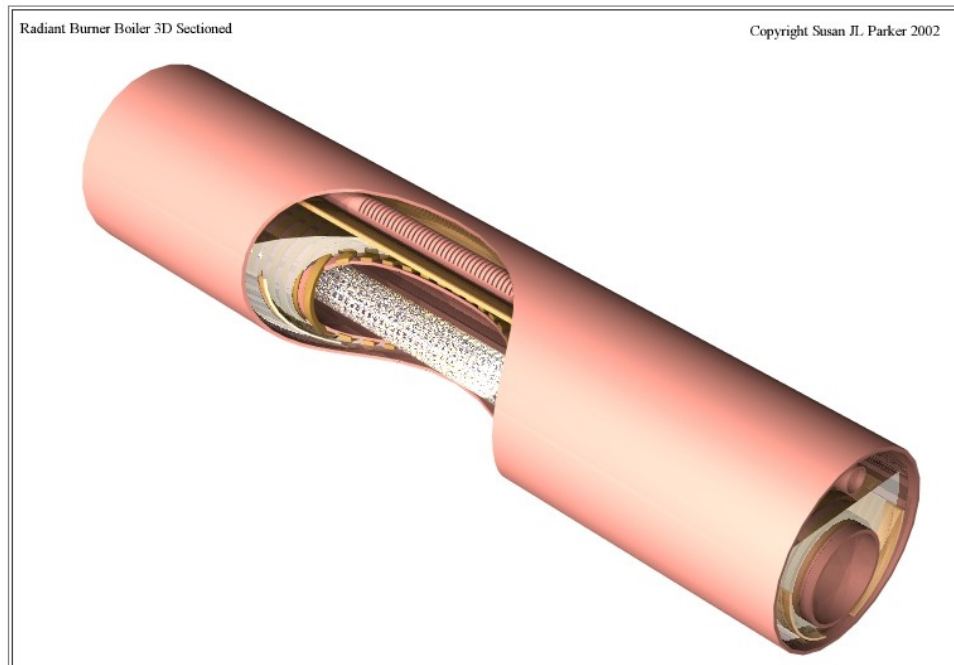


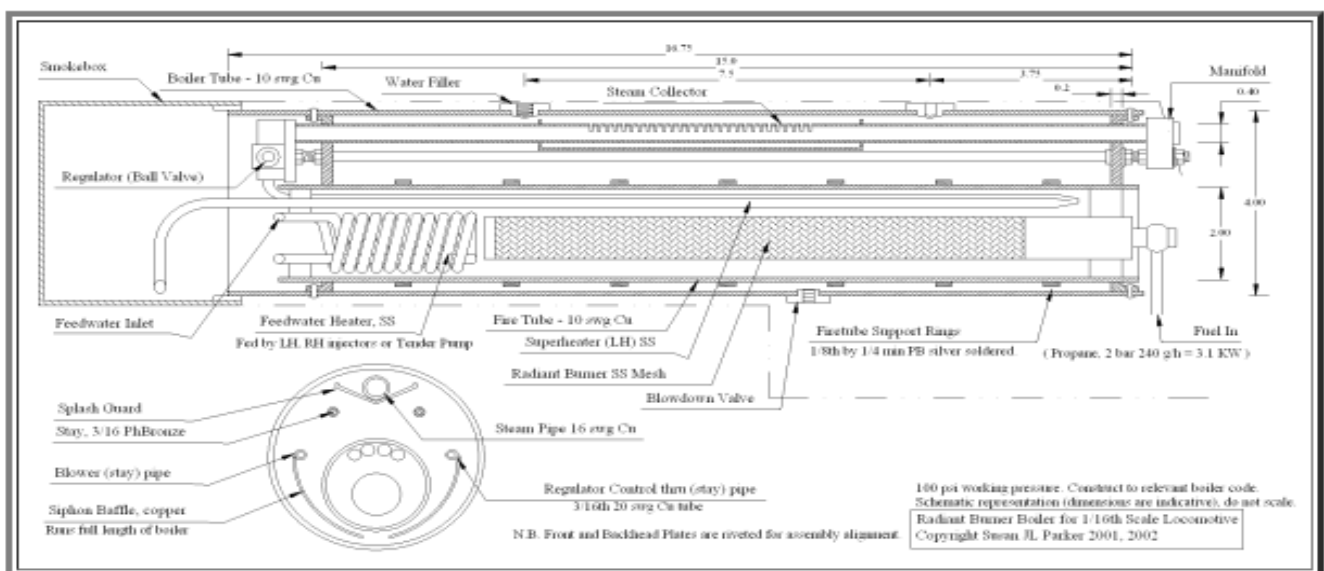
Extract From: <http://www.susan-parker.co.uk/susan-boiler.htm>

A Monoflue Gas Fired Radiant Burner Boiler

for live steam engines and locomotives.



DESIGN:



Basic concept boiler drawing (click on above image for 2000 x 1400 pixel version).

Note: The design has been updated during construction, with a more tightly wrapped spiral strengthening on the flue as per the 3D CAD drawing plus additional staying.

I have designed the boiler with the aim to meet the requirements of the Australian copper boiler code which requires bushes on the longitudinal stays. This is not the case here in the UK but one of the objects of this design is to define a basic boiler which can be made and used worldwide.

The steam pipe has also been de-rated because of the steam collection slots and the main support for this section of the front and back heads is from the adjacent two stays. Note the splash guard which is fitted onto the top two stays.

The only large piercing of the outer boiler shell is the primary safety valve which is of a special design which will live under the sand dome and exhausts through two pipes directed downwards under the boiler and between the frames. It has a sufficient aperture to exhaust steam at a minimum of four times the maximum evaporation rate.

Secondary "safety" valves are connected to a manifold on the steam collection pipe and these are set to give normal boiler "regulation" and pressure indication to the driver.

In normal operation the burner will be regulated by the steam pressure.

The spirally wound flue support can be seen in the pictures, which adds to the evaporative surface area available.

Drawing Design Notes:

Boiler has been designed to comply with the:

Australian Miniature Boiler Safety Committee
AMBSC Code Part 1

Issue 7-2001: Copper Boilers

<http://www.pnc.com.au/~wallison/codeone.htm>

General

The drawing is a schematic rather than a fully engineered drawing and although dimensioned the measurements are indicative rather than hard and fast (the major length of the boiler and size of smokebox are more or less accurate to fit the loco).

Burner

The burner prototype is a radiant stainless steel mesh over a slotted tube fed from a modified 3.1KW blow-lamp burner. The active part is some 10" in length (note the slots vary in size from one end to the other).

The stainless steel mesh will need replacing from time to time, so the burner assembly should be accessible for maintenance. Higher temperature materials could be used if available.

Flue

The mono-flue as shown is 2" O/D 10 SWG (0.128" - 3.25 mm) tube . It is important to note that the collapse pressure for a tube is NOT the same as its burst pressure. I have included a close pitch support spiral (that emulates conventional support rings) to ensure that the flue retains its round shape, having been advised that this are necessary to strengthen the flue for it's 8x margin.

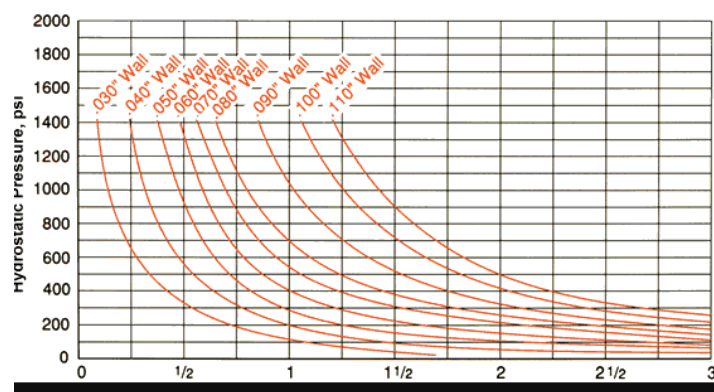
N.B. The 3D section shows spiral on a $\frac{1}{2}$ " pitch which is designed to give a substantial increase to the surface area in contact with the water. Easy to draw in CAD, not quite so simple to fit and silver solder!

Flue Tube Collapse Pressure:

There seems to be a certain amount of ambiguity surrounding collapse pressures of copper flue tubes. While the burst pressure, density of stays, number of rivets, etc. all seem to have formulae, flue tubes are specified by a table.

Tables are fine, but don't describe the reasoning for the values they contain. As it is important to design in safety as the primary component of any boiler I have been undertaking some research and I am working on developing a formula which fits experimental data derived from testing by copper tube manufacturers.

The graph below is from the [Copper Tube Handbook - Figure 3](#).



Flue tube collapse pressure diagram.

The formula will be for collapse pressures of annealed copper flue tube of various thicknesses and diameters, where length is six or more times the diameter. Note that the existing commercial formula as used for steel pipe in bore holes does not work for the small diameters in copper as used in our boilers. Also this does not cover shorter pieces where the length is similar to the diameter - such as is found in marine style boilers as used in the Sweet Pea design.

N.B. *These figures assume the tube is actually round (less than 1% eccentricity) and undented!*

I always assume fully annealed tube. This may not be the case in practice with standard copper boiler design as the tubes are brazed at the ends only and the centre sections may retain a degree of hardness. BUT without destructive testing - which

rather defeats the point - one cannot determine the amount this might be, so one should always use the fully annealed values.

Note (2005): This is clearly seen in the high pressure test as the profile of the boiler shell shows the effects of fully annealed sections ([see large 2200 pixel image](#)).

Fig 4 shows the affects of heating on the yield strength of copper. NOTE: This is not the operating temperature, but the maximum temperature the material has been raised to during fabrication or operation AT ANY TIME.

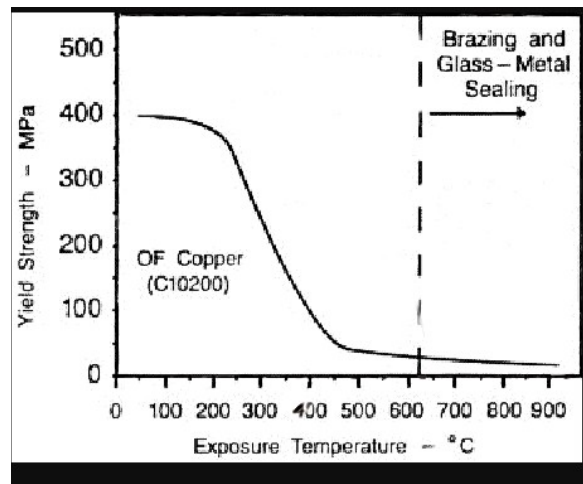


Fig 4: Copper Yield Strength v Heated Temperature

This graph demonstrates why it is so important to have an adequate safety margin in hand for safe operation.

**Metric Conversion 1000 psi = ksi x 6.894 = MPa
1 MPa = 145.03 psi**

Steam Pipe

The steam collection slots are indicative and would be made finer and in a greater number than that shown, allowing for scale build up.

Superheater

The superheaters also shadow the top of the flue and may provide some protection should the water level be low and slosh (shouldn't happen normally, but...). There are two superheater tubes, the left hand one feeds the left side piston and the right hand one the right side piston, i.e. they connect directly and thus reduce the complexity of the plumbing.

Note (2005): Subsequent to my original design I am now looking at the benefits of having a separate superheater module with it's own dedicated radiant burner. This would produce superheat on demand, and allow close regulation of the final dry steam temperature (of particular benefit for use with PTFE cylinder components).

Siphon Baffles

The siphon baffles are a major feature and should help promote circulation in the boiler. Although in implementation they are rather different from that which was in full size use they will operate in a similar manner. The baffles would also be appropriate for a G1 boiler, although perhaps rather more fiddly to fit.

Conclusion and Disclaimer

The basic premise is simplicity and strength, including minimising the number of incursions into the basic pressure vessel structure.

Please Note:

Although I have gone through this design fully with calculations any new boiler construction should be rechecked against the actual materials being used. Even small changes in gauge thickness, diameter or length can have a big effect on safety margins.

In my final implementation (see pictures) I following the Australian regs closely (for example more stays than those originally detailed in my drawings were used). I also used bushes for the stays which is not always common practise.

Any boiler design should be thoroughly checked using accepted practise before being built. Showing a boiler inspector the calculations and having them to hand for insurance purposes demonstrates "Due Diligence"!

Recommended maximum internal working pressure for a copper tube with brazed joints with saturated steam is 120 psi. See [Copper.org's Copper Tube Handbook for further Information](http://Copper.org's%20Copper%20Tube%20Handbook%20for%20further%20Information).

Inspirations

This design originated as I needed a boiler for my own use which I might have some chance to be able to construct myself, or at least have made at not too great an expense.

I decided that gas or liquid fuel firing was most appropriate for my requirements, as it can greatly simplify the overall design.

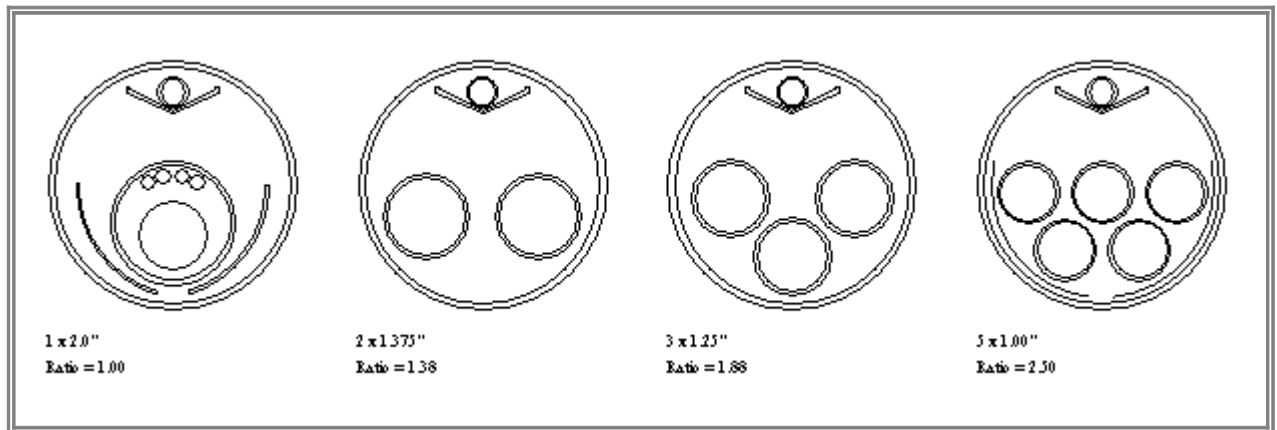


Fig 1: Single through five flue options for a 4" dia boiler.

Taking into consideration the size of burner(s) required to generate sufficient heat to produce efficient evaporation I chose the mono-flue "Cornish" option as this seemed most appropriate for a 4" OD boiler (and the simplest in construction).

Larger boilers for bigger locomotives would use two or more flues of up to 2" OD which is the maximum usable diameter for 10 gauge tube.

Whilst in appearance this concept looks like a big sister to a Gauge 1 (c. 1/32nd scale) boiler the design was done from first principles (my original inspiration when I first started looking into boiler design options was the Lentz boilers of over 100 years ago). Form follows function however...

The Radiant Burner concept has been successfully used in Gauge 1 scales, with documented improvement in operation compared to conventional gas burners.



Image 4: Radiant Burner by Kevin O'Connor

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