Little Steamers and Their Boilers

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Part 1: Theory

Background

When a small scale loco builder starts work on the generating department that is, on boilers -he or she faces a parting of the ways. On one hand is the Stephenson forced-draft "locomotive" boiler, with an air-tight smokebox at one end, an open firebox at the other, and a barrel full of firetubes surrounded by water to connect them. The exhaust steam is sent up through the smokebox as a jet, thus entraining the products of combustion from the firebox by way of the fire tubes. This in turn draws up oxygen from below the grate, causing the fire to blaze and boil the water into steam, which then, after working, repeats the cycle. The Stephenson boiler can be successfully miniaturized down to 7mm scale (0 scale), but its construction is both complicated and expensive.

On the other hand is the unforced "pot" boiler, which in full size as the "Cornish," "Galloway," or "Lancashire" boilers, had no application whatever for locomotive work, but which in miniature form can be adapted very successfully to small scale models for scenic operation. ["Scenic" operation is distinguished in that the trains are for looking at and not riding, as on a passenger hauling railroad. The "scenic" locomotive is too small to pull people. Ed.] The pot boiler is cheaper and easier to construct than the Stephenson and is adaptable to either spirit (alcohol) or gas (butane) firing. Until recently, however, it was regarded as suitable only for low performance steam toys.

For steam toys it was made as a plain drum of the thinnest possible material - often brass - and heated by an exposed spirit fire that, out of doors, required perfect weather conditions to keep the engine more or less in steam. Thus, the term "pot boiler" acquired a connotation of inferiority.

However, the unforced boiler of full size practice was not an inferior thing, and in the case of the Stanley, it was able to meet the exacting requirements of automobile use at remarkably high pressures. If the unforced boiler can be arranged conveniently on a miniature loco chassis, then it can be made to provide all the steam a small scale (scenic) loco can use.

I would like first to deal with only spirit fired boilers, for recent developments in gas firing are tending to push the gas fired pot in a new direction where spirit firing cannot follow, and gas thus merits special consideration. However, spirit firing possesses a number of real advantages and, with the improved designs described here, is capable of giving performances equal to just about anything that may be asked of a small scenic steamer, despite the low calorific value of the fuel. This, incidentally, is a point seldom given consideration by loco builders, but it has a very direct bearing on boiler design.

Here is a list of fuels in rank order of British Thermal Units (BTU's) per pound of weight:

Hydrogen	52,000
Propane	21,600
Butane	21,300
Gasoline	19,500
Kerosene	19,000
Steam Coal	13/15,000
Charcoal	12,000
Methylated Spirit	11,000
Hard Wood	7,400

It follows that with a fuel of such low calorific value, the only real advantage is convenience - in storage, refuelling, and fire feeding. Having said this, one must add that it can still yield a very useful performance indeed, quite in line with "scale prototype," if two courses of action are followed:

1) Screening the fire and boiler from adverse weather.

2) Increasing the boiler heating surface within the fire zone.

Screening the Fire

Taking action on (1) will improve the performance of a plain pot by eliminating heat loss to the air and to other parts of the loco. While merely shielding the fire with a side tank configuration will screen the fire from cold wind, something more is needed to prevent the loco as a whole from heating up, and the best "something more" is a pot boiler firebox. This can be made of sheet metal, about 23 gauge: tinplate, copper, brass, or stainless steel. The last named is best as its heat conductivity is low.

Needless to say, proportion is important, and the cross section shown in Figure 1 will give excellent results with a boiler of 2" in diameter. As the firebox provides combustion space on the lower flanks of the boiler, it can be seen that the boiler can be pitched closer to the fire than used to be regarded as correct in steam toy days. I have found that with the wicks trimmed right down to "skinhead" proportions, the boiler can be set at only 3/4" above the burners.

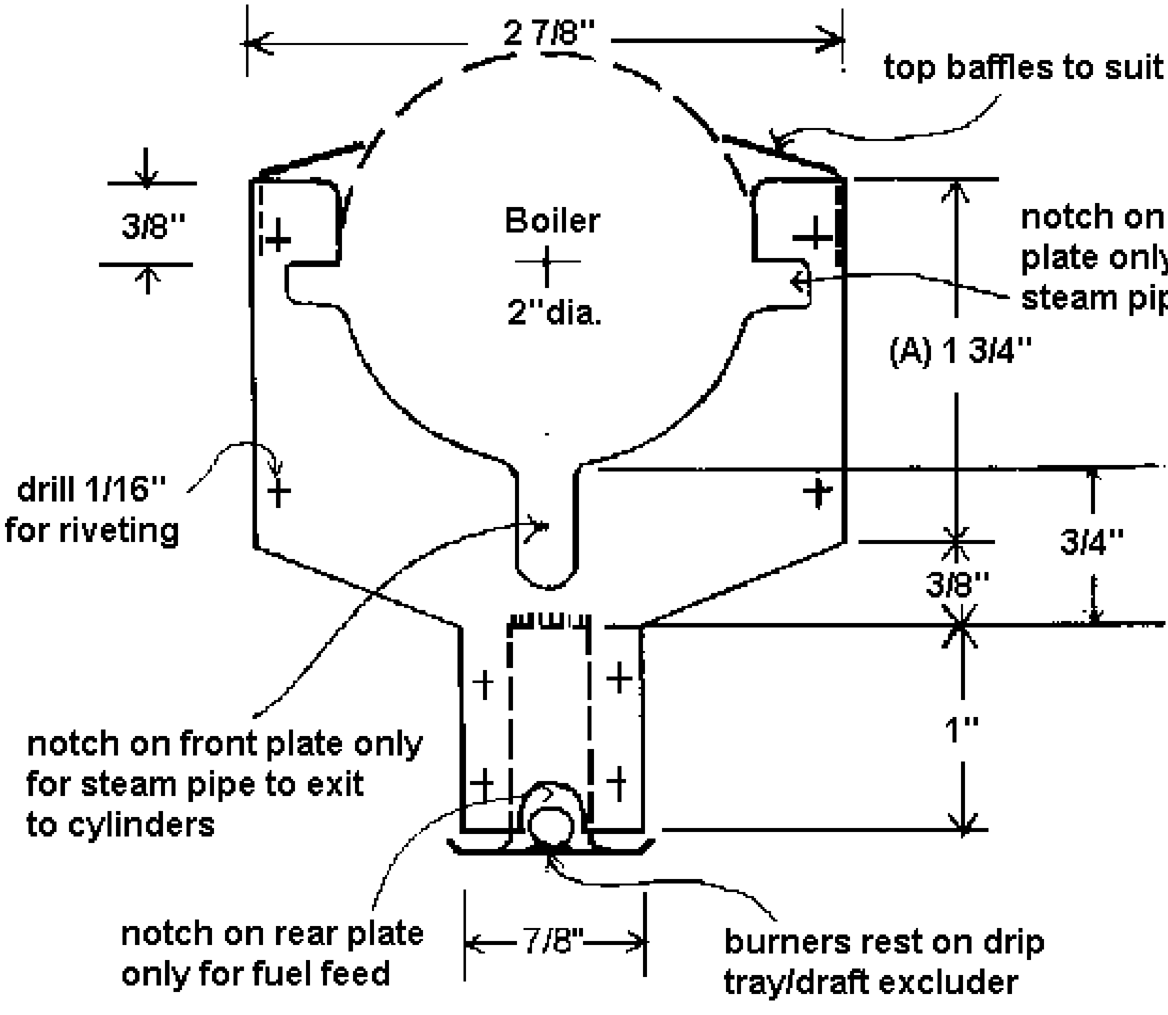

FIGURE 1

Cross-section of firebox for 2" diameter boiler. For a firebox for a boiler of 1 3/4" diameter, make overall width 2 3/4" and adjust dimension (A).

As to the length of the firebox, that is largely determined by the loco's configuration. The side panels are given extra length for tabs. After the panel is bent to conform to the shape of the end pieces, the tabs are bent 90° and riveted to the end pieces,

On an English side tank loco a full length firebox is possible. The same applies to saddle or pannier, if one does not object to a glimpse of unprototypical firebox beneath the lower edge of the tanks. But if the model is of a tender engine, then a different type of boiler must be used if one wishes to screen the fire - something to be discussed in another article.

I have found that with a boiler I 3/4" in diameter X 6" long, a firebox 4 1/2" long gave excellent results, as in the Charles Pooter design. Recently I built a 2-6-0T having a boiler 2" in diameter X 7 1/2" long with a firebox only 5" long. I gave this boiler increased heating surface and it proved to be a very fast and strong generator.

On the other hand, when I built a skinny boiler of only 1 5/8" diameter X 7" long with added heating surface, but with a firebox less than 5" long, the result was extremely rapid steam generation in fine weather, but a lack of stamina in adverse weather conditions. In reducing the boiler diameter to less than 1 3/4" I had crossed some kind of watershed in performance - a point to be discussed under Heating Surface.

Fireboxes are best arranged so as not to touch the superstructure at all, and to be supported on the frames by no more than four finger-tip contact points, either by riveting lugs to the frames or cutting part of the frames away. If this is done and the proportions shown are adhered to or improved upon, the loco as a whole, and its fuel, will remain perfectly cool to handle, while the fire blazes in a secure environment and the boiler gets all the heat.

Heating Surface

All steam generation depends entirely on the transfer of heat from the fire, through the boiler skin, to the water. On a plain pot, the heating surface of the boiler is approximately its lower half within the fire zone. This area can be increased without significantly increasing the volume of water to be heated, if the boiler is given any one of the following (Figure 2):

1) Circulation pipes

2) Teats

3) Sub-boilers slung on the lower flanks of the main boiler

4) Porcupine quills

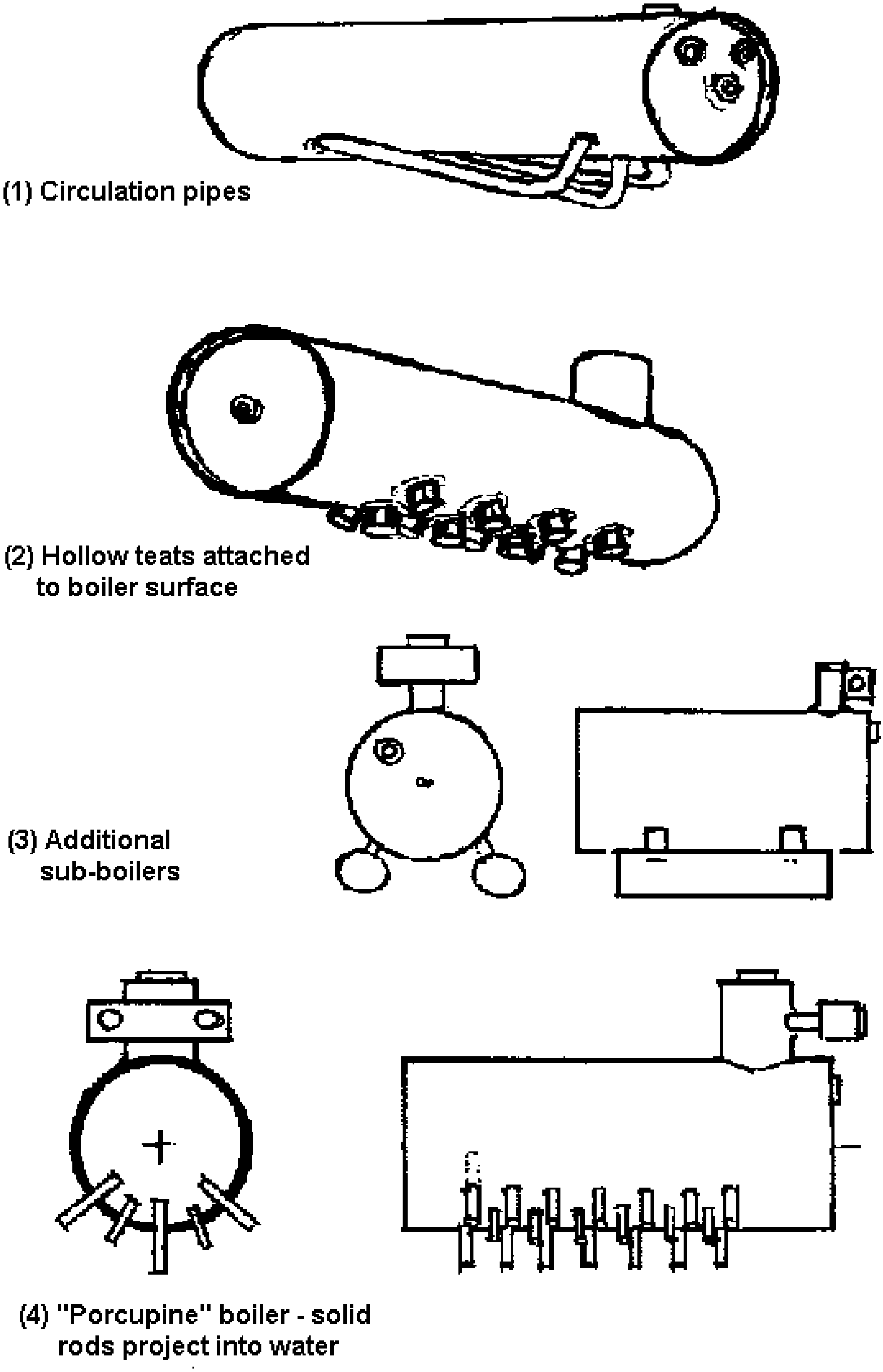

FIGURE 2

I have made boilers with all these devices and can say that only 3 and 4 showed marked improvement over the plain pot, and of these two, 4 won hands down. In my view, 1 and 2 are a waste of time and materials.

In full size practice the porcupine boiler has been used on river launches and fire engines, with hollow spikes attached to the boiler shell. But in our small scales it is far better to use solid spikes of copper or gunmetal with half their length projecting through the shell into the water.

For my first experiment with "porkies" I used 1/8" diameter gunmetal rods, 3/4" long, with half the length reduced to 3/32" diameter, this being the portion projecting into the boiler. Twenty-seven rods were arranged in 3 longitudinal runs at 1/2" spacing, the locations being staggered. I found the performance of this boiler to be excellent. Indoors and out, generation exceeded the consumption of a pair of 9/16" X 5/8" cylinders.

John Turner Models then decided to adopt the porky, but instead of my tailored spikes, simply used a host of 3/32" X 3/4" copper rivets inserted more than half way, in about five longitudinal runs. Generation fully equalled that on my tailored porky. Then I made a boiler of 2" diameter X 7" length with only 15 tailored spikes, interspersed with two rows of 1/16" X 1/2" copper rivets inserted half-length. This boiler was a really fast generator! To keep it within bounds it has been necessary to reduce the fire.

So far. Porky design is wide open. It seems certain that conducting heat into the water gives these exciting results, but clearly there must be a critical length for inward projection, beyond which the rod has given up its heat from the fire and has begun to take it back from the water. I hope this article gives rise to experiment, for the Porky really takes the pot boiler into new realms of performance. I have one, powering a single Mamod cylinder unit, that rockets up to 110 psi when the engine is shut down to tick-over. Opening the throttle wide at this pressure really makes that Mamod rev like a motor bike! This, incidentally, disposes of the myth that high pressure blows an oscillating cylinder off the port face. It doesn't. It just revs madly in a mist of lubricating oil.

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I have mentioned the disappointing bad weather performance of a 1 5/8" diameter Porky boiler with a short firebox. The problem is that reduction of diameter increases the ratio of surface area to boiler volume. This is fine for speeding heat transfer in the firebox zone, but in bad weather there is a proportionate amount of "give-away" boiler surface outside the firebox zone. The conclusion is that small diameter boilers need longer fireboxes, on the same principle That babies need to be well wrapped up to keep them warm.

The principle works thus: A cube of 2" per side has a volume of 8 cubic inches and a surface area of 24 square inches. The ratio of volume to surface area is 1:3. A cube of only 1" per side has a volume of only 1 cubic inch, but a surface area of 6 square inches, or a ratio of 1:6. Got it?

In practical terms, a boiler of from 1 3/4" to 2" diameter, with the heat retaining/increased surface devices described above, will have a very useful cushion of generating performance in the worst weather, and in fine weather will generate steam at rates directly comparable to forced-draft boiler performance.

Part 2: Constructing the Boiler

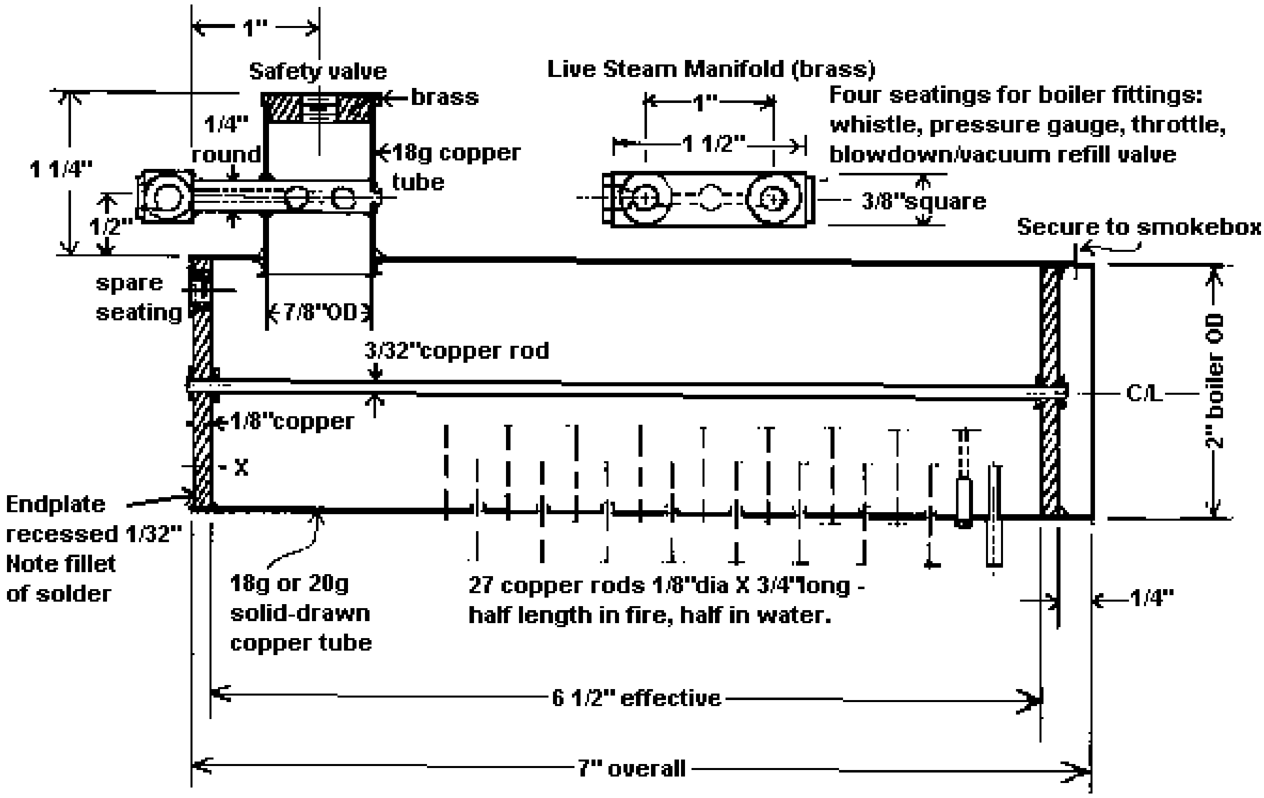
Materials

Copper is the best material for boiler making because it transfers heat rapidly. It is a homogeneous metal, easy to work, and parts made from it can be securely held together with silver solder.

Once upon a time it was customary to use very thin boiler material, to get some degree of heat Transfer from an exposed fire. On "designed" boiler/fireboxes as described in this series, solid drawn copper tube of 18 or 20 gauge, with copper endplates say 3/32" Thick, gives superabundant strength and excellent heat transfer. But an unshielded pot boiler in 18 gauge is Indeed a non-starter, for then the heat prefers to travel sideways along the copper to the unheated ends, where it gives itself to the passing breeze.

Endplates should be turned an exact fit inside the boiler barrel and recessed slightly so that a fillet of silver solder can form around their circumferences. For super safety, the endplates can be connected by a copper stay made of 3/32" diameter rod.

Before drilling the holes in the barrel for the porky spikes and the steam turret, you will find it useful to make a wooden former to slide inside the barrel to prevent the copper from deforming when gripped in the vise and when being center punched and drilled. At present I make steam turrets from 7/8" diameter copper tubing with brass cap and steam manifold (Fig. 3). I drill the barrel 1/2" first, then open out to 7/8" with half-round files.



X optional - a brass screw can be silver-soldered here to secure boiler to a mounting bracket

Volume = 20 cu. in. (approx)

All joints silver soldered with "Easy-Flo" or equivalent:
Melts at 620°C; tensile strength, 30 trons/sq. in.
NOTE: Hydraulically test before steaming

FIGURE 3
High performance pot boiler when installed in a firebox

Silver Soldering

Silver soldering is quite as easy as soft soldering. One needs to make a hearth from an arrangement of fire bricks, preferably contained in a sheet iron open top box with legs.

A Propane gas torch with various jet sizes is the source of heat. For small work, silver solder wire pre-encased in flux is exceedingly useful. For larger work, separate wire and flux are better.

Before heating up, rub all parts bright with wire wool and wash them in boiling water.

On a big job like a boiler end plate put a thick paste of flux and water round the joint, heat up, and as the flux goes clear and boils apply the silver solder. It will flash round the joint within the area brought to the necessary heat. Take the heat round the joint, applying more flux and solder where necessary.

On small work just heat up, and in doing so, warm the silver solder rod. Dip it in flux - it will pick this up at the hot end. As the workpiece nears red heat, test the fluxed rod on the joint. At the correct heat the joint will be fluxed and soldered at one go. With practice the deposit of solder becomes neater. Turn the workpiece with a piece of steel rod to get at the other side. When preparing to heat any workpiece, arrange a "cupboard" of firebrick around it to conserve heat and speed the job.

When you finish the job, or perhaps when you complete each stage of a big job, you pickle it in dilute sulphuric acid as Is used in automobile batteries. [Ed. Note: There are safer materials designed specifically for pickling metal which come in powdered form. Check with your local jewelry supply house or lapidary shop. MH] This cleans off the flux and makes the work ready for washing in water and for examination. I keep my pickle in a plastic pail with a lid.

Let a workpiece cool somewhat before placing it in the pickle. It is dangerous to plunge a large item such as a boiler barre1 straight from the fire into the pickle. After being pickled, the workpiece is washed under a running tap and cleaned up with wire wool. All the joints are examined and any doubtful places are scratched with a scriber. Sometimes you find pinholes, or even a part that you have missed with the solder, your eye having been deceived by the glare of the torch and the running flux. If this occurs, reflux, heat again, and apply solder. Then cool, pickle, and wash again. In the end, after successive heats, your boiler will stand complete with spikes, turret, and manifold, so bright and pretty in copper, gold, and silver that you'll feel reluctant to paint it. And In fact you can't yet, because first the boiler must be tested.

Testing

For this job you need a test pressure gauge with an adapter to enable it to screw into the safety valve seat on the turret. You also need a hand operated ram-type water pump, a copper pipe with a loose union at each end to connect the pump to the boiler, and a set of plugs and aluminum washers to close all other boiler openings.

After closing all these, you then fill the boiler with tapwater, being careful to leave no air trapped anywhere inside. Then connect the pump pipe. Top up the water if necessary, then screw in the test pressure gauge. Pump away, and watch the needle swing across. If all is well the boiler will hold pressure when- ever you stop pumping. Go up to 150 psi! Any defect will be revealed at once by a tiny jet of water and instant loss of pressure on the gauge. In this way the boiler is tested to above normal working pressure in perfect safety, Even if an end plate came out under hydraulic test there would be no danger whatever - just a very wet workbench, Never test an untried boiler under steam or compressed air. The safe hydraulic test must come first to prove the boiler's holding strength. After a successful hydraulic test you may possibly find, under steam, that a pinhole leak has developed somewhere, where a tiny piece of dirt was lodged unseen at the silver soldering, to be boiled out at the first steaming. That can be irritating, but it is not dangerous. It just means stripping down, scrubbing, marking the spot with a scriber, and reheating.

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At last, with everything as it should be, you can put that porky in its firebox, connect the steam-pipe to the cylinders and lubricator, and light up. And then you learn what is meant by RSG, Rapid Steam Generation!