Boiler Types and Design Considerations

Bob Sorenson

Objectives

Types of boilers

- Locomotive
- Stationary

Design Considerations

- Capacity
- Barrel thickness
- Flues
- End Plates
- Stays

Testing to Destruction

References

Model Boilers and Boilermaking, K.N. Harris

Model Locomotive and Marine Boilers, Martin Evans

Model Engineer's Handbook, "Tubal Cain" (Tom Walshaw)

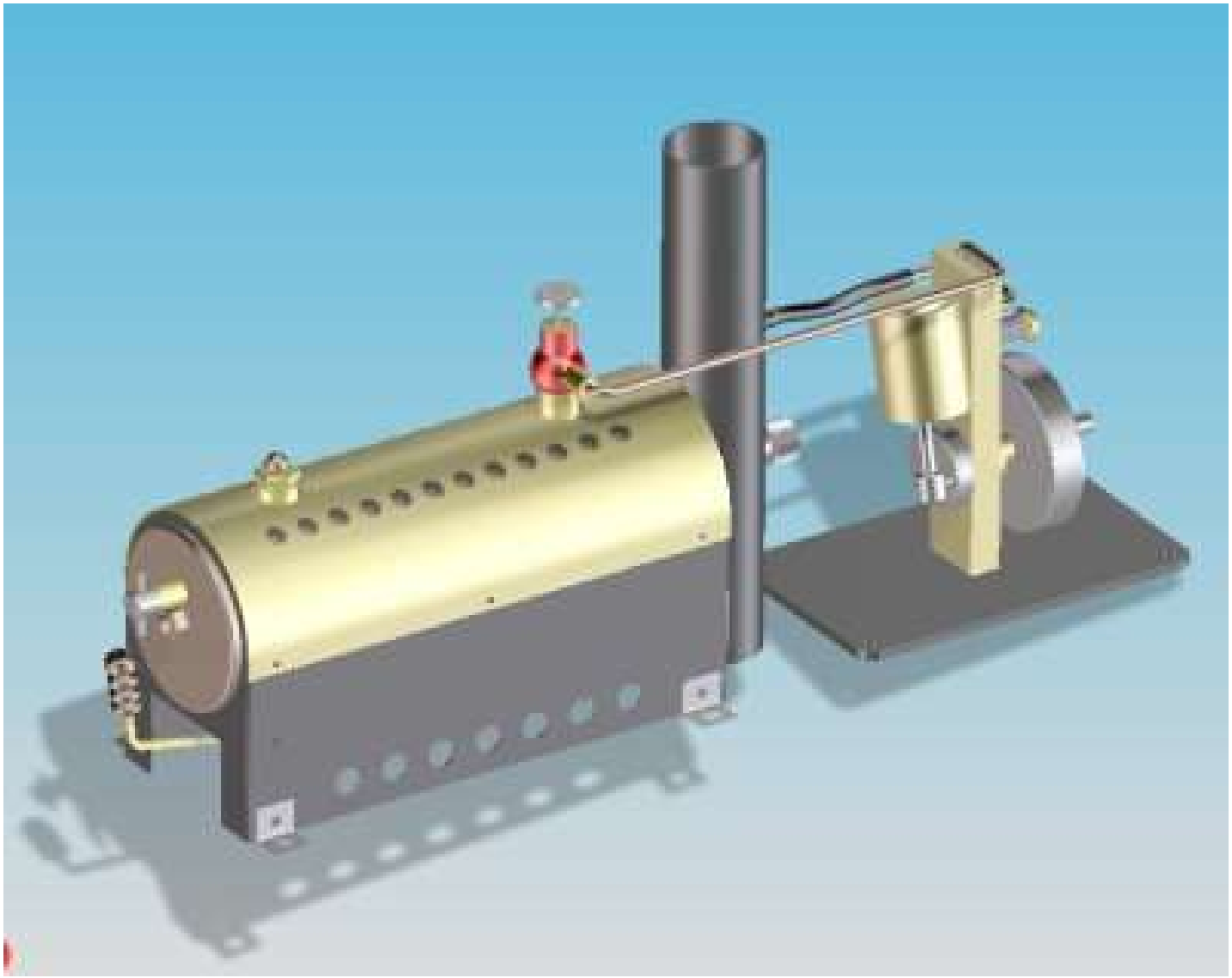
Making Small Gas-Fired Boilers for Steam Models, Alex Weiss

Building the New Shay, Kozo Hiraoka

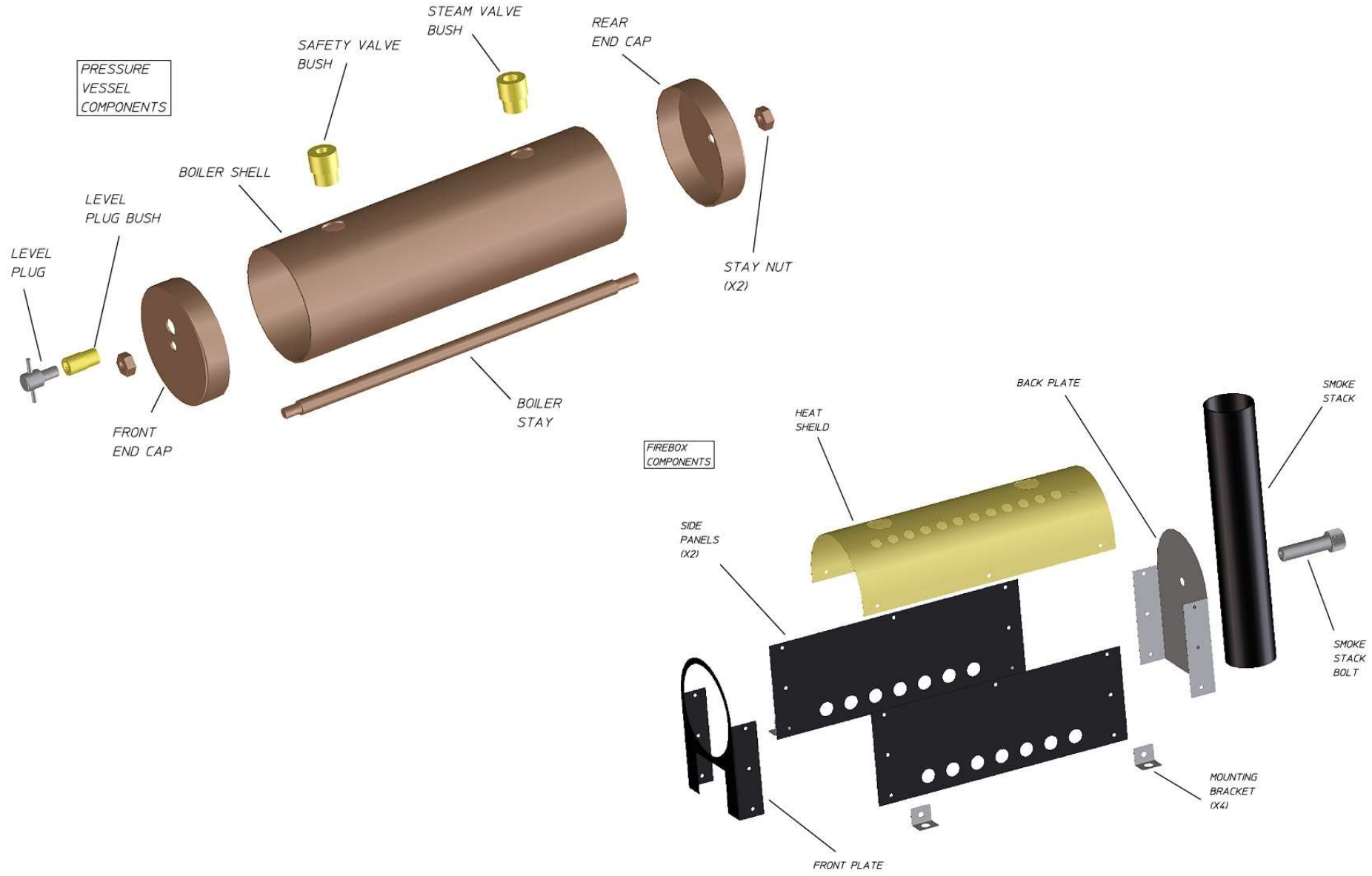
AMBSC Code Part 3, Issue 1.0

A Passion for Steam, Marc Horovitz

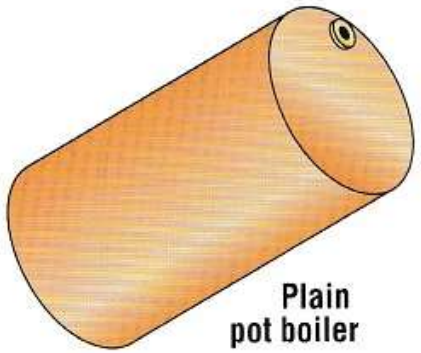
Pot Boilers



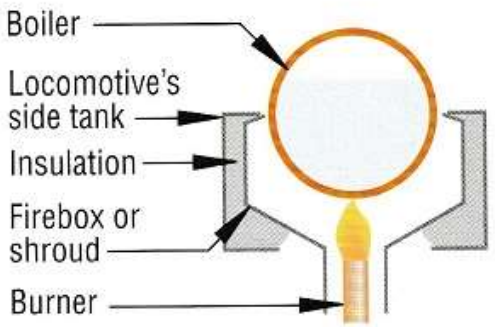
Pot Boilers


PRESSURE VESSEL COMPONENTS
STEAM VALVE BUSH
SAFETY VALVE BUSH
REAR END CAP
BOILER SHELL
LEVEL PLUG BUSH
LEVEL PLUG
STAY NUT (X2)
FRONT END CAP
BOILER STAY
FIREBOX COMPONENTS
BACK PLATE
SMOKE STACK
HEAT SHEILD
SIDE PANELS (X2)
SMOKE STACK BOLT
MOUNTING BRACKET (X4)
FRONT PLATE

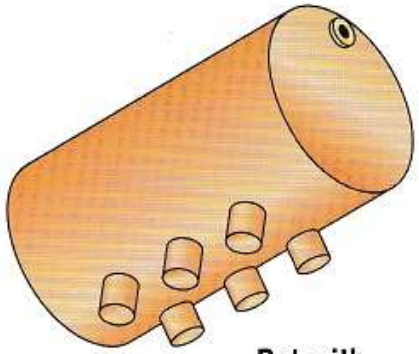
Pot Boilers



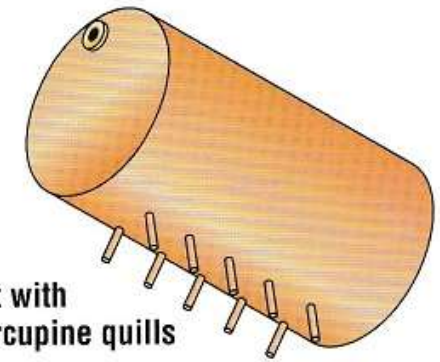
Plain
pot boiler



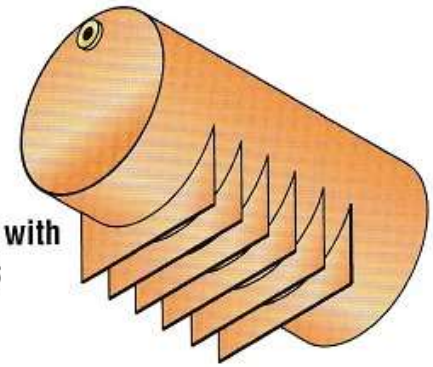
Wheldon's pot-boiler shielding



Pot with
hollow quills



Pot with
porcupine quills



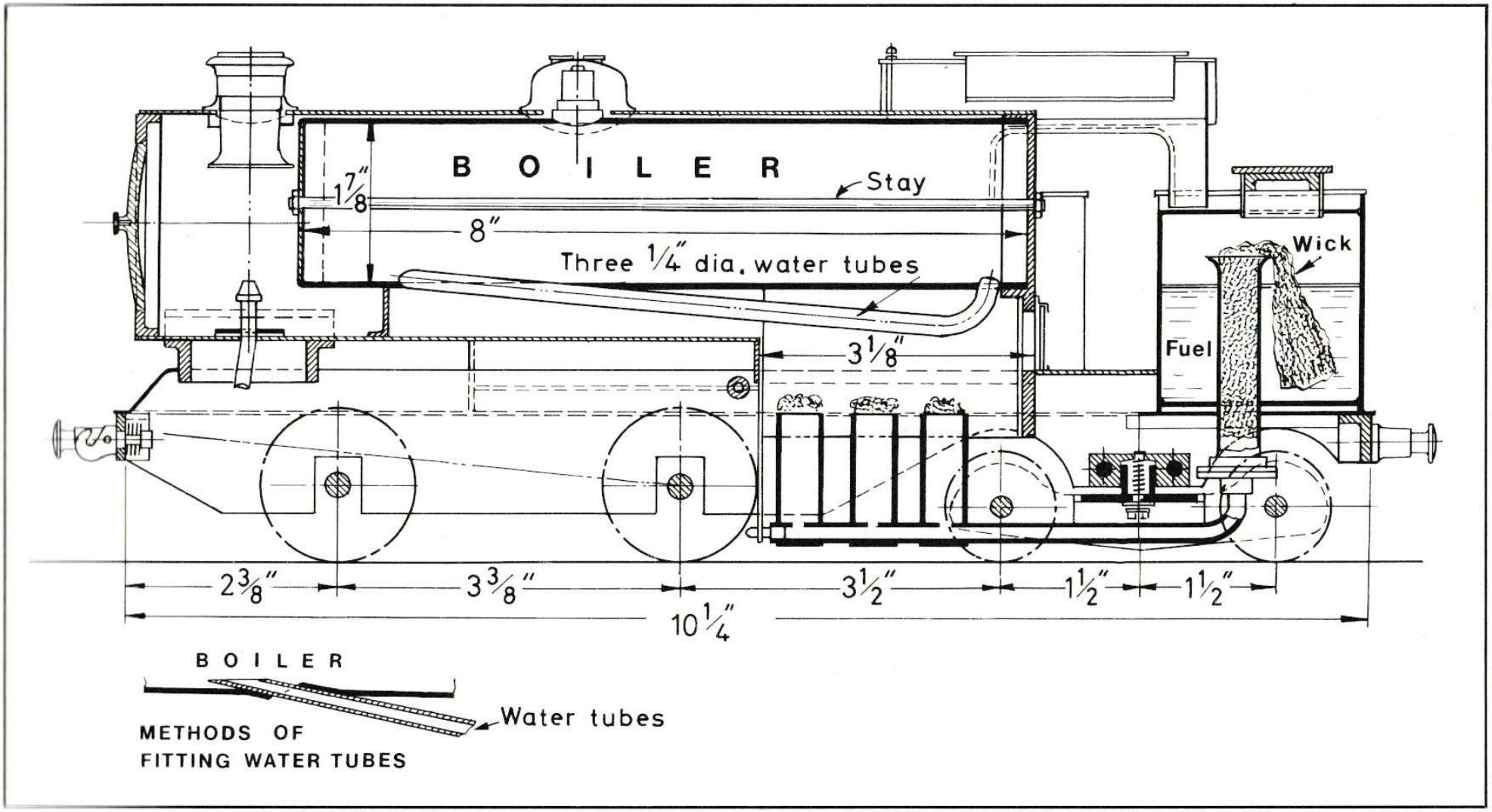
Pot with
fins

Marc Horovitz

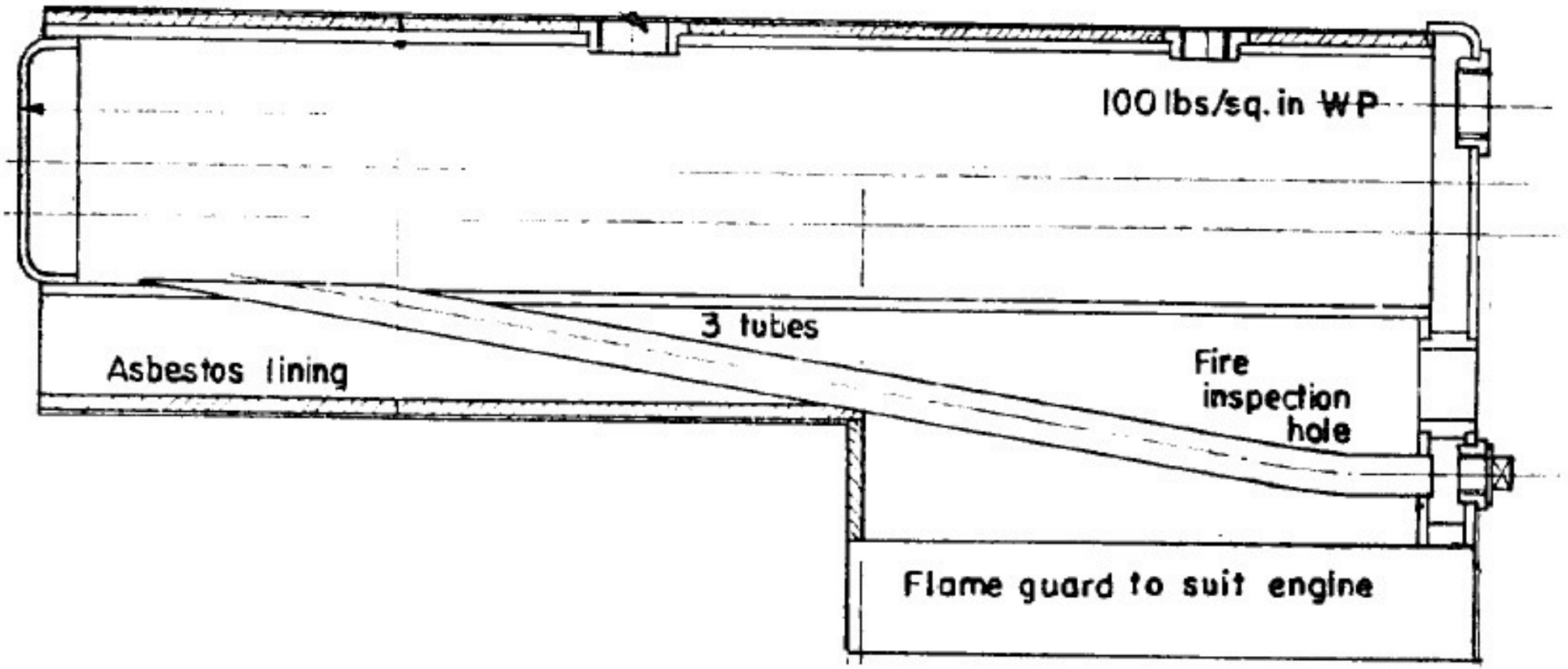
Pot Boilers

Marc Horovitz

Smithies Boilers



Smithies Boilers



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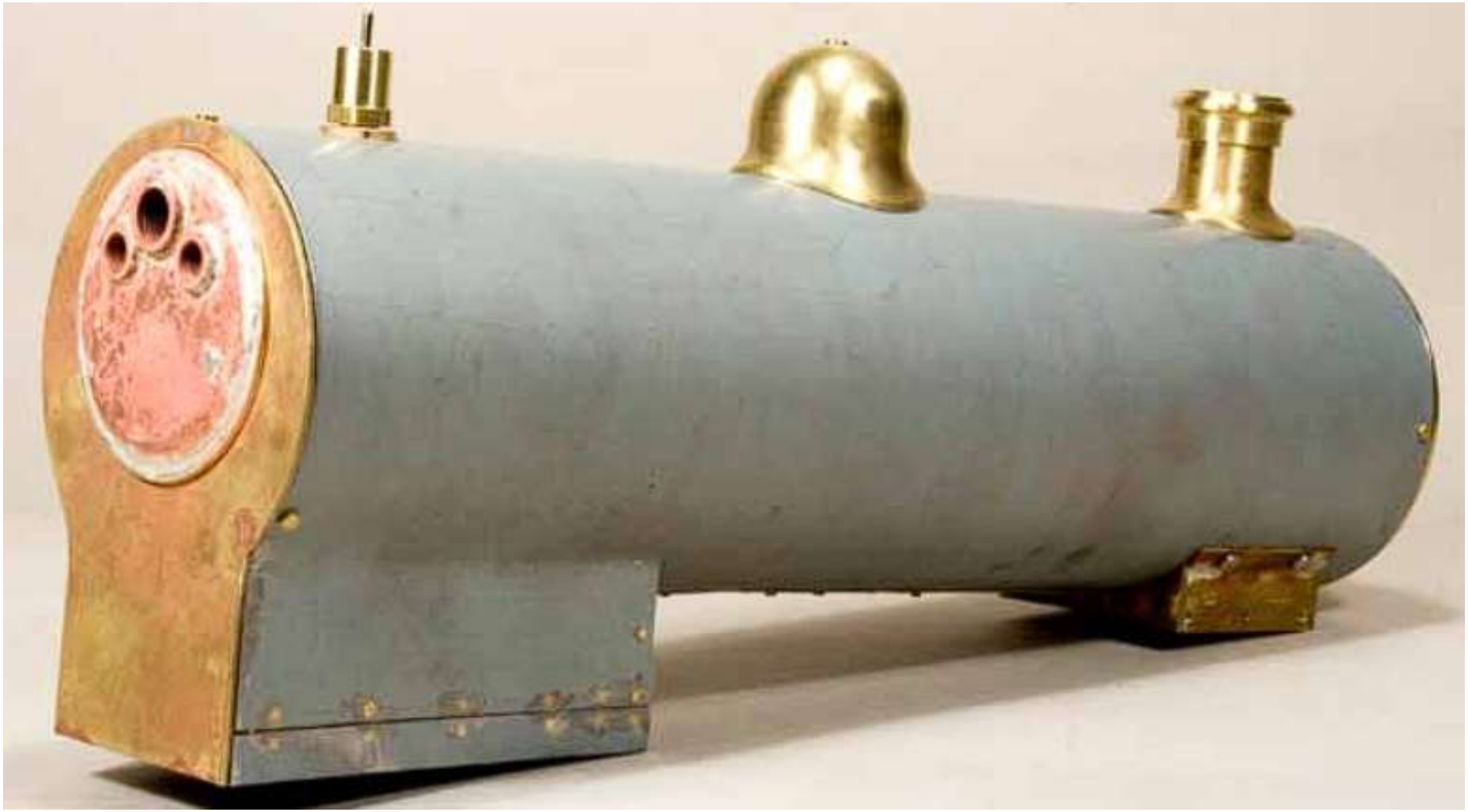

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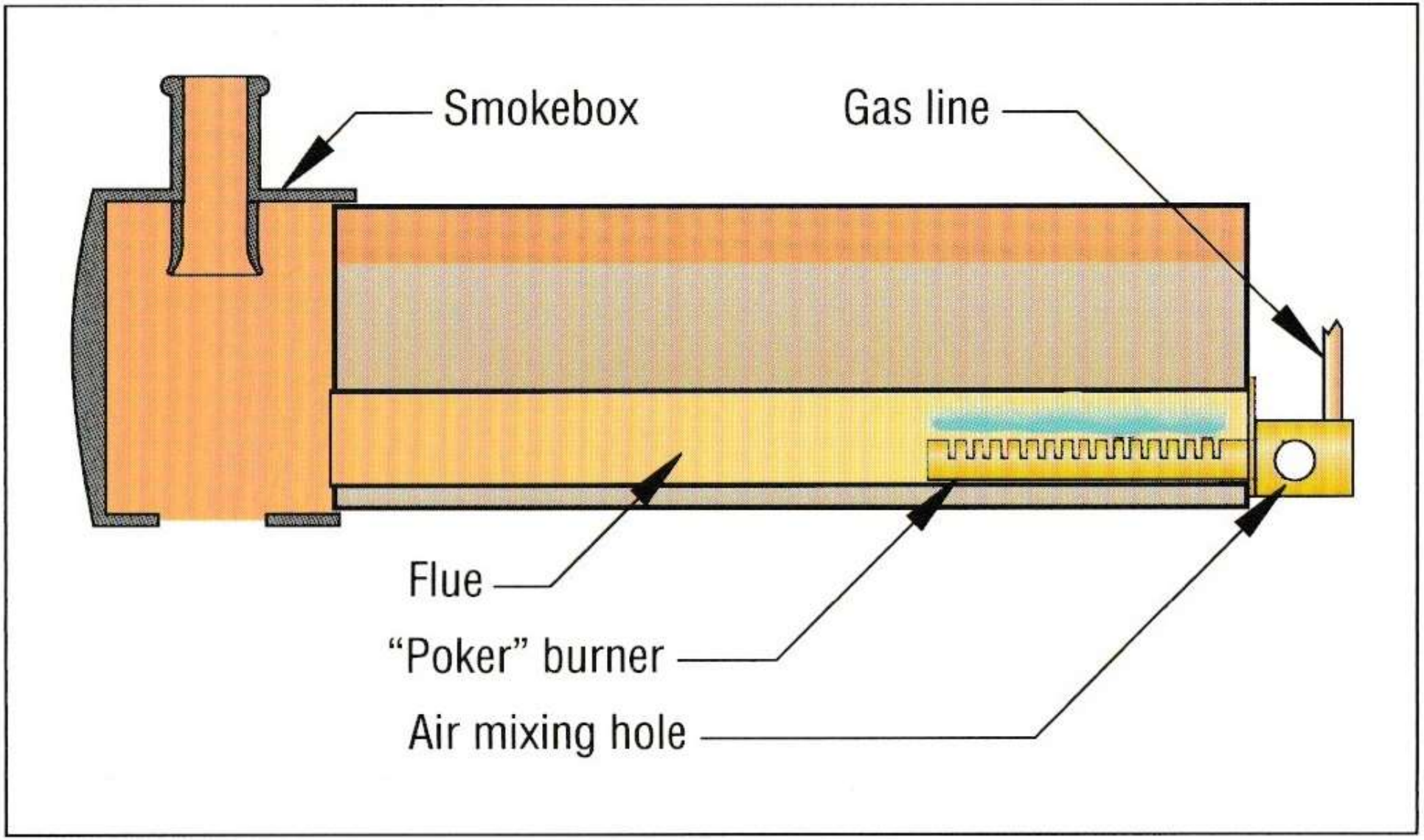
Center Flue Boilers



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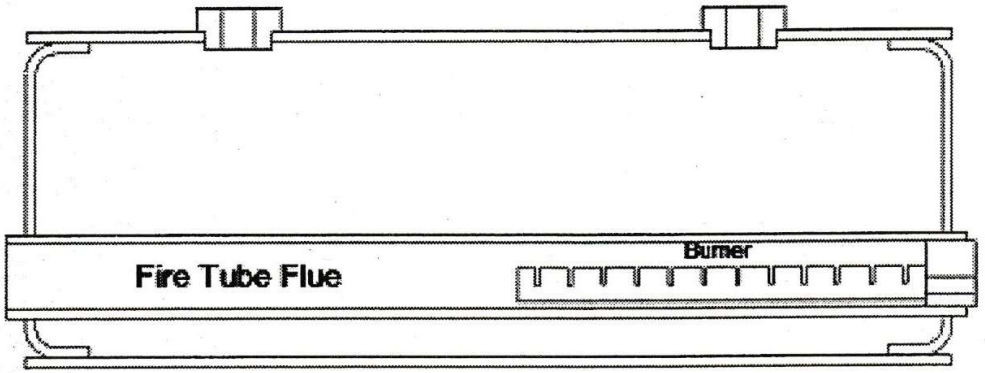
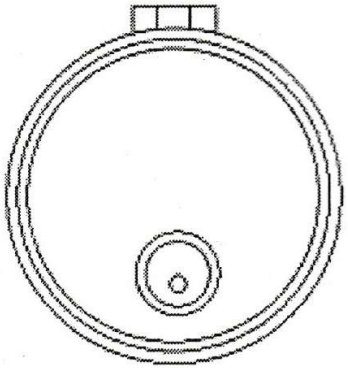
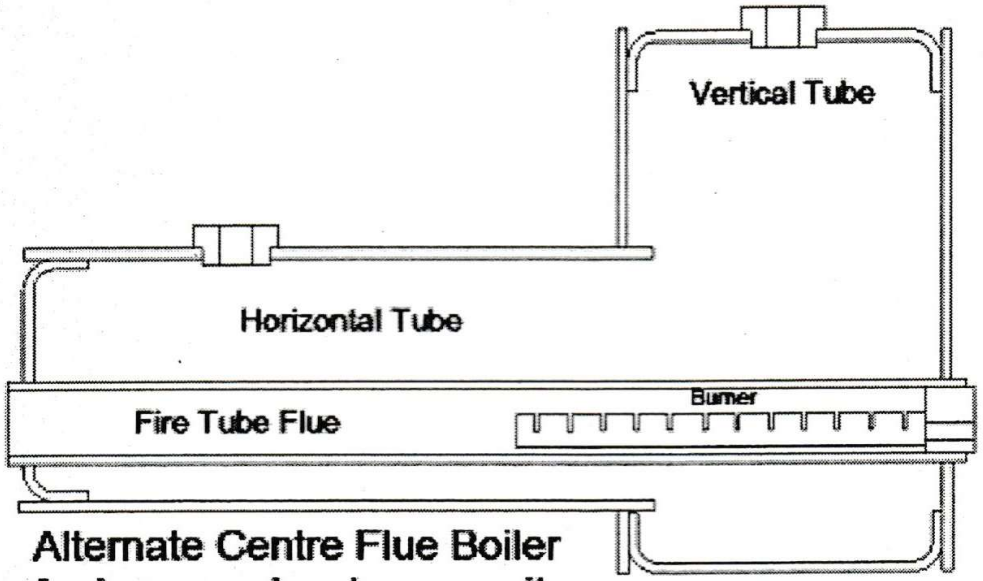
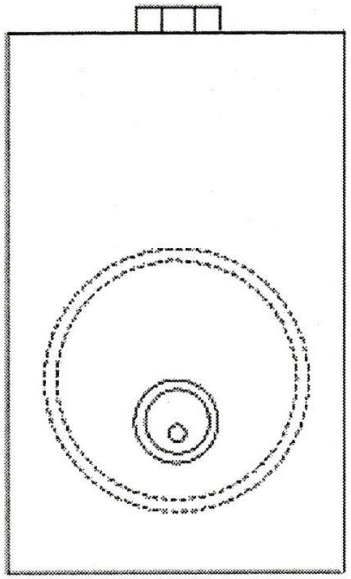
Center Flue Boilers





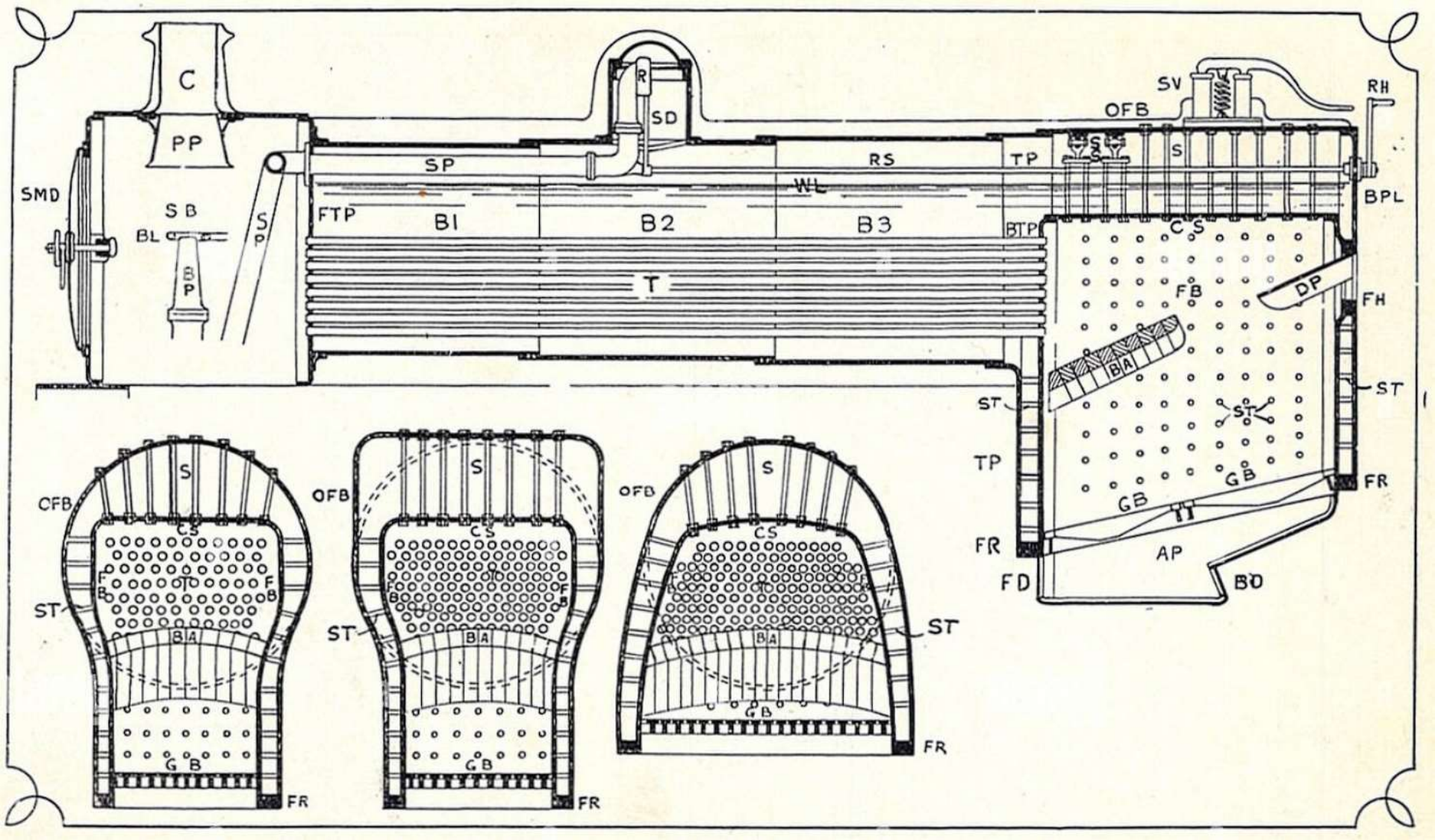
Centre Flue Boiler



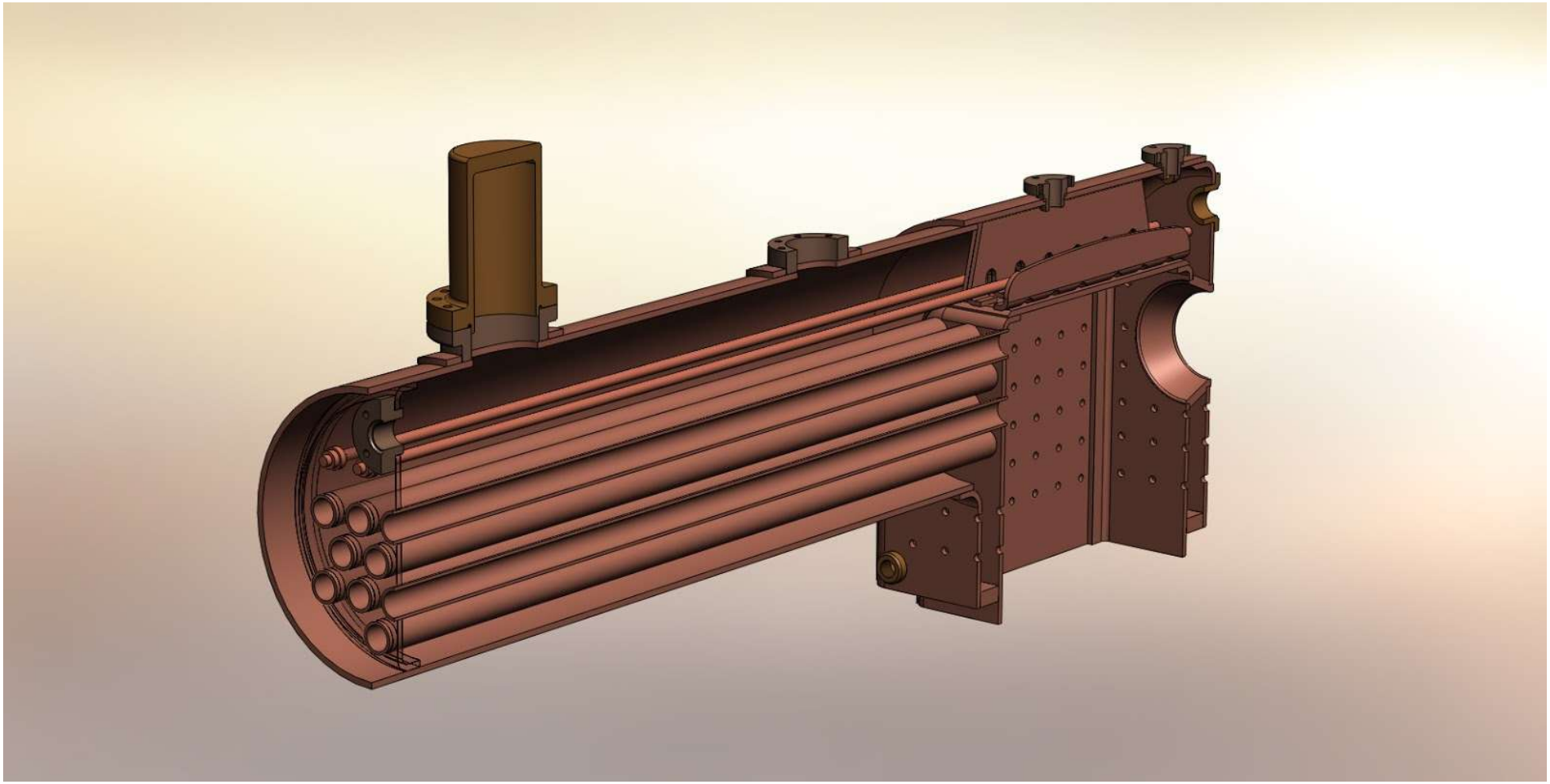


Alternate Centre Flue Boiler
for increased water capacity

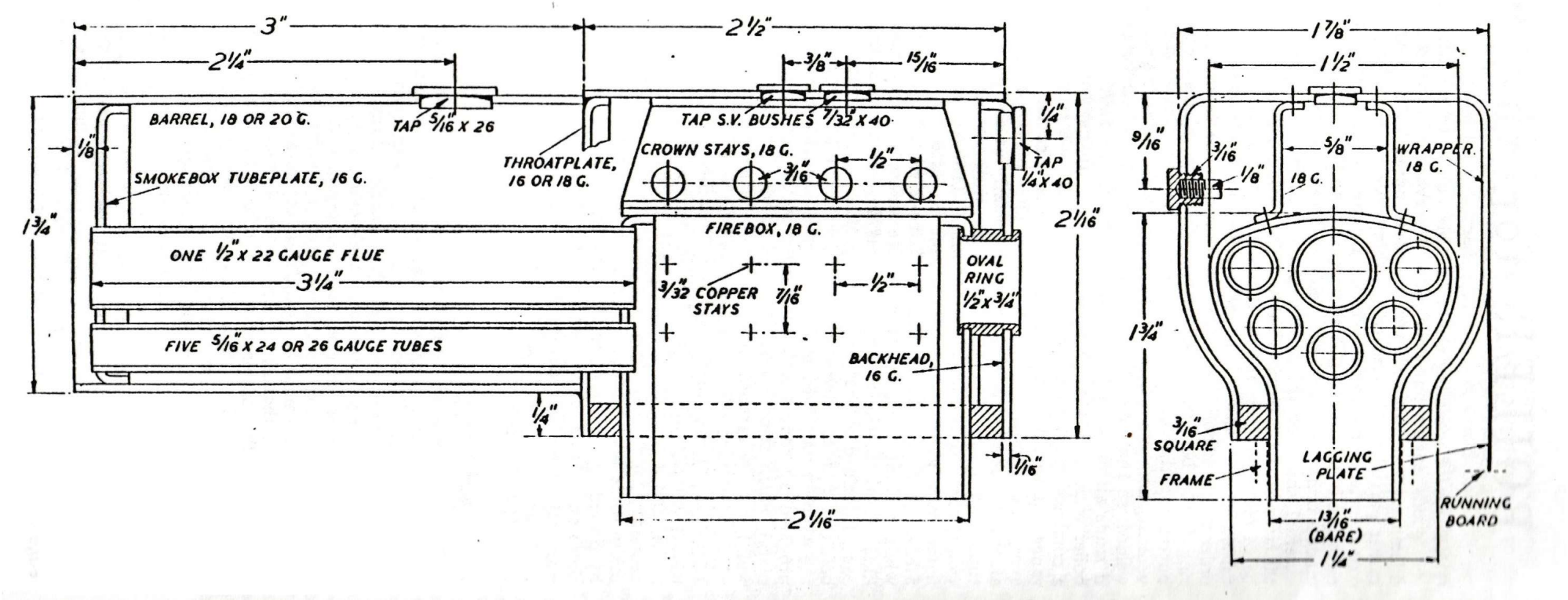
Locomotive Boilers



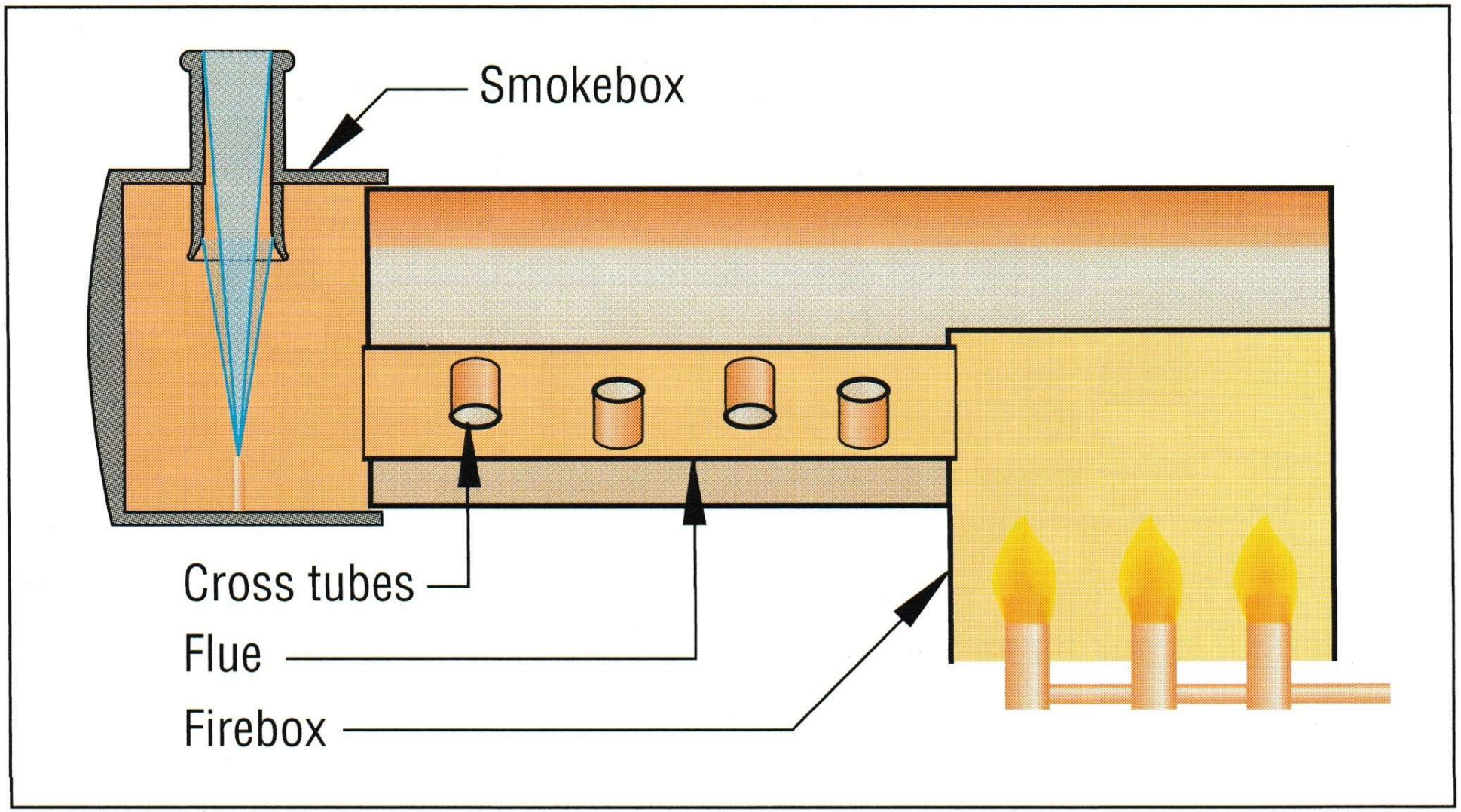
Locomotive Boilers



Locomotive Boilers



Wrighton Boilers



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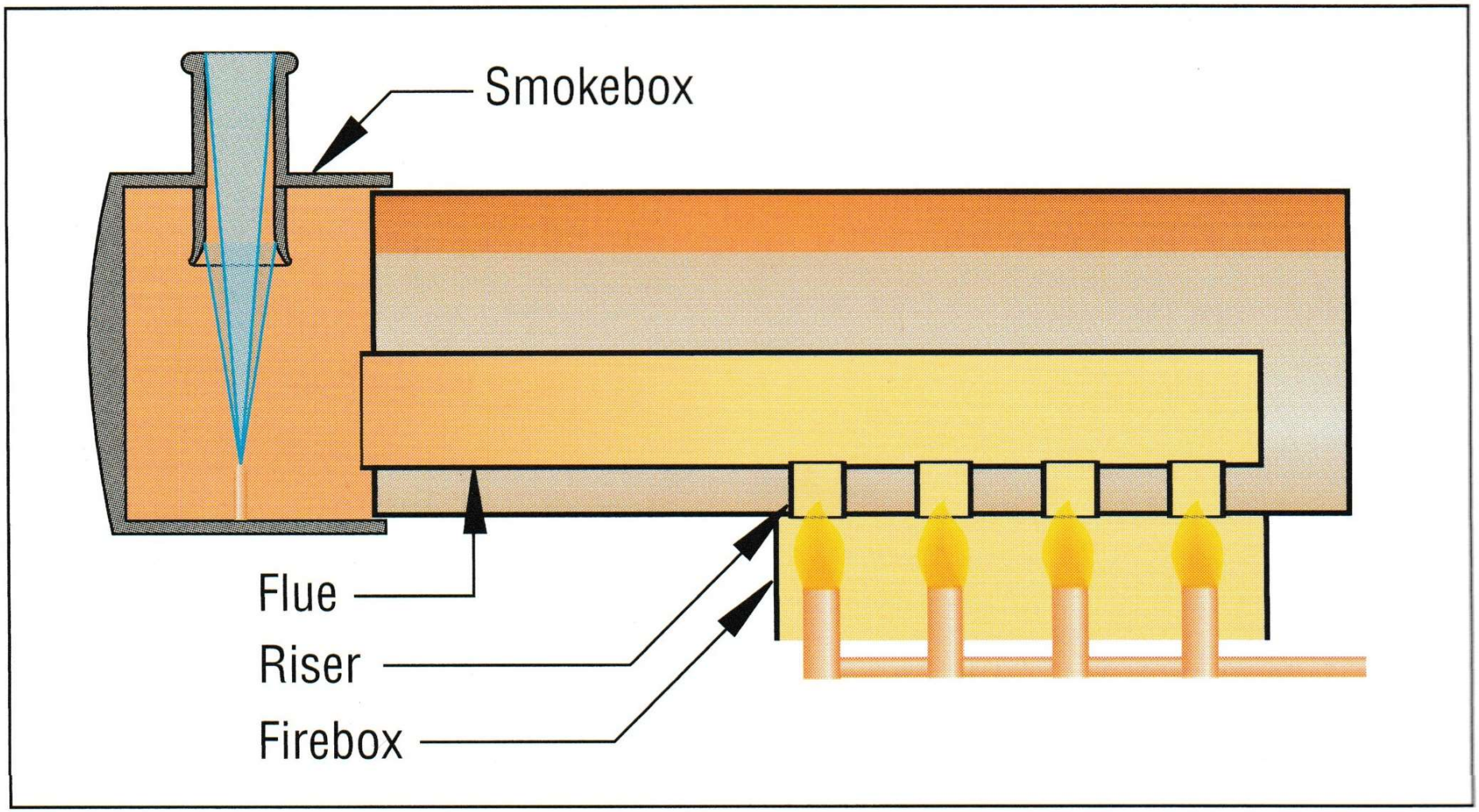
Aster Baldwin Boilers



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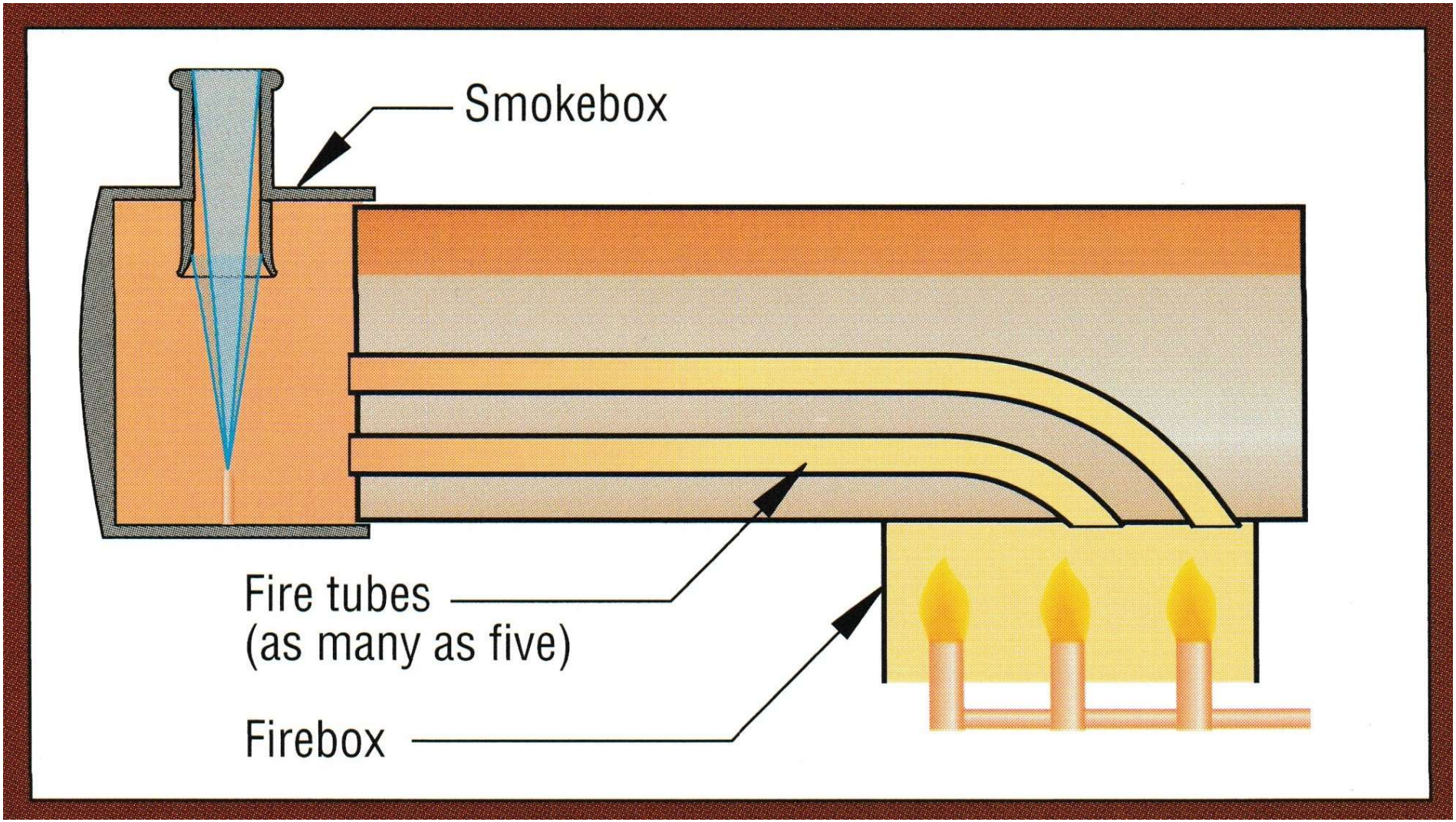
JvR, Type B Boilers



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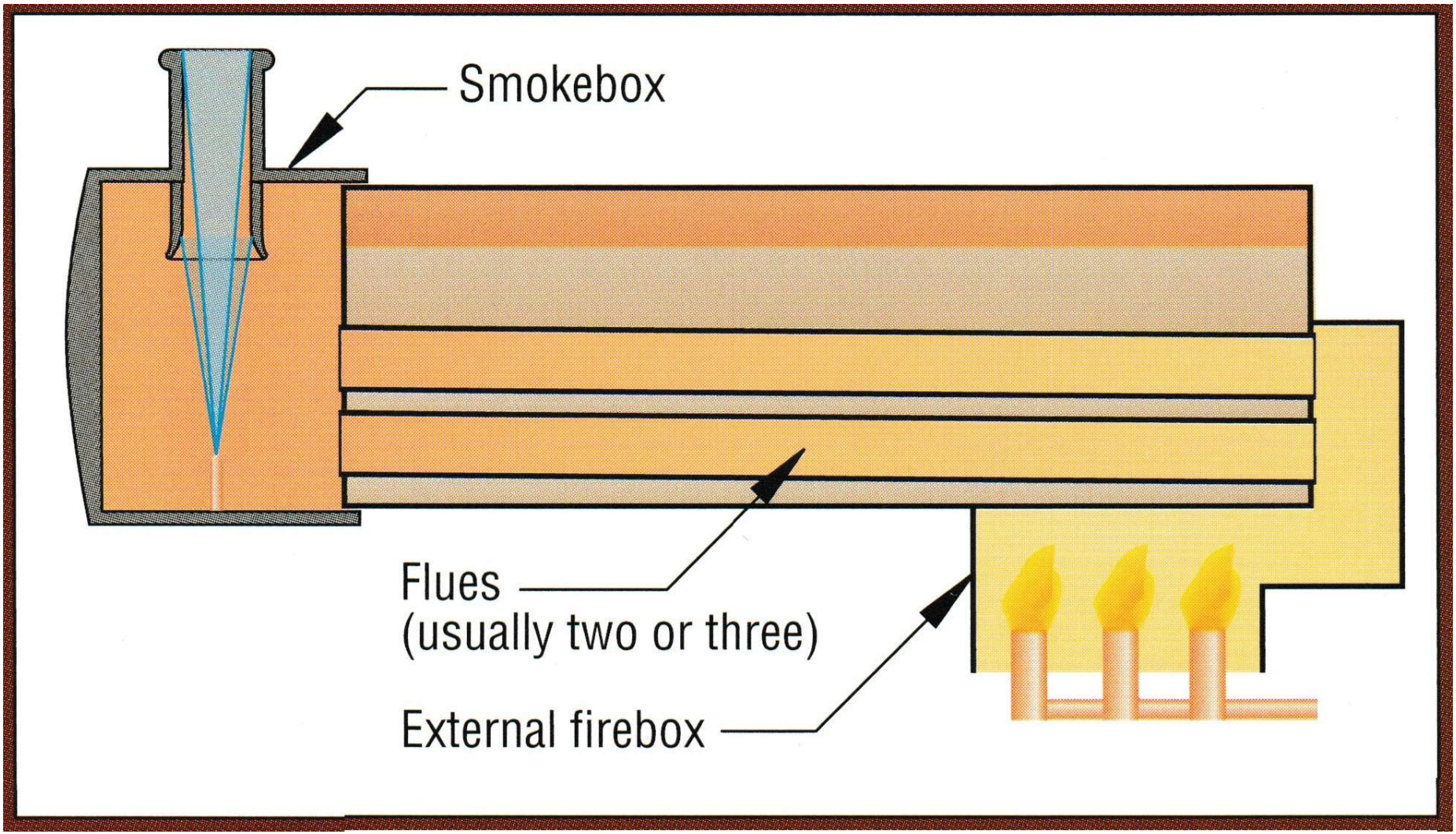
JvR, Type C Boilers



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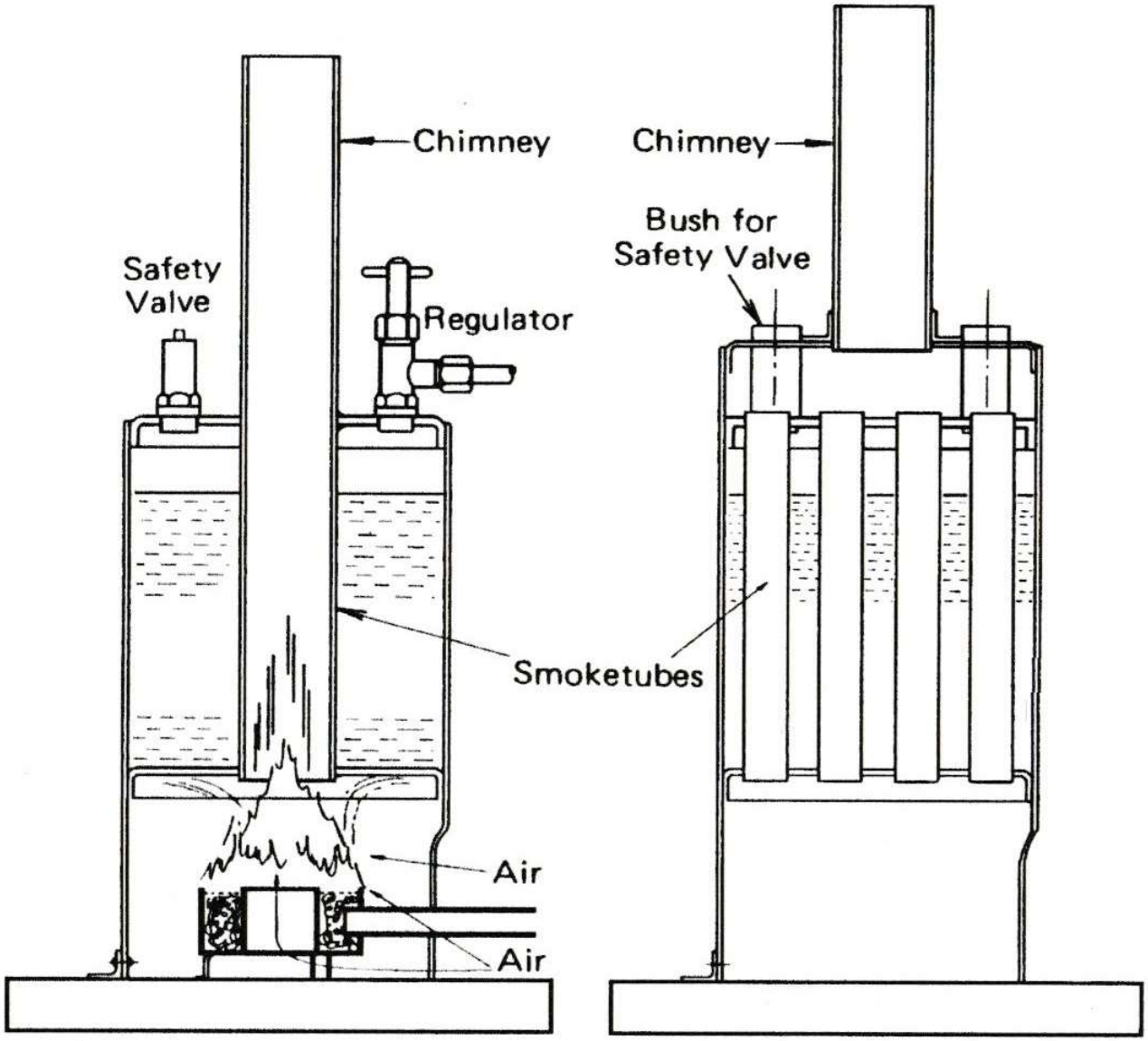
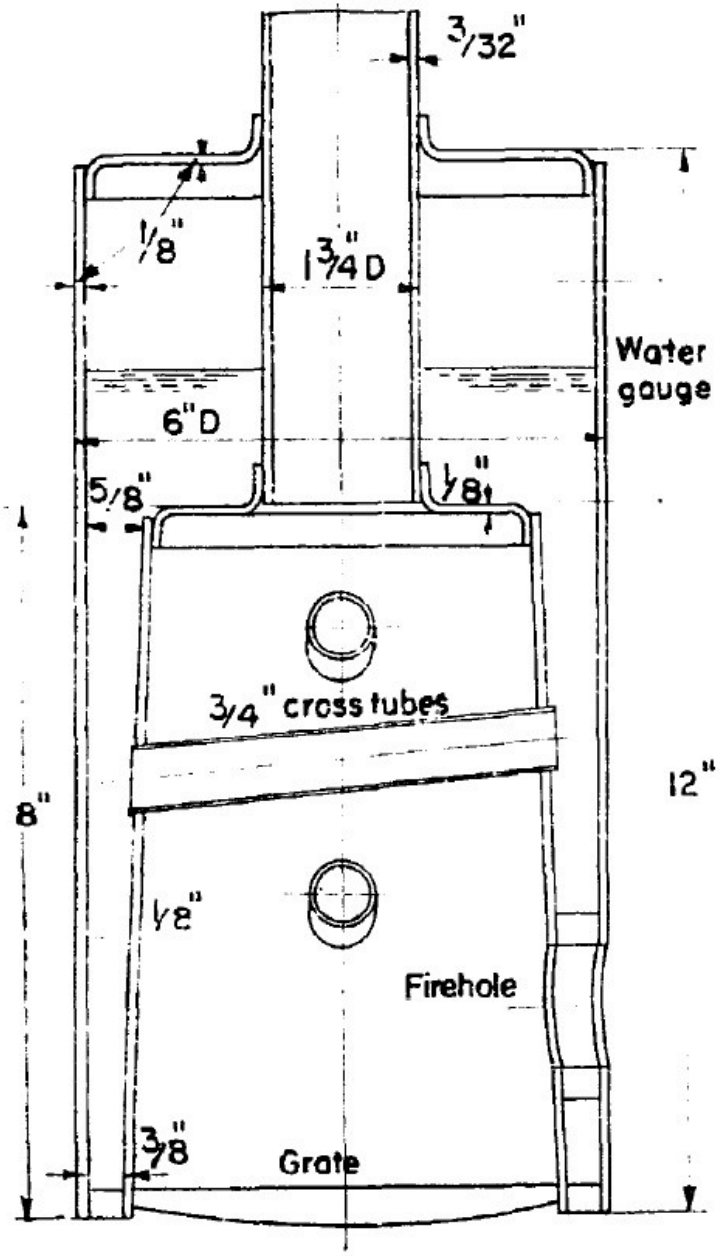
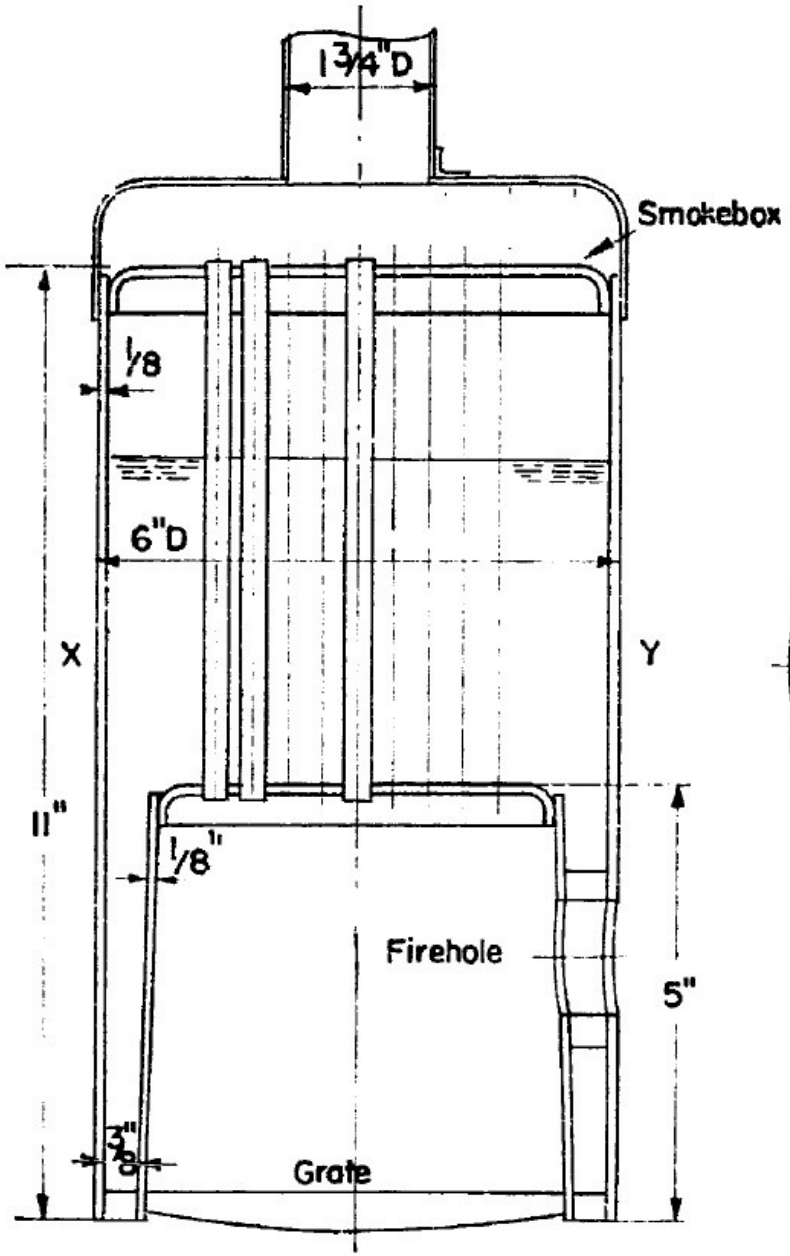
Vertical Boilers

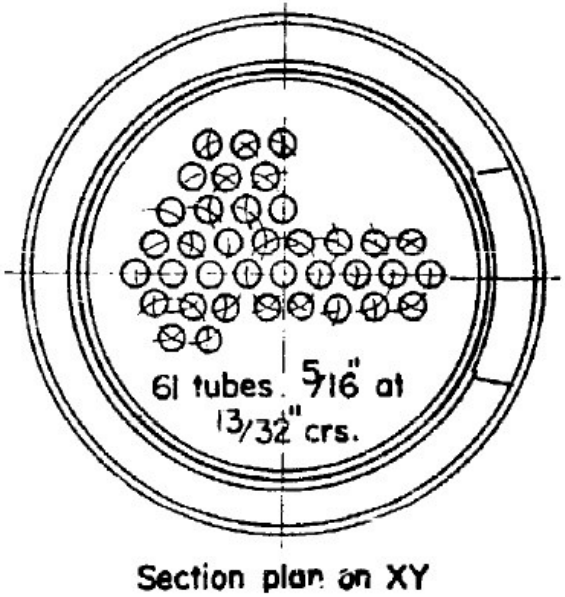


Vertical Boilers



Vertical Boilers



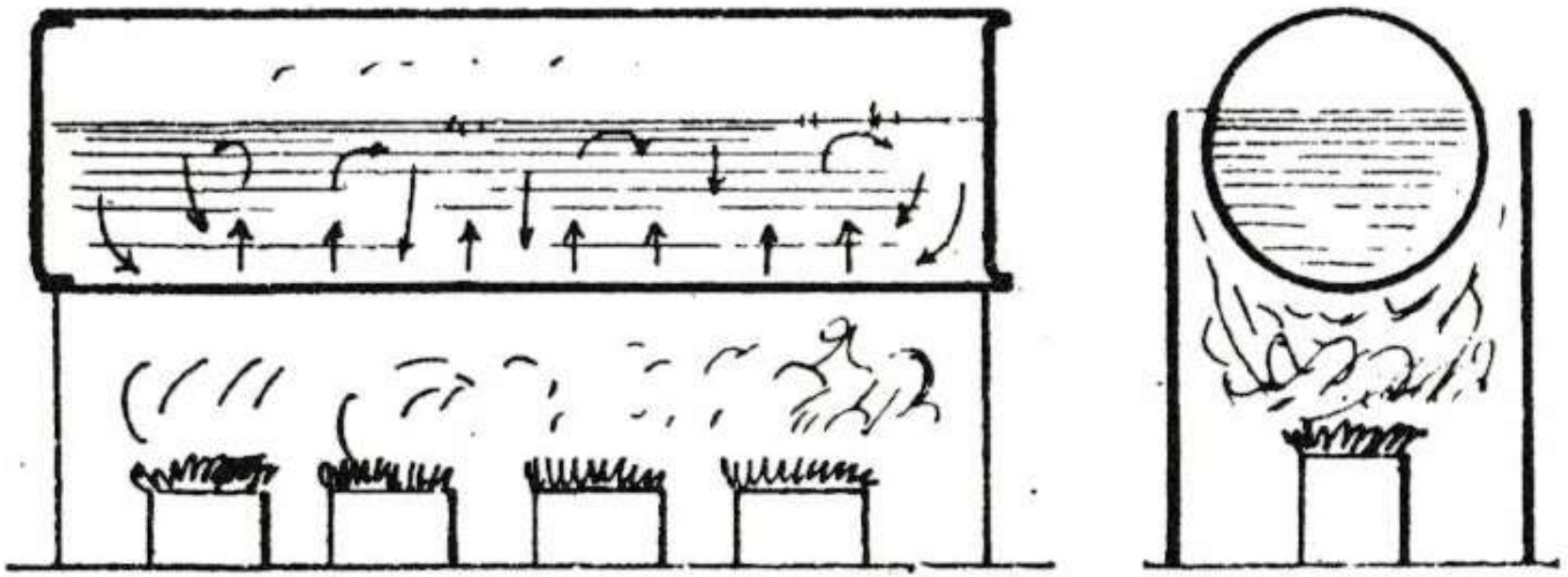


Section plan on XY

Design Considerations

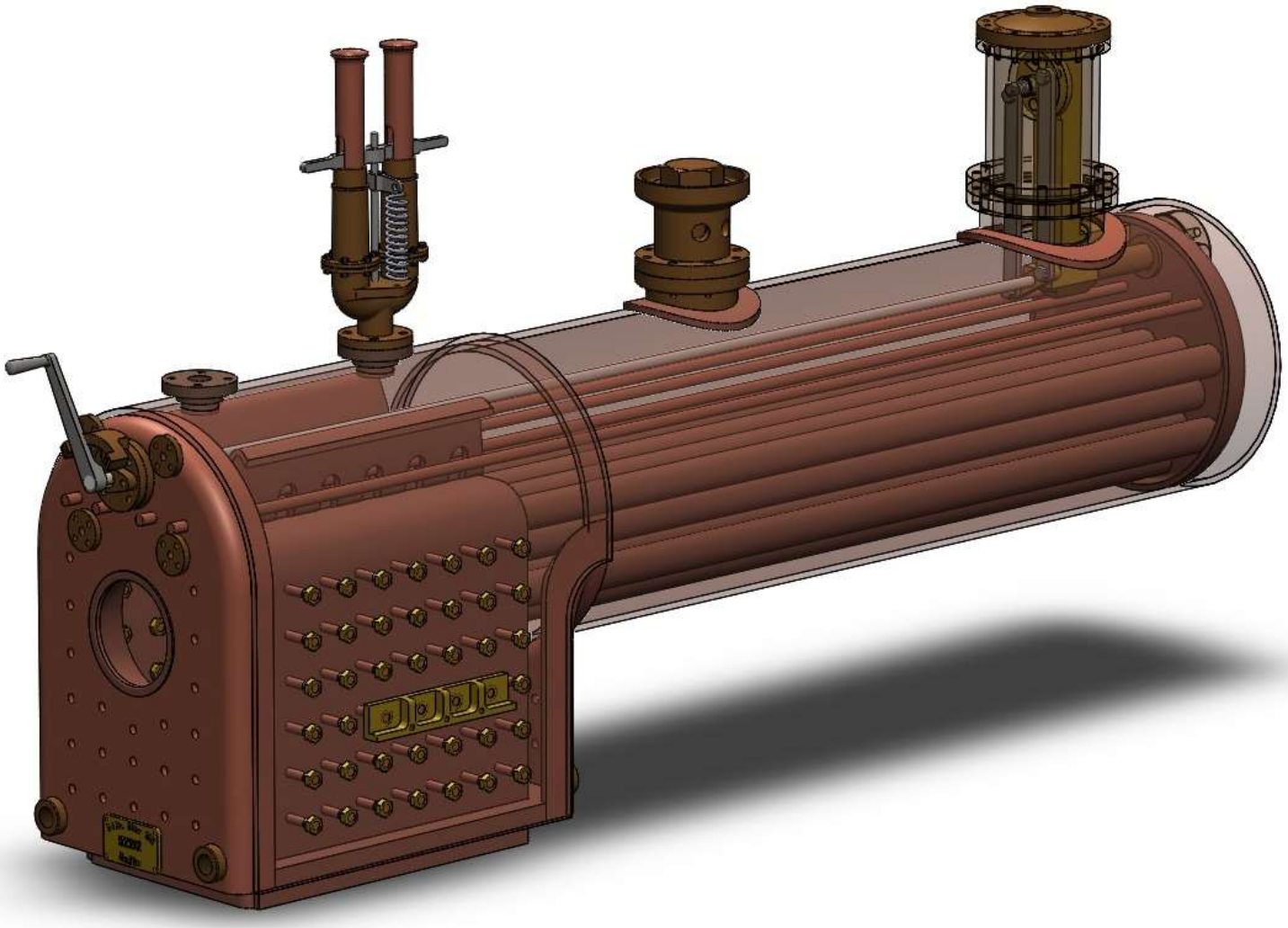
Example

Heating Surface



The heating surface is any part of the boiler where combustion is on one side and water on the other. Expressed in square inches.

Heating Surface



Heating Surface

Steam Production

Conversion of water to steam

Expressed as Cubic Inches of steam from one Cubic Inch of water per minute
Per 100 Square Inches of heating surface.

Function of Pressure

Steam Production

PROPERTIES OF SATURATED STEAM

Pressure above atmosphere lb. sq. in.	Temperature degrees F.	Volume cu. in. steam from 1 cu. in. water
10	240	1,036
15	250	838
20	259	726
25	267	640
30	274	572
35	281	518
40	287	474
45	292	437
50	298	405
55	303	378
60	307	354
65	312	333
70	316	318
75	320	298

Steam Production

Example: 0.500” bore x 0.875” stroke
Two cylinders, double acting
250 RPM
50 PSI

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Volume = $\Pi r^2 h$

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Two cylinders, double acting
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50 PSI

Volume = $\Pi r^2 h$ = 0.172 in^3

Total Cylinder Vol. = Volume * 2 * 2 * 250RPM

Steam Production

Example: 0.500” bore x 0.875” stroke
Two cylinders, double acting
250 RPM
50 PSI

Volume = $\Pi r^2 h$ = 0.172 in^3

Total Cylinder Vol. = Volume * 2 * 2 * 250RPM

Total Cylinder Vol. = 172 in^3 @ 50 PSI/minute
= 0.42 in^3 water/minute

Steam Production

$$\text{Heating Surface Required} = \frac{\text{Water @ in}^3 * 100}{\text{Boiler Efficiency}}$$

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Boiler Efficiency

Pot Boiler	= 1.0
Center Flue, gas fired	= 2.0
Locomotive Boiler	= 3.0
Marine Yarrow Boiler	= 5.0

Steam Production

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$$\text{Heating Surface Required} = \frac{0.42\ \text{in}^3 * 100}{2.0} = 21\ \text{in}^2$$

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$$\text{Heating Surface Required} = \frac{0.42\ \text{in}^3 * 100}{2.0} = 21\ \text{in}^2$$

Conclusion: Center Flue 0.875” dia, 9” long = 25 in²

Boiler Barrel Thickness

$$T = \frac{P * D}{2t}$$

Where T = Thickness of Barrel in inches
P = Working Pressure in PSI
D = Internal Diameter in inches
t = Maximum ***safe stress*** of the boiler material in PSI (for copper t = 3125 PSI)

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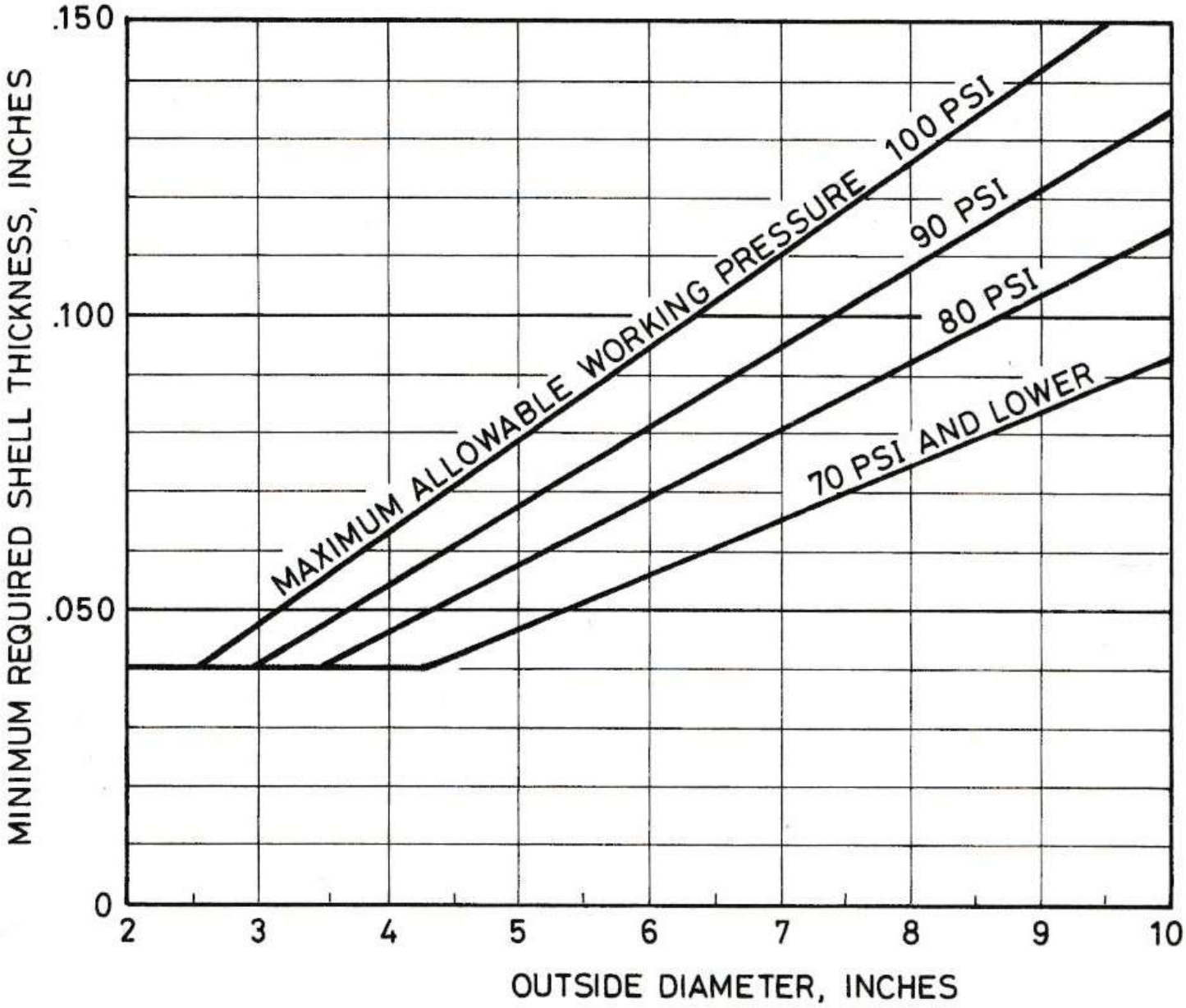
$$T = \frac{50 * 2}{2 * 3125} = 0.016”$$

Standard 2” copper plumbing pipe is 0.058”

Boiler Barrel Thickness



Kozo Hiraoka

Boiler Barrel Thickness

Australian Miniature Boiler Safety Committee (AMBSC) practice

0.91mm (0.036”) minimum for diameters up to 60mm (2.36”).

1.2mm (0.047”) minimum for diameters up to 77mm (3.03”).

75 PSI max pressure

Center Flue Stress

$$S = \frac{P * D}{2t}$$

Where S = Stress on the Flue in PSI
P = Working Pressure in PSI
D = External Diameter in inches
t = Wall Thickness in inches

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Where S = Stress on the Flue in PSI
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D = External Diameter in inches
t = Wall Thickness in inches

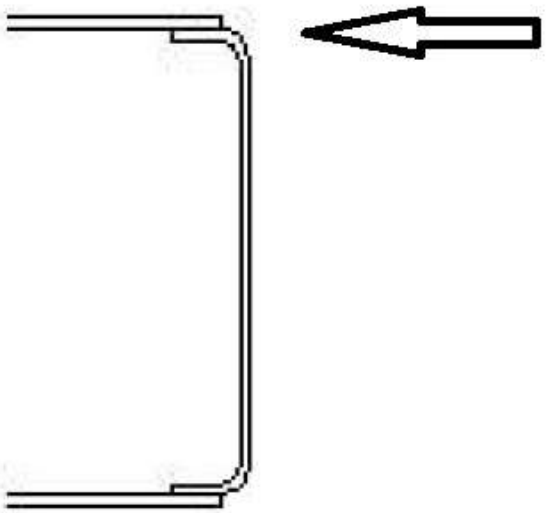
$$S = \frac{50 * 0.875}{2 * 0.040} = 531 \text{ PSI}$$

End Plates

Butt Joint

Plain Disk Joint

Flange overlap is
3 times plate thickness



Flanged Joint

AMBSC

End Plates unflanged

1.6mm (0.063”) minimum for diameters up to 60mm (2.36”).

2.0mm (0.079”) minimum for diameters up to 77mm (3.03”).

75 PSI max pressure

End Plates flanged

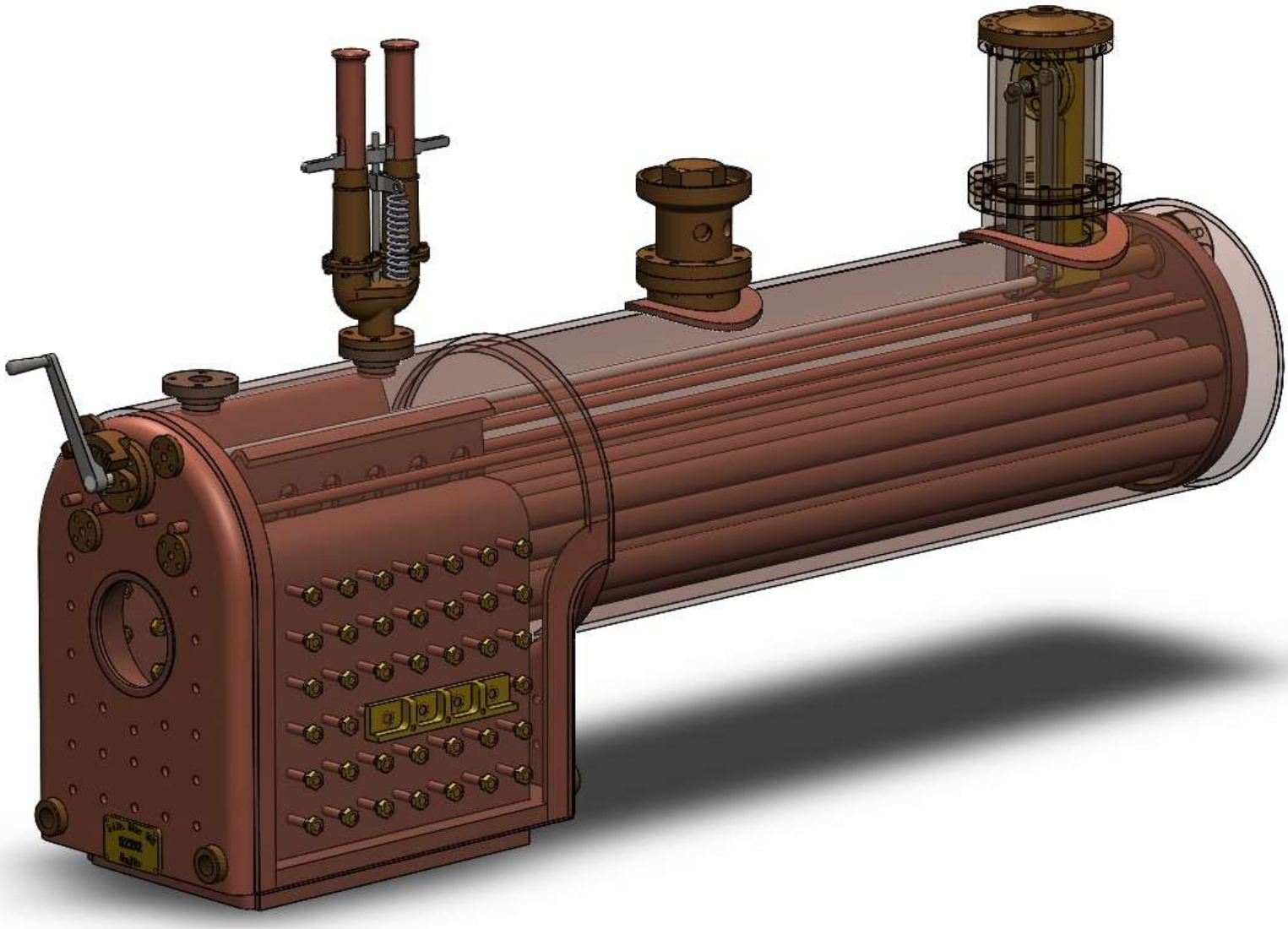
0.91mm (0.036”) minimum for diameters up to 39mm (1.54”).

1.2mm (0.047”) minimum for diameters up to 51mm (2”).

1.6mm (0.063”) minimum for diameters up to 77mm (3.03”).

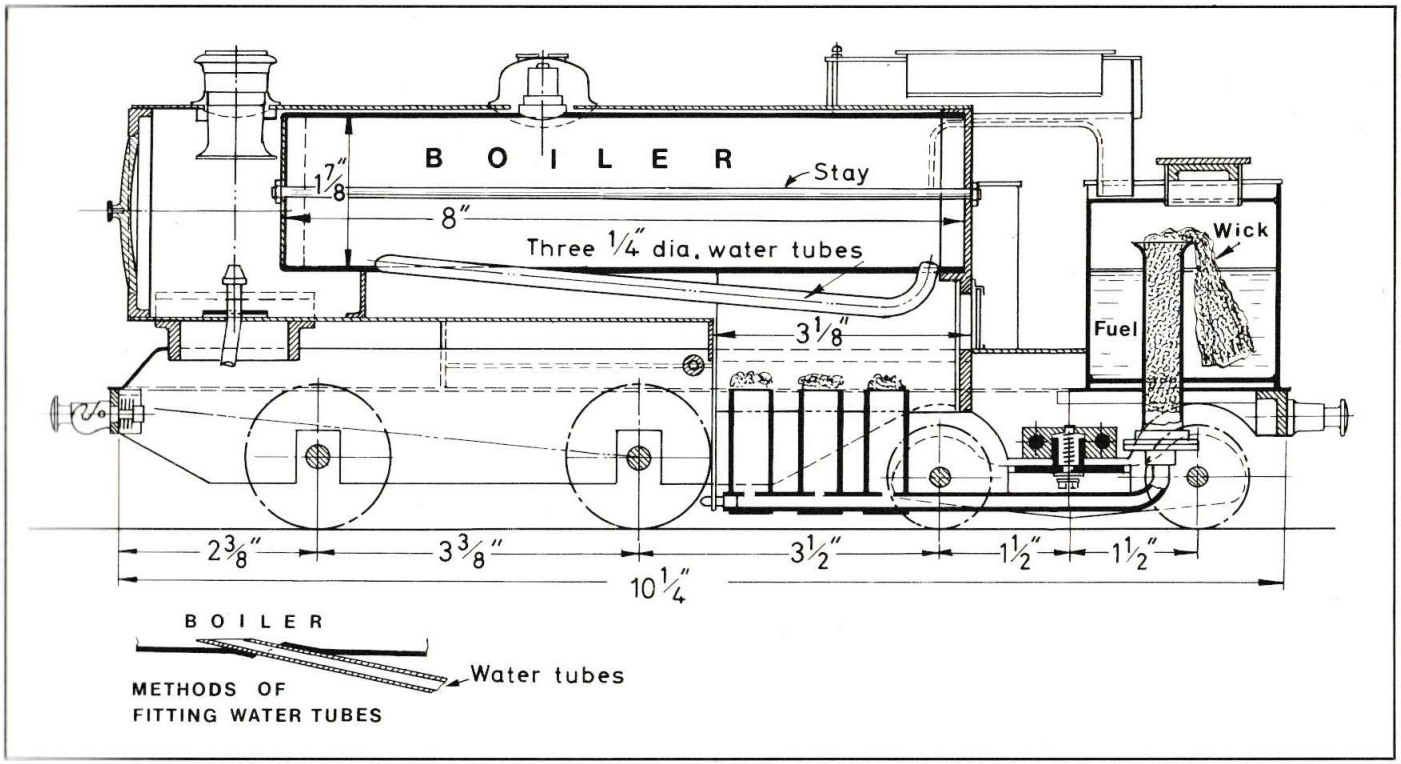
75 PSI max pressure

Stays

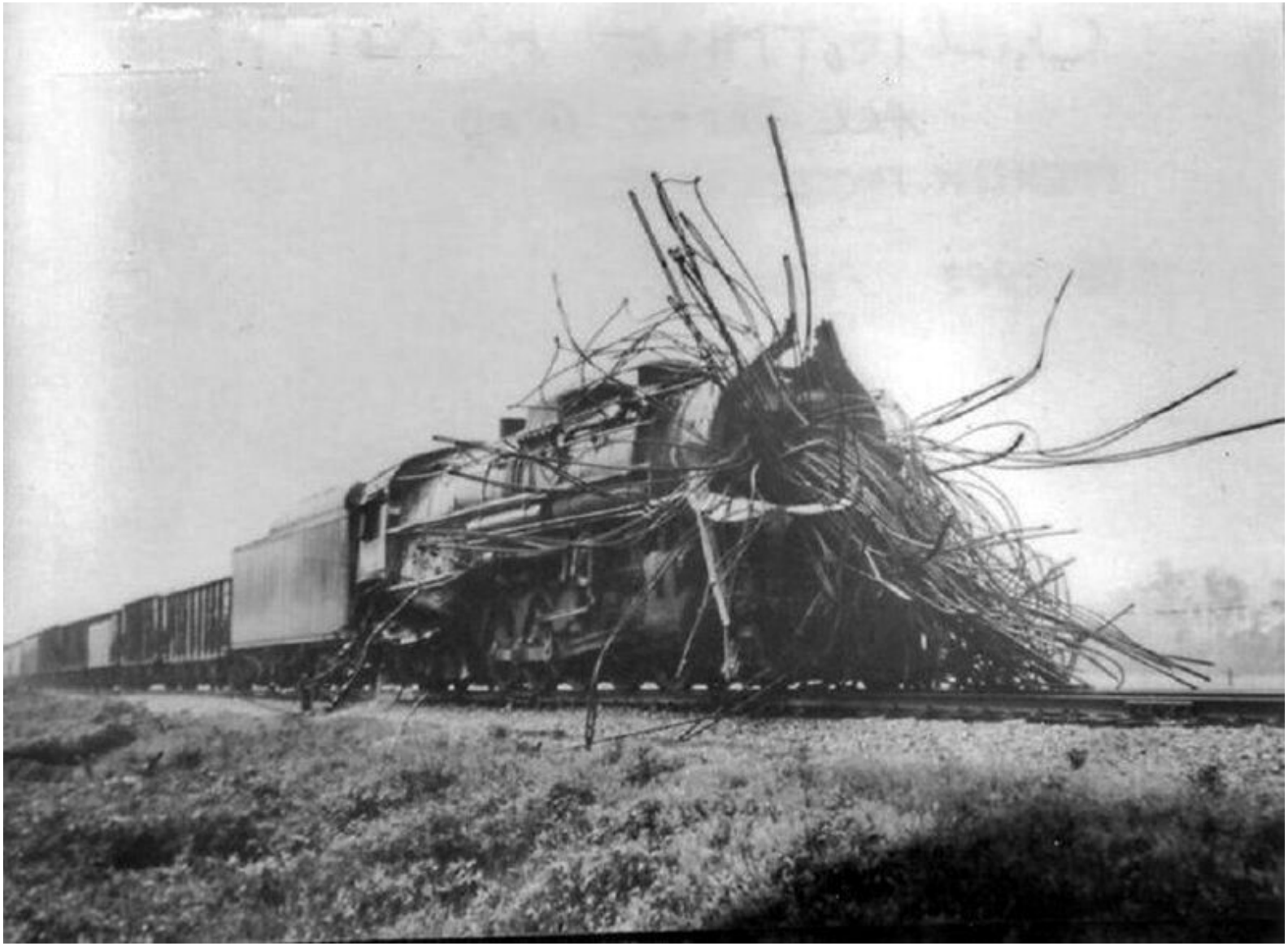


Stays

Made from copper or bronze
1/8” diameter, space evenly every 0.75”
5/32” diameter, space evenly every 0.875”
3/16” diameter, space evenly every 1.125”



Tested to Destruction



AMBSC Joint Design Test, 2004

- 11 test boilers, 50.8mm to 76mm
- Seamless copper tube
- 1.2mm, 1.6mm 2mm endplates
- Stayed and unstayed
- Disk and flanged endplates
- 19mm and 25.4mm flues
- Silver soldered with 45% alloy
- Initial leak test to 100 PSI

AMBSC Joint Design Test, 2004

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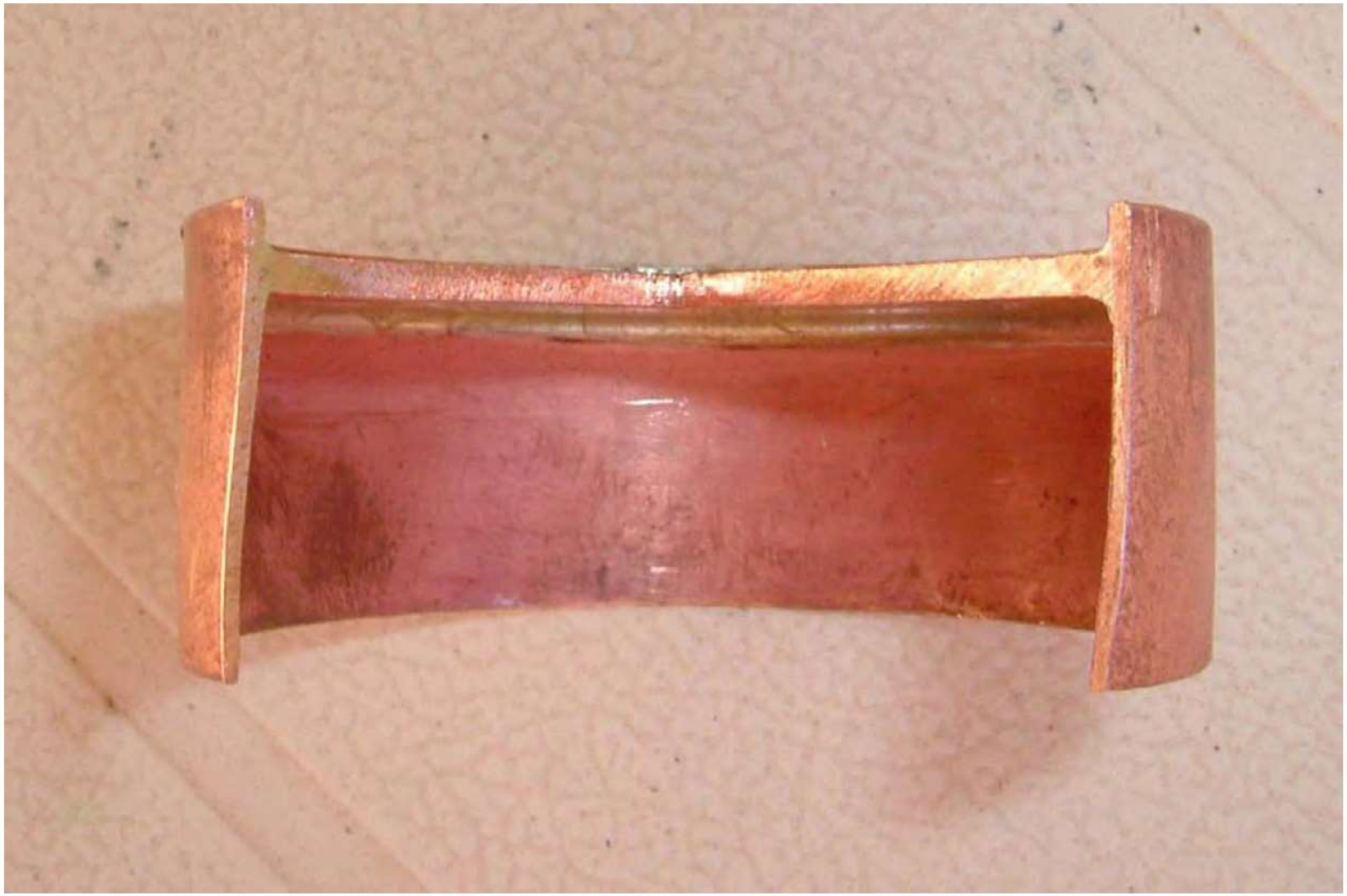

AMBSC Joint Design Test, 2004

Failure range 1000 PSI to 1600 PSI

Crack in the barrel near a bushing

Joint damage from collapsed flue

One stay failure

One contaminated solder joint

AMBSC Joint Design Test, 2004

Conclusions

No difference between flanged and plain disk endplates.

Shell splits were along marks left from the die used in manufacturing the pipe

Endplates should be easy fit in the barrel to allow solder penetration.

Questions?