

# **Cylinder Heat Jackets**

by Doug Landau

# An old Idea

Cylinder steam jackets of various forms have a long history, particularly in the field of traction engines and steam rollers, etc , where it was virtually standard practice.

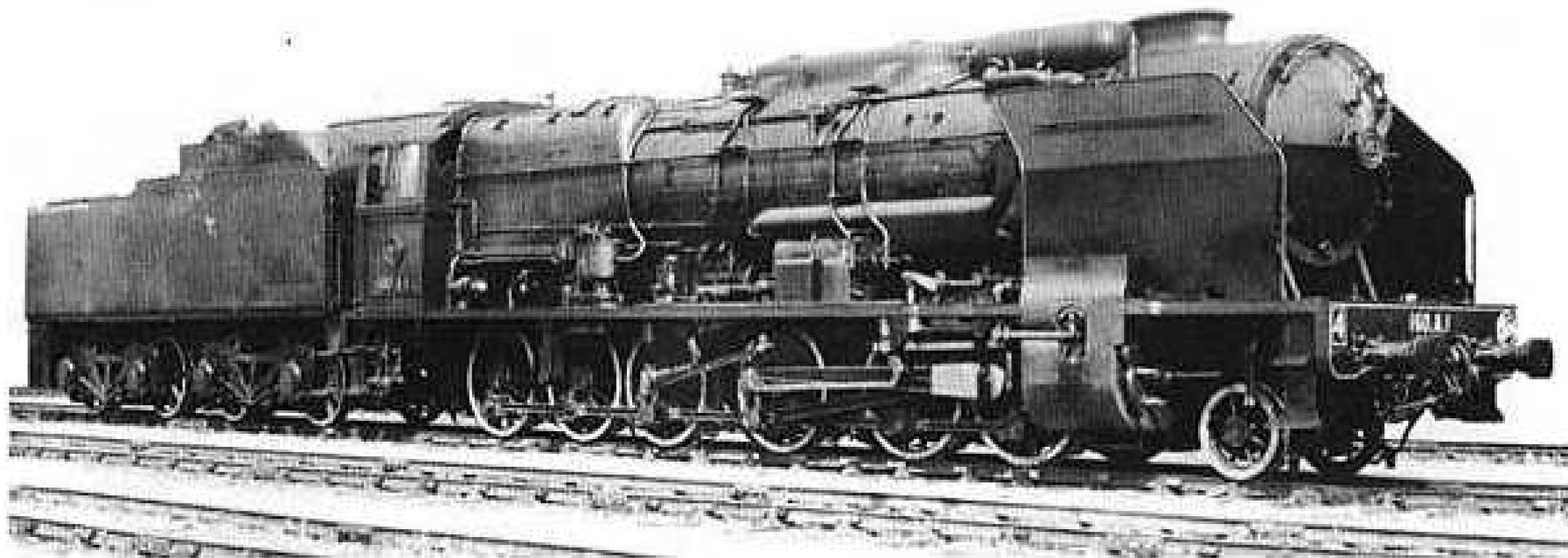
Application to steam locomotives has been more tenuous, with some cylinder set-ups providing a degree of steam jacketing. The introduction of superheating, early in the 19th century pretty well killed off the idea for the next three decades. Along the way, some cylinder layouts, particularly when inside the frame, retained some semblance of steam jacketing.

# A Late Revival

In 1936 the Paris - Orleans Railway started development of 6 cylinder compound 2-12-0 160 A1. It was a novel development featuring steam jackets for all cylinders, and a re-heating superheater for the low pressure steam. Progress was slow, it was not completed at Tours works until 1940. Given the wartime, and immediate post-war situation, it was not possible to conduct any testing until 1948.

# A Late Revival

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**SNCF 160 A 1 - 1F h6v**

# A Late Revival

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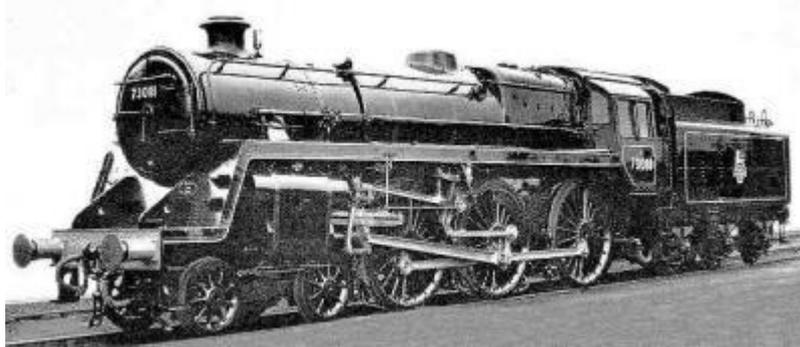
During the initial constant speed road tests, some experiments reducing the superheat showed no measurable decline in efficiency; an outcome attributed to the steam jackets. Chapelon subsequently removed the superheater without deleterious effect, and even without reheating there was only a 6% penalty with all saturated steam, provided the steam jackets were in use.

# A Late Revival

*continued*

A 6% reduction in cylinder efficiency is not insignificant, but Chapelon's experiments showed that steam jacketing alone could achieve 70 to 80% of the economies attributable to superheating.

# Experiments in Britain



Superheater experiments with BR5 73031 in 1959 indicated savings of 25% attributable to superheating in its "as built" condition.

In its de-superheated condition there was around 50°F of superheat, some heat being picked up in the smokebox by the cylinder steam pipes.

# Experiments in Britain

*continued*

<b>BR5 73030 Superheater Experiments 1959</b>				
<b>Steam Rate 18,000 lb/hr</b>				
Condition	Indicated Horsepower			
	20 mph	30 mph	45 mph	65 mph
Standard	1045	1165	1245	1225
De-Superheated	830	875	885	880
	Specific Steam Consumption - Lb/IHP.hr			
Standard	17.2	15.5	14.5	14.7
De-Superheated	21.7	20.6	20.3	20.5
Superheat Saving	20.6%	24.9%	28.9%	28.2%
Average Saving	25.6%			

# Experiments in Britain

*continued*

The thinking behind the Rugby experiments was not so much raising maximum steam temperatures as significantly increasing it at low combustion rates. It was here the greatest economies could be effected. The same would be true of steam jacketing.

The smokebox waste heat jacketing being proposed would put an end to cold starts.

# Smokebox Waste Heat Recovery

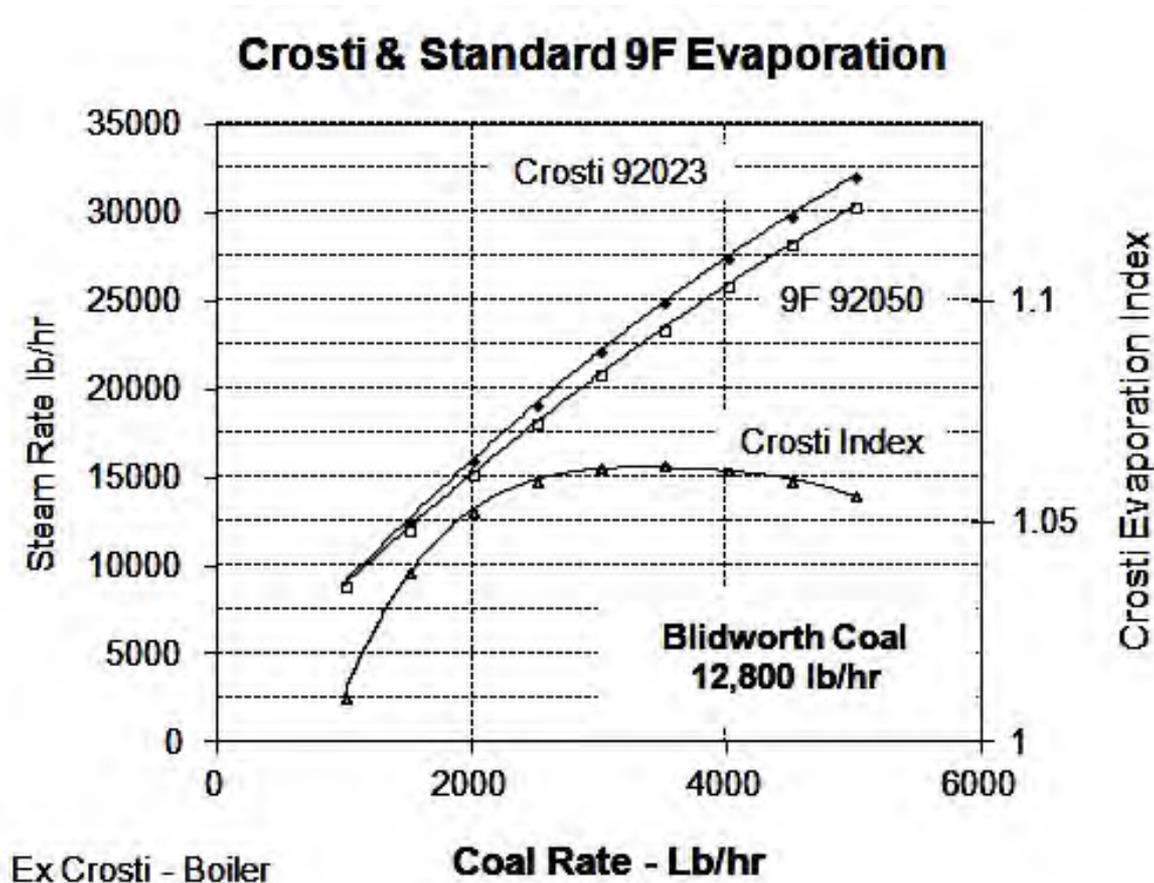
Some time ago I was asked to look at the potential for developing a smokebox feed water heater for 71000. It was difficult to achieve much heat recovery within the confines of the smokebox.

Occupying 115 cubic feet and over 19 ft long, the Crosti pre-heater for the 9F gives some idea of where such ambitions for a pre-heater can lead.

# Smokebox Waste Heat Recovery

*continued*

For interest the comparative Crosti and Standard 9F evaporation rates are plotted below.



# Smokebox Waste Heat Recovery

*continued*

The pre-heater was of little benefit at the lowest combustion rates; maximum economy appears to plateau at about 6%. The apparent droop at the highest combustion rates could possibly be more to do with the limited plots and random scatter pattern at these rates, rather than a real trend. The pre-heater design included an exhaust steam jacket to maximise heat recovery.

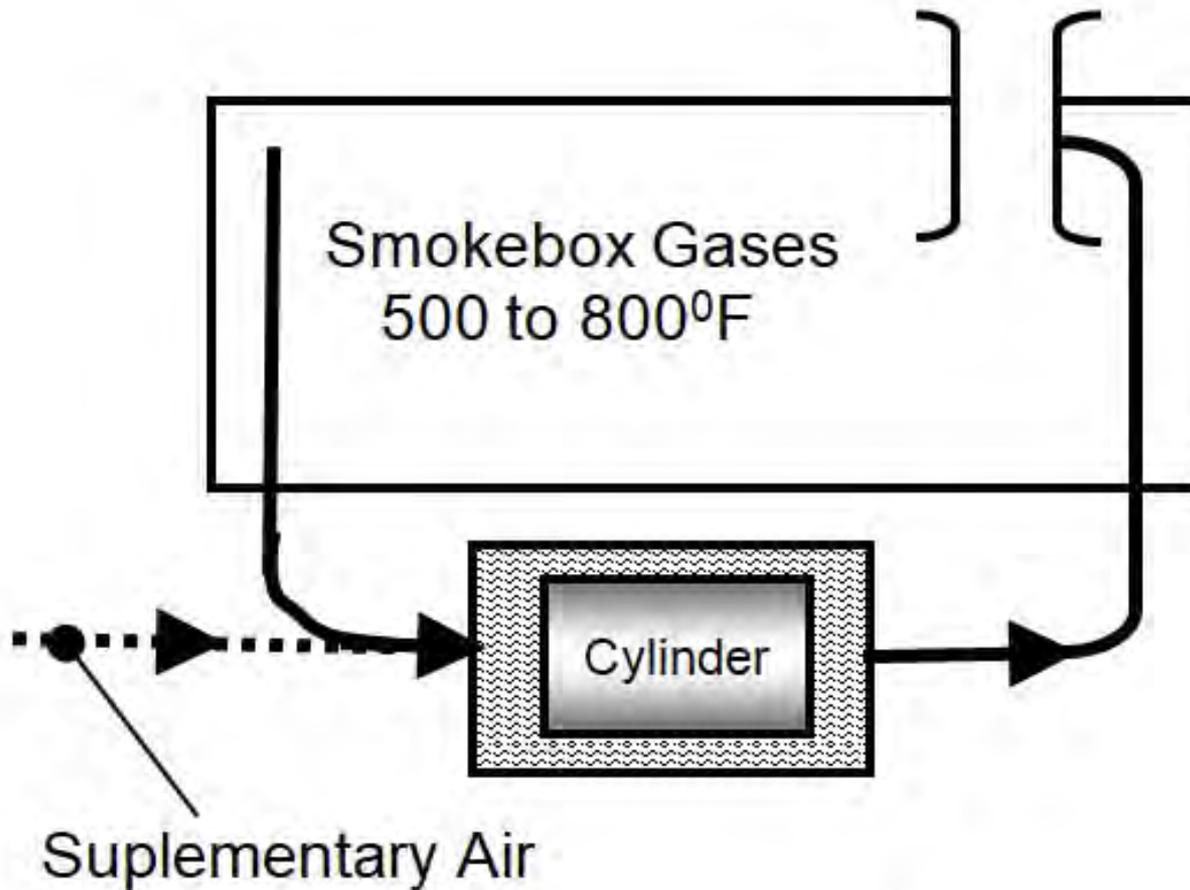
# Smokebox Waste Heat Recovery

*continued*

It only occurred to me very recently that the hot smokebox gases might be a means of keeping the cylinders warm. At its most basic, assuming it could be made to work in such a guise, it is of extreme simplicity in the conceptual sense and would operate automatically free of supervision, as set out in the rudimentary schematic below.

# Smokebox Waste Heat Recovery

*continued*



# Smokebox Waste Heat Recovery

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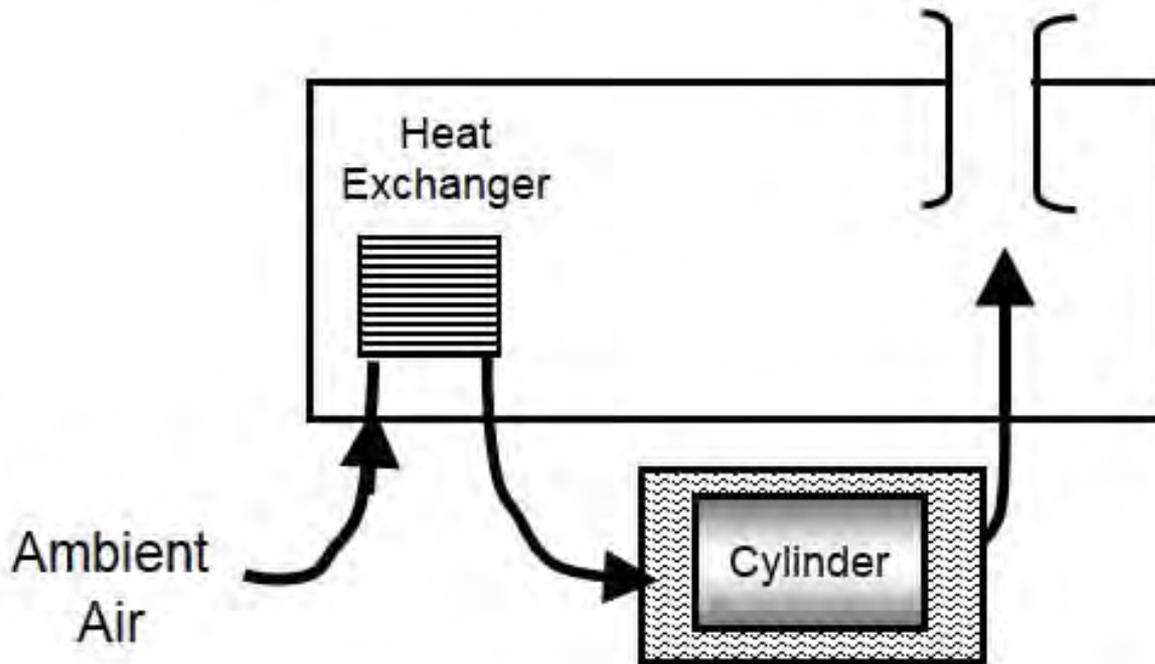
The basic system functions as a by-pass to the draughting circuit. Thus there will be circulation whenever the locomotive is working or stationary with the blower in operation.

Given the potential gas temperatures, some means of regulation will be required to keep within the lubrication system temperature limitations; hence the supplementary regulating air supply shown. The return pipe exhausts into the chimney choke at the point of maximum vacuum.

# Smokebox Waste Heat Recovery

*continued*

An alternative heat exchanger scheme shown below is seen as a fall-back alternative - a complication preferably avoided



**Alternative Heat Exchanger Scheme**

# Smokebox Gas Temperatures

In regard to the potential for retro-fitting waste-heat cylinder jackets to existing locomotives, this is confined, at least for the time being, to outside cylinders only.

Even at low combustion rates, the available gas temperatures are substantially higher than working pressure saturation temperatures. Given this, economies superior to steam jacketing are probable.

# Smokebox Gas Temperatures

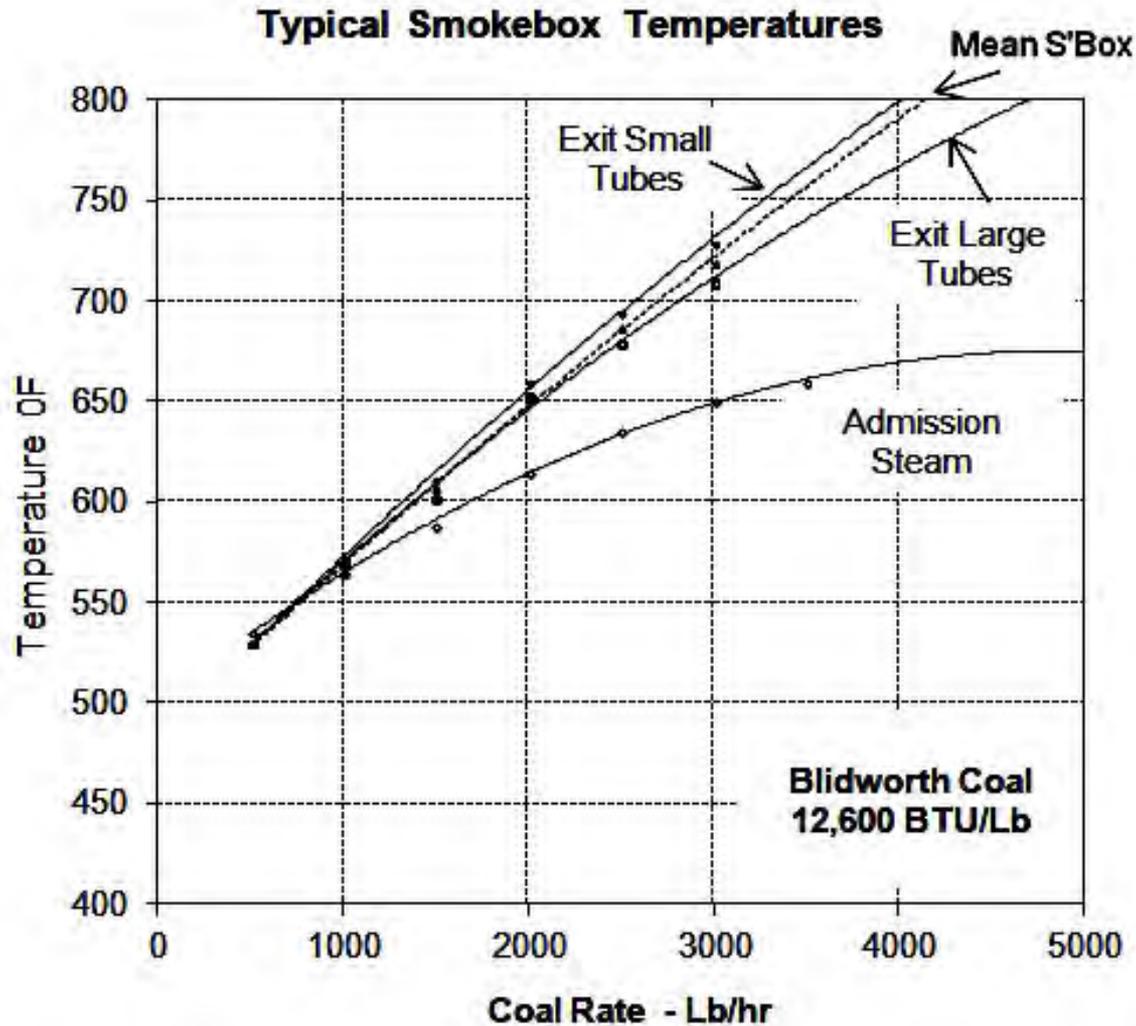
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As a low pressure system (sub-atmospheric), the waste heat installation would be low cost relative the retro fitted steam jacketing schemes and less troublesome to maintain. A possible problem is that in its simplest form, things may get too hot for comfort, in which case a fresh air bleed may be required to regulate temperatures. This can best be determined by experiment. The initially experimental set-up being proposed allows for this.

# Smokebox Gas Temperatures

*continued*

Below a plot of typical smokebox gas temperatures from BR5 as Test Bulletin No. 6 Figure 31:



# Smokebox Gas Temperatures

*continued*

Below the potential range of saturation temperatures among the UK's preserved locomotive stock:

<b>Working Pressures and Saturation Temperatures</b>				
Pressure - Lb/sq.in	175	200	225	250
Temperature - °F	377.5	388	397	406

# Preliminary Experiments

Some research with a thermal imaging camera to determine the smokebox and cylinder cladding skin temperatures obtaining for working locomotives would be helpful. When working hard, or even more comfortably, it would probably not be a good idea to touch the sides of the smokebox.

This information would be a proxy for potential waste heated cylinder cladding surface temperatures in the absence of any outer insulation. A need for such insulation is likely, the effect on waste heat gas circulation would not be unduly compromised.

## **Preliminary Experiments**

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A second experimental phase would be data logging cylinder outer surface temperatures in two or three places, firstly with the lagging in situ, then with it removed.

# Preliminary Experiments

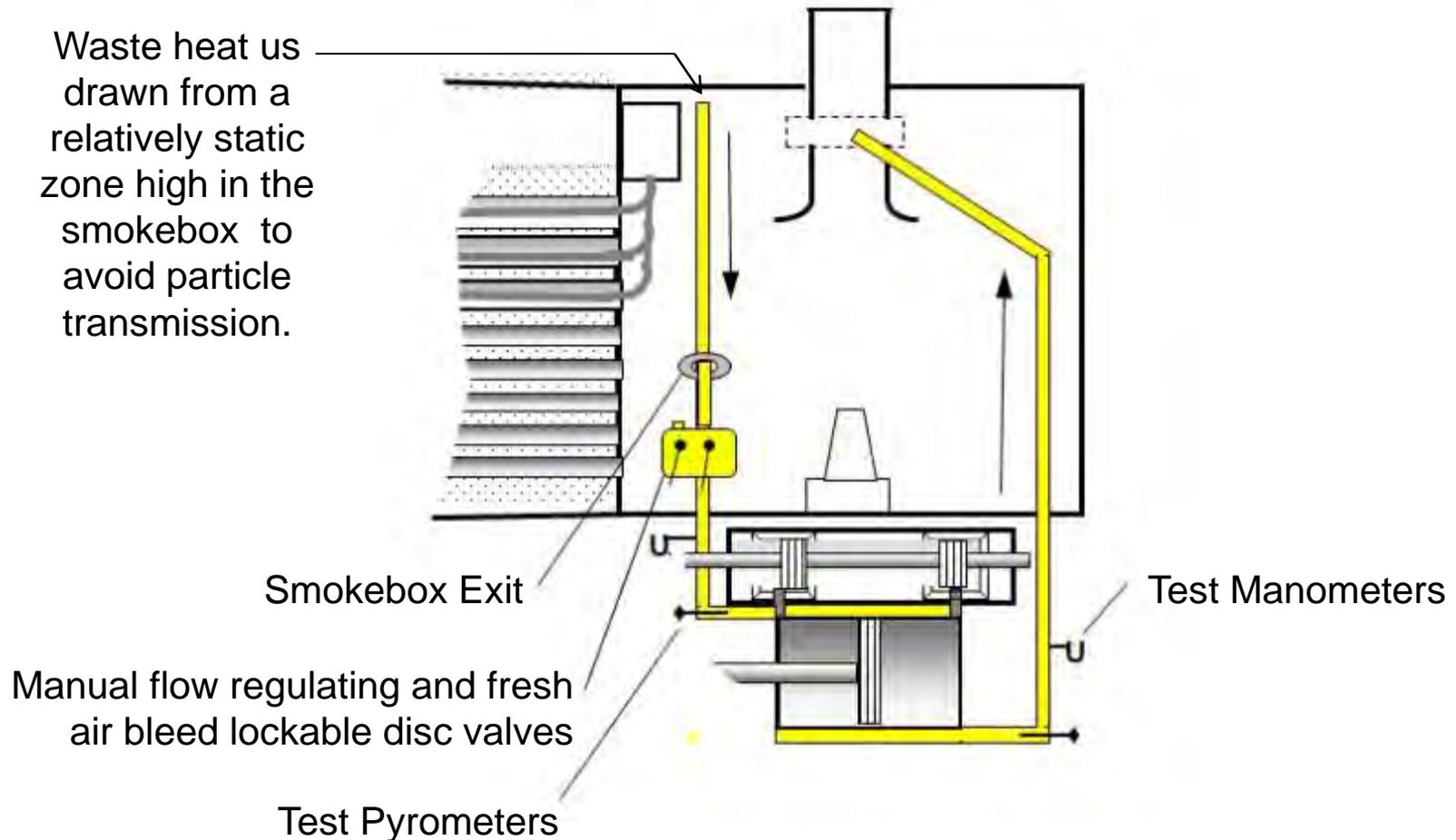
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These experiments would best be carried out on a preserved railway, such as the *North Yorkshire Moors* or the *Mid-Hants* where some hard work is part of the daily routine. Volunteers would only be asked to donate a single cylinder (complete with locomotive!) for the initial experimental phase.

Cylinders of Stanier or BR origin appear to have the potential for retro-fitting waste heat jacketing.

# Initial Tests of Scheme

The trial installation proposed, as sketched below, is designed for 'tuning up' with regard to gas flow using a regulating valve:



**Schematic of Waste Heating Circuit**

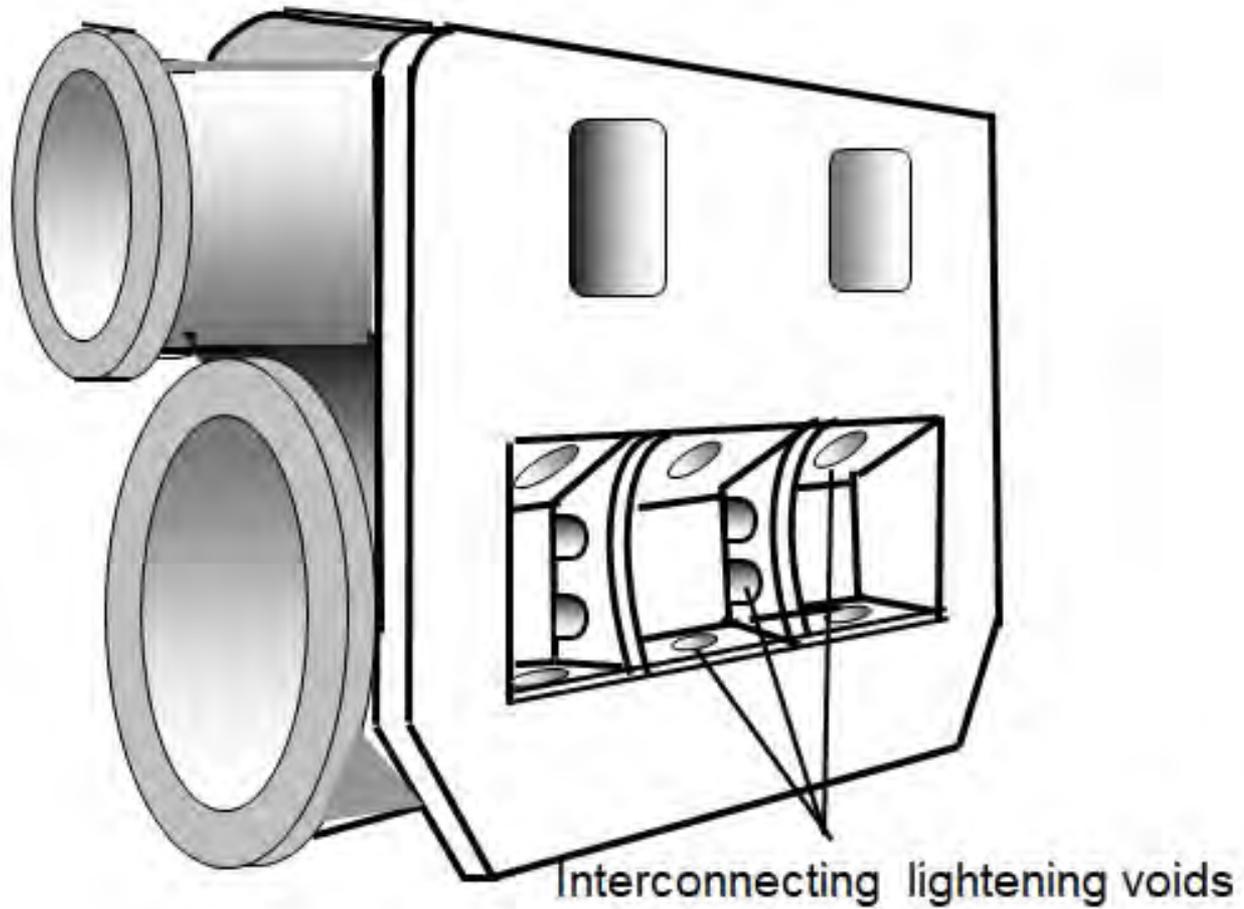
# Initial Tests of Scheme

*continued*

A fresh air bleed valve is also provided should this prove necessary to stop things getting too hot. Much could be determined with a stationary locomotive when steam raising with the blower in operation.

For road tests something like an indicating shelter with easy access to regulating valves and instrumentation would be required.

# Cylinders



**Rough Sketch of Raw Cylinder Casting**

# Cylinders

*continued*

So far, only the potential of LMS Stanier-type outside cylinders and the very similar British Railway pattern have been examined in detail. Although not ideal for waste heat application in all respects, they seem sufficiently adaptable to be worth experiment.

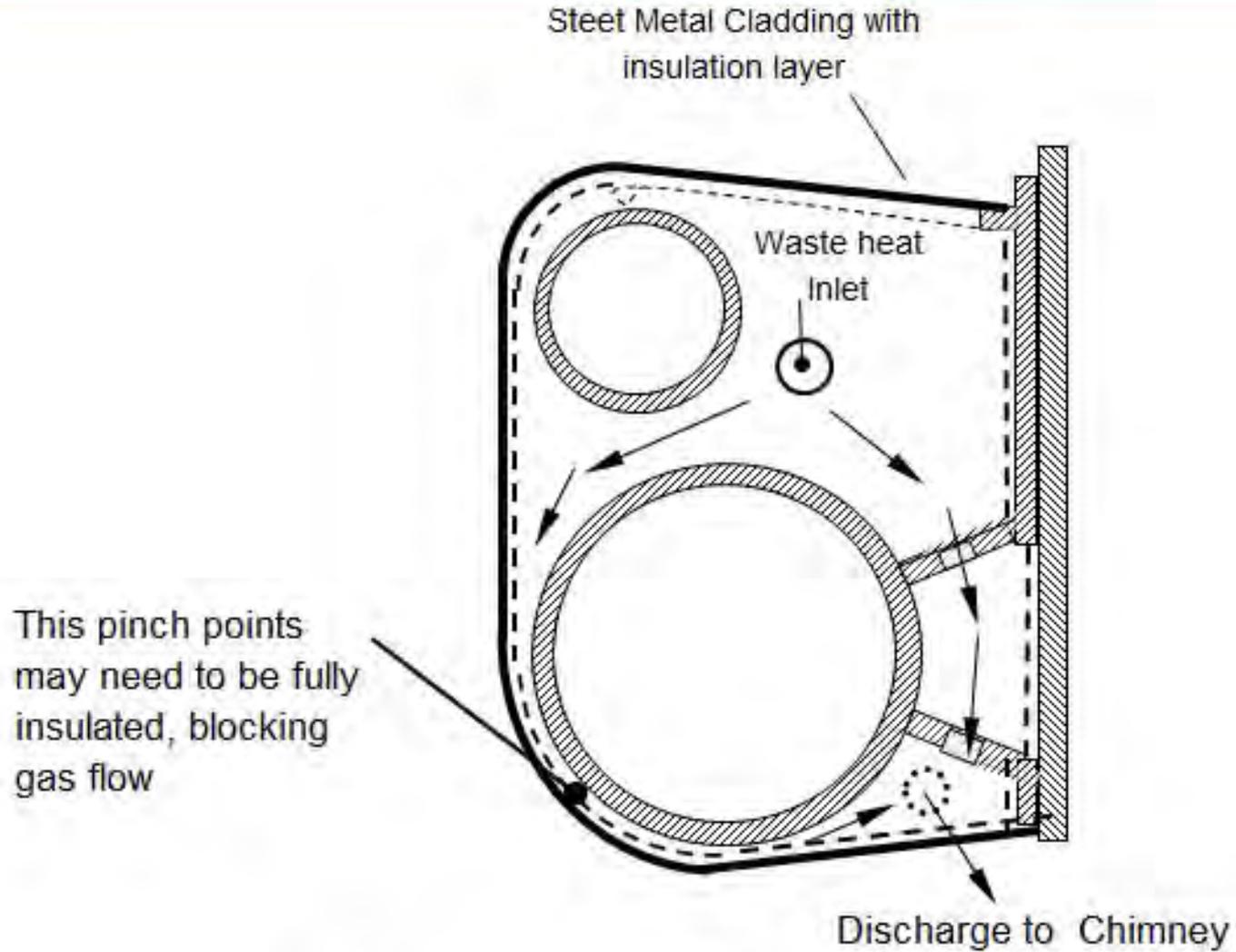
# Cylinders

*continued*

In the scheme proposed, the cylinder outer cladding together with the locomotive frame, forms a waste-heat plenum chamber for the circulating gases. The circulation is aided by some quite generous lightening holes in the main cylinder support webs. There's a pinch point at the cylinder outside lower quadrant.

# Cylinders

*continued*



**Cross Section of LMS/BR Outside Cylinder Casting**

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# Cylinders

*continued*

The waste heat gas flow in the cylinder plenum will likely be quite turbulent. This may be no bad thing, but determination of the optimum waste heat temperature with trouble free operation can only be determined by experiment. Aside from some initial field studies with thermal imaging cameras. The next stage would probably be best served with a model single cylinder stationary engine driving a generator connected to a resistance bank. Something fairly substantial would be sensible, say 3" bore x  $4\frac{1}{2}$ " stroke.

# Cylinder Covers

Although some ideas for jacketing the cylinder covers have been examined, simple solutions are elusive. On the back cover, given the obstructions of the crosshead supports and the gland stuffing box, the scope for thermodynamic enhancement would likely be very limited. In the light of this, I've concluded the cylinder covers are best left unchanged. The potential of waste heat jacketing in the form being proposed would be little compromised by this omission.

# Insulation Practice

The standard practice which survived to the last years of British Railways steam was to plaster the steam chest and cylinder with white asbestos paste. This became rock hard in service. The current practice is mineral wool glass blankets. Below some contemporary insulation options, showing the maximum working temperatures and transmission factors are tabled below. Some insulation is envisaged for the outer cylinder cladding.

<b>Insulation Options</b>				
Material	Max °C	Max °F	W/sq.m/°C	BTU/sq.ft/in/°F
Mineral Wool - Glass	230	450	0.09	0.62
Mineral Wool - Rock	850	1560	0.088	0.61
Calcium Silicate	800	1470	0.085	0.59

# Quantification

Quantification of the waste heat mass flow and temperature required to realise worthwhile economies has not been attempted. Provided excessive heat loss from the cylinder plenum can be avoided, only moderate waste heat demand is anticipated. Given the expected economies, any negative effects on the draughting would be adequately compensated. To what extent the waste heat temperature may require regulation, and determination of the optimum temperature range is best determined by experiment.

# Quantification

*continued*

Help from the model engineering fraternity would seem the best place to start. As a test rig, a stationary single cylinder engine working on the Stephensonian cycle with a coal fired loco type boiler seems the best place to start.

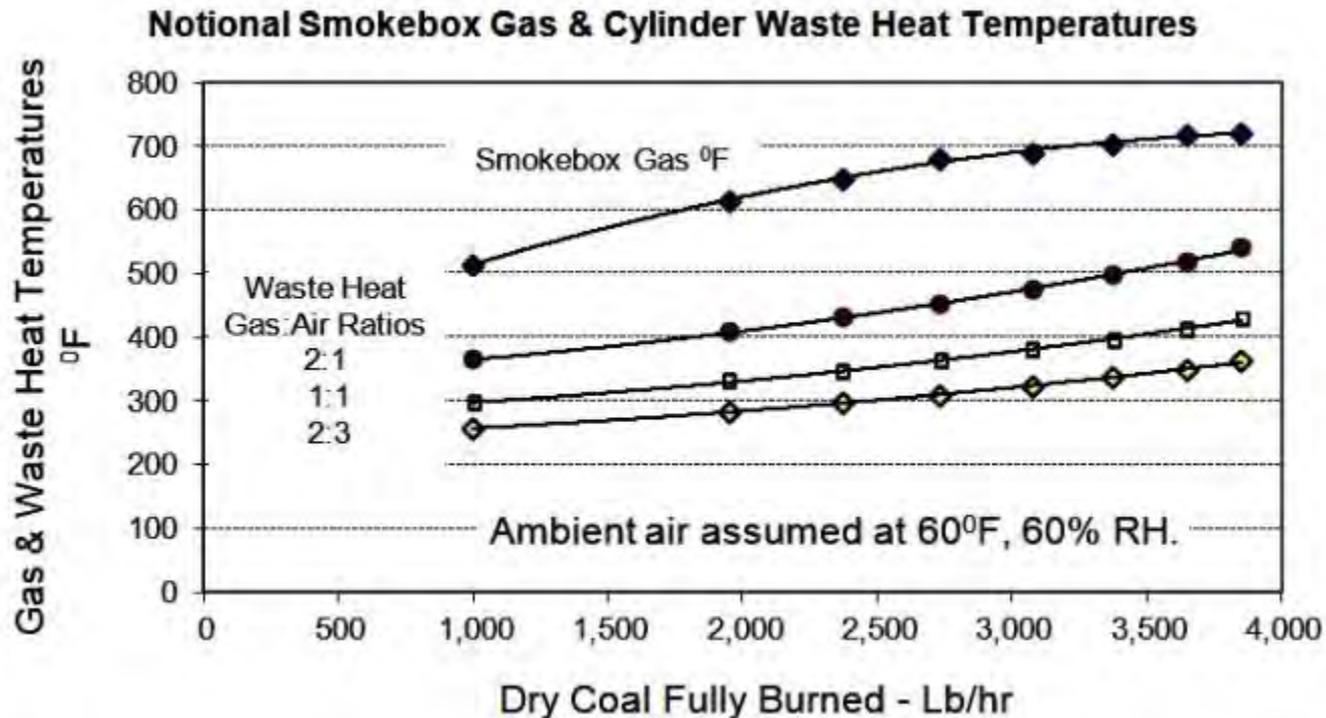
Driving a generator into a resistor bank would be the simplest way of monitoring the effects of waste heat gas temperature on power output and engine efficiency.

Electrical measurements are intrinsically of high accuracy and easier to monitor and log than getting involved with indicators.

# Quantification

*continued*

Some form of temperature control involving a waste heat-atmospheric air mix will probably be required. Below, some plots of how the waste heat ambient air mix would affect things. Ideally, once set up, the scheme would tolerate a sufficient band of waste heat temperatures over the working range to obviate the need for a regulating device.



# Summary

The scheme proposed is simple and of low cost relative to the potential economies. As a low pressure system it is easy to retrofit, and some, or possibly most outside cylinder types have the potential for its application.

The potential economies are likely superior to those obtainable from steam jacketing, and installation would be considerably simpler and cheaper to apply to existing types.

Maintenance requirements would be low. The initial way forward is by experimental stationary models.