SmokeBoxes

by Dick Thomas

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Summary of Boiler Series Talk given by Dick Thomas

Introduction

The topic of Dick's talk given on August 9th was smokeboxes. He started by explaining that the function of the front-end system or smokebox is to create a draft so that the products of combustion are drawn through the flues and firetubes, discharged into the atmosphere, and fresh air drawn in under the grate. The vacuum induced is maximum (about 20 inches of water) at the blast pipe and diminishes in the smokebox, the flues and firetubes, the firebox, and the ash pan. Even though the vacuum is only about ½ inch of water at the ashpan it's sufficient to produce the high combustion rate required.

Using a cross sectional view of the smokebox, Dick listed the major components contained therein as:

1. Exhaust connections from the cylinder
2. Exhaust stand pipe
3. Exhaust nozzle
4. Stack.

The first two items are necessary, but the nozzle and stack are the really important components. They make up what is generically known as a steam jet pump or ejector. These devices are not only found in locomotive front ends, but also in vacuum brake systems, process evaporators in sugar mills, conveying systems, and the like. The steam feedwater injector is a first cousin to the steam ejector.

Of course, there are other items in the smokebox such as front-end throttles, superheater elements, and spark arresting screens, but Dick did not cover them in this talk.

Dick then described the four components as follows:

1. There are two schools of thought on how to connect the exhaust pipes from the cylinders to the blast pipe. One group feels it's important to direct the exhaust upward via a curved elbow into the blast pipe to prevent the exhaust from going directly across to the other cylinder. The second group feels there is no noticeable difference in performance between the two arrangements so go with the simple tee since it's easy to make. Sometimes a small concession is made for separation by putting a simple baffle in the center of the tee.
2. The exhaust stand provides the path for the exhaust steam from the cylinders to the nozzle. Since some experimenting with nozzle shapes will necessary, the nozzle connection should be made for easy replacement.
3. The two important parameters of the nozzle are its diameter and the shape of the bore.
4. The stack (or technically the venturi) is another component that evokes a spirited discussion. Should the bore be straight or tapered? Should the bottom be a straight bore, conical, or curved out like a trumpet bell. Important dimensions of the stack include length, choke diameter, shape of bore (tapered or not) and distance above the nozzle.

Dick pointed out that early engine designers tried a variety of schemes from double venturi tubes (petticoat pipes) to adjustable nozzles in an attempt to get the maximum steaming performance. However, in the end, fixed components of a single nozzle and venturi prevailed. There was some investigation of multi-ported nozzles and even there, the simpler designs were better.

Grate Area = 67.5 square inches, Flue Area = 7.4 square inches.

Calculations: F = .16D = .16 x 8 = 1.3
C = .21D + .16F = .21 x 8 + .16 x 1.3 = 1.9
B = .5D = 2C = 2 x 1.9 = 3.8
J + H = .32D = .32 x D = 2.6
H = .22D = .22 x 8 = 1.6
G = .18D = .18 x 8 = 1.4
A_1 = .25 of the Cylinder Diameter
A_1 = .25 x 2.25 = .56
A_2 = 1/200th of the Grate Area
A_2 = 67.5/200 = .34 (seems low)

From other sources:

C = .25 of Flue Area = .25 x 7.4 = 1.9 (right on, but maybe a coincidence!)
C = .24 times the square root of the Grate Area = .24 x 8.21 = 2.0 (pretty good)
A = .25C = .25 x 1.9 = .48 (Pretty good)
F + G = 2.3C = 2.3 x 1.9 = 4.4 (F+G from above is 2.7. Way off.)
B = 1.9C = 1.9 x 1.9 = 3.6 (Pretty good)

This is a very approximate method as can be seen by variation in results. While there is agreement among some parameters, others are inconsistent. Clearly, some experimentation will be in order. For example, although two different sources give the nozzle bore to be about .50, maybe the .34 value will work better. If nothing else at least doing the arithmetic will give the builder the range of values that the construction should accommodate.

Slap some paper on your drawing board (or turn your CAD system) and layout the above smokebox assuming steam issues from the nozzle at an included angle of 16°. Would you cut metal to that layout?

Alignment Procedure

Dick recommended the construction of an alignment rod made to fit in the nozzle bore and extending upward into the stack. Two disks are fitted tightly into the stack bore and drilled for the alignment rod. When all pieces are coaxial the rod should slide easily. Based on full size practice, which required accuracy to 1/16, model practice requires accuracy to about .007.

Conclusion

Dick concluded his talk with the customary question-answer period and mentioned that the talk was part one of a two-part presentation. Dick's second talk will cover the experimental phase of constructing a smokebox. Many thanks to Dick for his well illustrated and informative presentation.

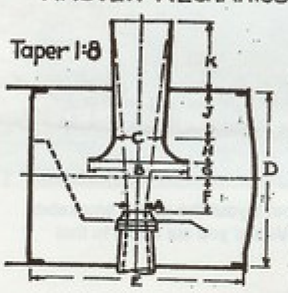
Wide ranges of opinions and empirical design formulae have appeared in the model engineering press regarding how to design a front end. Most are based on some aspects of full size practice. For example, in the USA the Association of American Railroads, The Pennsylvania Railroad, and Purdue University worked together to produce in 1902 what became known as the Master Mechanic's Front end. In the UK a good reference is E. S. Cox's *British Railways Standard Steam Locomotives.*

The determination of answers to the above problems or questions depends on the interest and inclination of the builder. If you are comfortable with technical reading, number crunching, and experimental analysis then have a crack at designing your own front end. Otherwise, stick to published designs, but if you do and problems arise, you may have to do some adjusting of the smokebox components.

Published Relationships

Dick showed several outline drawings of smokeboxes to illustrate the many different schemes that are available to the builder. He focused on the Master Mechanic's version shown below.

MASTER MECHANICS' FRONT END - 1902



1. Make K and F as large as possible.
2. C = 0.21D + 0.16F.
3. B = 2C or = 0.5D.
4. J + H = 0.32D.
5. H = 0.22D.
6. G = 0.18D.

From Loco.Cyc.-1925

	B	C	F	G
High	.47D	.29D	.25D	.15D
Low	.36D	.23D	.12D	.07D
Avg.	.42D	.25D	.16D	.09D

From Other Sources:

7. A(diam) = 0.25 cyl. diam.
8. A(area) = $\frac{\text{Grate Area}}{200}$ both in square inches.
9. F + G = C, about.
10. F + G = [illegible] D

The design procedure using the Master Mechanic's Front End will be explained via proposed layout for a 1 ½" Mikado.

Start with the known or given information. In this case: D = 8, K = 3.5.