppermost) outer edge of the pressure ring, and also each nut showed signs of silver, confirming that the solder had flowed properly where it was needed, and a good seal was made.

To check whether your joint is successful and to neutralise the chemical properties of the flux, you need to remove any remaining flux and residues, and this can be achieved by letting the warm metalwork soak in a dilute solution of acid.

Generally sulphuric acid (the type you get in car batteries) is the best option, but citric acid is more readily available (from most home-brew shops or chemists) and does virtually the same job.

A weak solution is best for your safety, as your hands can be immersed in it readily, although it is best to rinse them off after each immersion - I use eight 25 gram packs of citric acid, that's around 8 ounces, in a 25 litre tub, say a 5 gallon wide-topped wine-brewing tub, topped up to within 5cm (a few inches) from the top, with clean cold water - and the metal can be left in for around an hour to neutralise and dissolve the residues off.

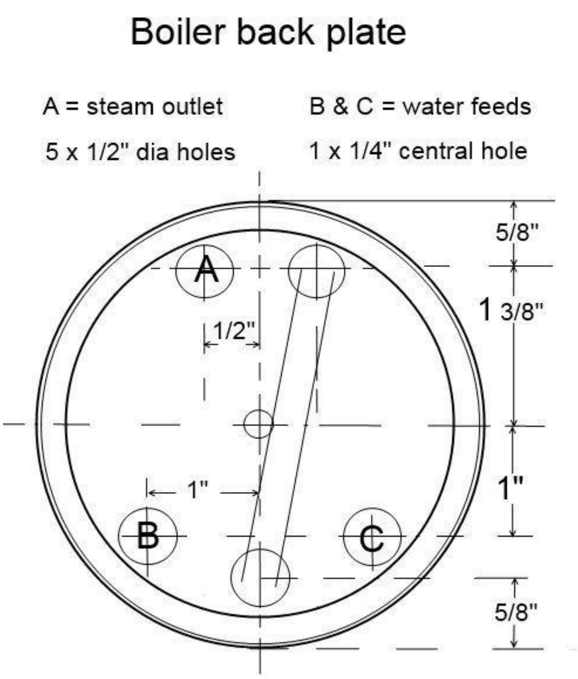
The acid needs to be rinsed off in clean water and then the joint can be inspected more thoroughly after cleaning up with wire wool or something similar.

Do not place the metal in the acid solution while it is still hot as you may well be softening parts of the barrel, which can lead to a misshapen barrel, apart from you getting splashes (even dilute sulphuric acid vapour is very corrosive to denim) or surrounded by hot, scalding steam in the process.

I have found that if a joint was left uncleaned for a few days after soldering, that the flux residues form a white cover over the joint, which eventually turns green, and this most surely is a chemical reaction between the flux and the copper or solder. It may well be eating into the joint, making it weaker! So make a point of cleaning it off with an acid solution, for your benefit later on.

As an aside here, the more you use this acid bath, the more you neutralise the acidity with the alkaline flux, so you will need to add more acid powder as time goes by. For the purposes of this traction engine build, the initial acid content is plenty to complete this model and perhaps a second one as well. A sure sign that the acid bath is losing its acidity is the fact that algae may begin to grow on the top once the solution is neutralised if it is kept in the light.

Next we go to the back end of the boiler.



The same process needs to be done here with the pressure/anchor ring, but before this is done the rear 13-gauge plate needs to be marked and drilled for its necessary parts.

This drawing is wrong as there should be 4 x 15/32 inch (12mm) diameter holes and 1 at A @ 13mm with the central one at 1/4inch (6mm).

From the drawing you can see the upright centre line is marked and the two upper hole centres are 1/2inch (12mm) either side of this line and 5/8 inch (16mm) down from what will be the outside edge of the boiler tube, so that makes it 9/16 inch (14mm) from the inside edge of the tube, or 1 and 3/8 inch (35mm) up from the central crossing point.

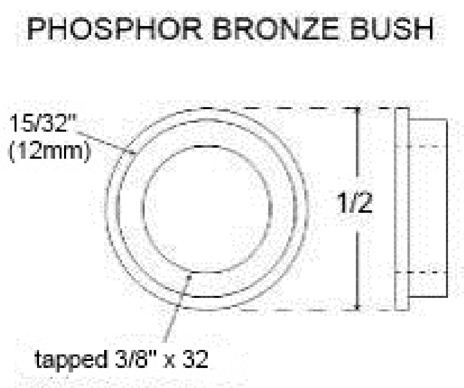
A is the steam take-off point and the other top one is the top fitting for your sight gauge with the bottom one sitting centrally at the bottom of the boiler plate.

From the central crossing point a horizontal line needs to be marked at 1 inch (25mm) below centre with marks at 1 inch (25mm) either side to provide the two water inlet points B and C.

B is the water connection from the mechanical water pump and C is the connection for the hand pump.

Centre punch each of these points, along with the central one for the boiler stay to poke through.

If you now trim it down to just fit inside the rear of the barrel, and with the line upright as in the picture, the central hole needs to be drilled 1/4inch (6mm) to match your phosphor bronze stay rod diameter and the other four can be drilled with a 15/32" (12mm), with **A** drilled at 13mm.



The next item on the agenda is to produce five phosphor bronze bushes.

Four are from a 1/2inch (13mm) rod as per this drawing, but the hole is drilled at 7/32inch and tapped through with 1/4inch x 40 for the water feeds and the two sight gauge bushes, while the steam take off connection (**A**) starts as a 9/16inch (14mm) diameter bush for 1/16inch (1.5mm) and reduces down to 13mm for 3/16inch (5mm). The internal thread is 7/16inch x 32. Preferably using the 13mm rather than 1/2inch to allow for the depth of internal thread.

The last one, the steam take-off connection (A) is a little bigger as it has a larger flow through it and needs a tap built in to the fitting beyond the bush to shut the steam off.

(If you are planning on buying the fittings for your three cock water gauge (a requirement of the latest steam regs), rather than making them yourself, then stick with the internal imperial size as metric is not available commercially so far – that I am aware of) – more of this is shown in the pipework chapter.

The reason for the larger fitting is that the feed piping needs to be 5/32" (8mm) outside diameter to accommodate the flow of steam should the relief valves lift, whereas the water feeds and sight gauge do not need to be so big.

One point here is that you should not use brass for your bushes as brass tends to corrode slowly with water and heat and will fail over time, whereas bronze will definitely outlast your model traction engine. This is the reason that bolt-on fittings are made of brass as they are more readily replaced when faulty *(although twenty or thirty years is no problem for brass fittings, depending on the chemical make-up of the brass)*.

Once these items are completed, the second pressure ring can be shaped and drilled in the same way as the front end, but for the final assembly things need to be altered a little.

Firstly, you need to produce three nuts at ¼ inch (6mm) deep from the ⅜ inch (10mm) hexagonal phosphor bronze rod, tapped ¼ x 40 (6mm x 1), and the bronze rod needs centre drilling and ¼ x 40 (6mm x 1) threads running down for ¾ inch (19mm +) at both ends as the rear 13-gauge plate needs the bronze rod nutting to it with the end of the rod level with the top of the proposed outside nut and the inside nut pinched tight to the plate.

Doing it this way allows the remainder of the rod to sit inside the barrel and just poke through the front central hole by ¼ inch (6mm) which is ideal for the remaining nut height on the front end, which will be added later, once the back end is soldered.

The rod needs to be in place to support the rear plate about to be soldered, and if the barrel is sat on a flat surface on its front end, then the rod should hold the plate in the right position, with the rear edge of the back pressure ring being beautifully in line with the back end of the boiler barrel.

If you started off with the barrel a little shorter, then adjust the rear pressure ring so that it sits flush with the rear end of the barrel. The rod length can easily be reduced to match the length of the boiler barrel once the parts are soldered together.

Take the whole lot apart and clean it up ready for the soldering of the rear end, including the thread where the nuts sit and the underside of the nuts against the plate (but not where the nut will be at the front end for now) and upon re-assembly, make sure the upright line on this plate matches up with either of the lines along the barrel.

If you have already chosen one line on your barrel as the upper one, then make sure you have the pressure ring the right way up. This is most important, as these lines are what everything else works from.

If you have a preference for the top and bottom parts of the barrel, then it can be pointed out here that the whole barrel is not seen when the engine is complete, as half will be in the fire-box and the other half will be encased in lagging.

With everything cleaned and fluxed, just like on the front end, with brass studding or bolts replacing the steel bolts, anoint the inside of each hole and also the thinner part of the outer body of the bushes (making a point of not to get any flux on the internal threads), not forgetting to shine around the bush holes, and place the bushes in their appropriate holes.

With insulating blocks around the work, you can now begin the warm-up.

If you start heating directly at the top on the pressure plate, just to build up the temperature evenly, once you see the flux turn to a clear liquid and shortly after your solder is applied and runs, simply work around the pressure ring before adding a blob to each of the bushes and finally the central nut and rod, making sure the solder is showing all around the various protruding parts, but make a point of not getting any in the centre-drilled end of the rod.

The bushes, being threaded internally, allow for any expansion of air due to the heat, and that way everything is safe, as the last thing you want is to be heating a sealed container.

Once it has cooled sufficiently to be handled, up-end the boiler so the front is uppermost and clean the plate around the screwed bronze rod and the underside of the remaining nut. Apply flux to both, including the thread, and tighten the nut on the rod, making sure there is the necessary gap for the solder to run (finger tight), and simply solder it in place.

The boiler barrel is now taking shape, so after cleaning and checking the seals, a method of checking the pressure holding capacity is needed.

What I have done is to use a brass tyre connector (the sort of thing you can find at any tyre depot).

It is basically a ⅜ inch ((10mm) piece of brass, one inch (25mm) square, with a hole drilled right through ¼ inch (6mm) in from one edge and another drilled to meet it around half way along its length. This forms a hollow T shape, with soft soldered brass fittings attached to each hole.

The first is a $^{7}/_{32}$ by 40 thread, which attaches to my pressure gauge (imperial sizes again - if you have a pressure gauge with different sized threads, then work yours accordingly). The second is ¼ by 40 and attaches to a flange on the barrel being tested, whilst the third is a valve (ex-lorry ones are best, as they have a brass body *with the valve itself removed before soldering commences, otherwise the plastic and /or rubber core parts will be melted with the heat*) which connects to your pump.

If you make up one blank from 10mm (⅜) hex brass, threaded ⅜ by 32, plus another three with a ¼ x 40 thread, these can be inserted into the holes in the back plate and the pressure can be pumped in through the other through an adapter.

The blanks may leak just a little, so wrapping a little PTFE thread tape around the threads before installing the blanks will cure that.

If you give it around ten pounds of pressure as a trial, you may see small bubbles rising through the water you are testing it in. If you do, simply bore out that particular point with a fine drill and insert some bright, fluxed copper wire of a slightly smaller diameter and then solder it up again. If the leak is on a seam or joint, then plugging it with small wedges of clean copper before applying the flux and solder once more may do the trick.

Otherwise it may simply be a case of re-melting the solder to get it to flow better, but try to keep the part you are heating in a horizontal position, or as the silver solder melts and becomes a liquid, it can flow away from the point you want to seal if your gaps are too large.

Once you have achieved 10 pounds per square inch on air with no sign of bubbles, then it is best to do a hydraulic test in stages up to one hundred pounds pressure (double the proposed working pressure – that way incorporating a good safety margin when under steam).

Fill the barrel completely with water and repeat the air test up to 50 lbs pressure and let it stand for around half an hour. Water being denser will take longer to escape from the boiler should there be a leak. The pressure should drop, but only fractionally. What happens is that the water absorbs some of the air because of the pressure difference.

If after half an hour, you are still around 45/50lbs, then congratulations are in order.

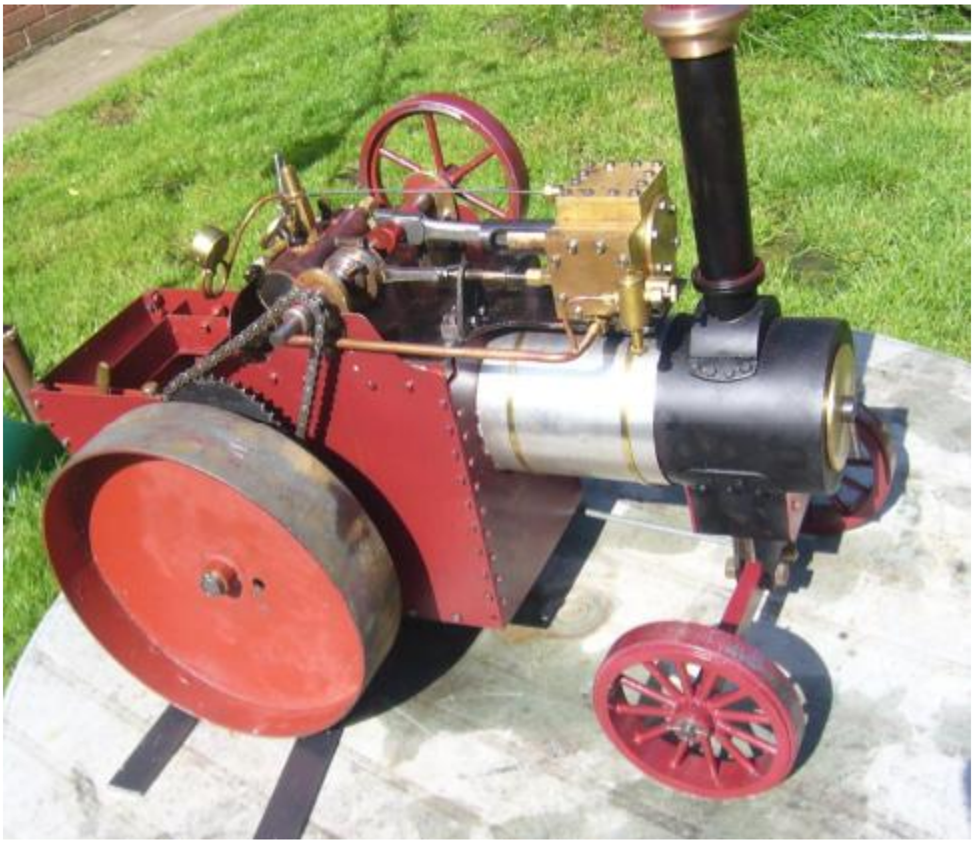
Pump more pressure in up to the 100lbs mark and wait again.

If you find the pressure drops quickly, then doing an air-only test at higher pressure will reveal any leaks when submerged in water, and can only be remedied by sealing the leaks by soldering in copper wire or small wedges of copper.

This hydraulic test should be done in front of your boiler examiner once you are happy with it so he can verify it holds the pressure without too much distortion at the required pressure. The examiner wants to be able to see the boiler shell holding tight before he can consider giving the necessary documentation.

However, that is only part of the test before the documentation and certification number can be given (and before he can stamp that number on the boiler showing it has been fine at double the proposed working pressure) as there needs to be a live steam test at 1.5 times normal working pressure including all the required fittings.

An alternative for your own testing is to have it on your bench and dab some water containing a little washing up liquid (soap) all around the boiler. Any bubbles being blown show where the leak is and requires attention, but you will need to do the hydraulic test before having the inspector check it out.



This is the engine in a part finished state and it gives you an idea of how she will look when finished.

An improved version, still from the original concept can be seen at https://in.groups.yahoo.com/neo/groups/pyrte/photos/albums/1515974528/lightbox/197136694#zax/197136694 which shows what can be done by a novice with a first attempt. In fact the same chap has also posted a short video of his same engine in steam and pulling him along which should get your build interest fired up all the more.