THE RELATION OF CYLINDER AND BOILER POWER IN LOCOMOTIVE RATING.

Paper No. 73.

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(See Vol. IX., No. 39, p. 276.)

COMMUNICATIONS RESPECTING MR. LAWFORD H. FRY'S REMARKS.

(Journal No. 41, p. 506.)

Mr. F. W. Brewer: I should like to ask Mr. Fry whether it was the fact that, until the St. Louis tests took place, American locomotive engineers were unaware that the efficiency of combustion decreased as the rate of combustion increased? Mr. Fry states (p. 506): "Again, the drop in boiler efficiency as the rate of combustion is increased has been shown to be due to a falling-off in the efficiency of combustion and not to lack of heat absorbing capacity in the boiler. Mr. Rowland quotes the writer's analysis of the St. Louis tests as showing this. Further tests at Altoona have fully established this fact, which was quite unsuspected until the accurate test plan experiments enabled the writer to work out exact heat balances for locomotives."

What does Mr. Fry mean by "unsuspected"? The fact that the higher rates of combustion are attended by relatively greater heat losses, has been known in this country for very many years—long before the St. Louis tests were carried out. It has been particularly noticeable in regard to the running of express trains. As the speed rises, the consumption of steam augments, but the production of steam does not increase in the same ratio as the combustion. In other words, although the total quantity of water converted into steam is greater in a given time, yet the number of pounds of water evaporated per pound of coal decreases with the speed and with the amount of fuel burnt per square foot of grate area per hour. In a sense, the total output is greater, but the loss of heat is also greater, as a smaller and smaller percentage of the fuel is converted into work as the rate of combustion goes up.

Other things being equal, the higher rates of combustion are nearly always associated with the higher rates of speed. Apart from other considerations, that is one reason why high speed is costly. Hutton, in his "Practical Engineer's Handbook," argues that "if the speed of the engine be doubled and the weight of the train remain the same, the quantity of fuel burned in a given time would also be doubled; but as only one-half of the time would be occupied in travelling a mile, the consumption of fuel per mile would be the same in both cases; therefore the rate of consumption of fuel per train mile varies with the weight of the train, and is independent of the speed." That theory is not borne out by practice. Some years ago the L. & N.W.R. people carefully tested the effect of speed on coal consumption. Two runs were made from Crewe to Wolverton (105 miles), one at an average speed of 24 miles an hour and the other at an average rate of 45.6. The weight of each train was approximately the same, the difference between the two being only 5 tons 9 cwts. At the lower speed the consumption of coal per mile was 21.3lbs., and the pounds of water evaporated per pound of coal were 9.77. On the other hand, at the higher speed of $45\frac{1}{2}$ miles an hour, only 7.6lbs. of water were evaporated per pound of coal, while the fuel consumption rose to 57.6lbs. per mile, thus proving conclusively that combustion was more wasteful, and the boiler efficiency consequently lower, than in the case of the speed of 24 miles an hour. D. K. Clark early pointed out the drop in boiler efficiency as the rate of combustion increased, and it would appear that Mr. Fry has overlooked the fact. A slow speed, in conjunction with a late cut-off, will also augment the rate of combustion, of course.

Mr. H. Lawford Fry (Burnham, Pa.): Mr. Brewer's criticism of my remarks is based on a misunderstanding of what was said. The paragraph in question takes for granted that it was a well-established and well-known fact that the boiler efficiency fell as the rate of firing was increased. The point intended to be made was that the reasons for this drop in efficiency had not been accurately determined.

The overall boiler efficiency is dependent on two factors, first the efficiency of combustion and second the efficiency with which the heat produced is absorbed. Before the Pennsylvania locomotive testing plants results were analysed there was no accurate information as to the importance of the two factors, and it was quite generally believed that a large part of the loss in overall efficiency was due to a decrease in the efficiency with which the heat was absorbed by the heating surface of the boiler.

The Pennsylvania test plant results have permitted an accurate analysis of boiler efficiency and have shown that as the rate of firing increases the efficiency of combustion decreases, while the efficiency of heat absorption remains practically constant. This is the fact which I stated was unsuspected until the accurate test plant experiments had enabled exact heat balances to be worked out for locomotives. It may be pointed out that on first sight the increase in smoke-box temperature with an increase in rate of firing might be taken to indicate a decrease in the efficiency of heat absorption. The testing plant results, however, show that the increase in smoke-box temperature is more than offset by the increase in fire-box temperature, and by the decrease in weight of smoke-box gases per pound of coal fired.

The Author (Mr. E. M. Gass): With reference to Messrs. Brewer and Fry's remarks, I think the Paper makes clear the well-established fact that the rate of combustion and the rate of evaporation increases with increasing speeds. Further, the quantity of steam produced is not in equal ratio to the coal consumed.

For example, take the L. & Y. Railway Company's 0-8-0 Goods Engine running at 10 miles and 30 miles per hour. At 10 miles per hour the coal consumed per hour is 1,692lbs., at 30 miles per hour it has risen to 3,241lbs., an increase of over 91 per cent. At the same speeds the evaporation is 14,466lbs. and 21,552lbs. respectively, an increase of only 49 per cent.

Up to the advent of the stationary plant tests in America, this falling-off of efficiency was thought to be due to two factors—

(*a*) Decreased efficiency of combustion;
(*b*) Decreased capacity of the boiler to absorb the heat.

Mr. Fry's analysis of the St. Louis and Pennsylvania tests have proved this theory to be wrong, for the investigator points out that the falling-off in the overall efficiency of the boiler is entirely due to the decreased efficiency of the combustion, the efficiency of the heat absorption remaining practically constant.

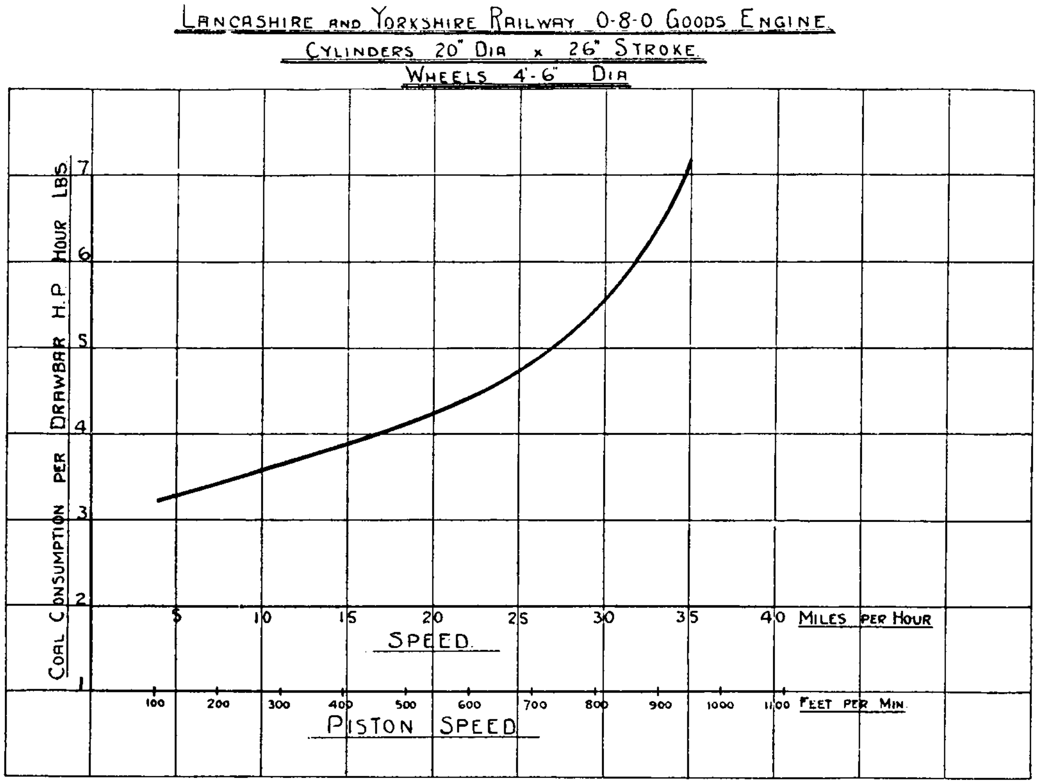
We have here another strong argument for the installation of a stationary test plant in this country where tests could be carried out and reliable conclusions formed.

Experiments in actual service are certainly useful, but due to the changing conditions met with, it is impossible from this data alone to solve the numerous complex problems associated with the locomotive.

As the measure of work is at the drawbar the following table and diagram may be of interest, as showing the amount of coal burnt per drawbar horse power hour at various speeds. The results are based on particulars given in the Paper.

LANCS. & YORKS. RLY. CO.'S 0-8-0 GOODS ENGINE.—Cylinders 20in. diameter × 26in. stroke. Wheels 4ft. 6in. diameter.

Speed—Miles per hour	5	10	15	20	25	30	35
Speed—Feet per minute (corresponding to above) ...	440	880	1320	1760	2200	2640	3080
Corresponding Piston Speeds—Feet per minute ...	135	270	405	540	675	810	945
Coal burnt per sq. ft. of heating surface per hour (see Fig. 9)	.485	.83	1.09	1.31	1.48	1.59	1.655
Total Heating Surface = 2,038.6 sq. ft. (Table A) ... Total Coal Consumption	.485 × 2038.6 = 988 lbs.	.83 × 2038.6 = 1692 lbs.	1.09 × 2038.6 = 2223 lbs.	1.31 × 2038.6 = 2670 lbs.	1.48 × 2038.6 = 3017 lbs.	1.59 × 2038.6 = 3241 lbs.	1.655 × 2038.6 = 3374 lbs.
Corresponding evaporation per hour per lb. of coal consumed (Fig. 9)	11.0 lbs.	8.55 lbs.	7.8 lbs.	7.3 lbs.	6.8 lbs.	6.65 lbs.	6.52 lbs.
Total evaporation per hour	11 × 988 = 10868 lbs.	8.55 × 1692 = 14466 lbs.	7.8 × 2223 = 17239 lbs.	7.3 × 2670 = 19491 lbs.	6.8 × 3017 = 20515 lbs.	6.65 × 3241 = 21552 lbs.	6.52 × 3374 = 21998 lbs.
Steam Consumption per I.H.P. hour (Fig. 10) ...	33 lbs.	28 lbs.	25.9 lbs.	25.1 lbs.	25.2 lbs.	26.1 lbs.	28.5 lbs.
I.H.P. $= \dfrac{\text{Total steam consumption p.h.}}{\text{Steam consumption per I.H.P. hr.}}$ ...	$\frac{10868}{33} = 329$	$\frac{14466}{28} = 517$	$\frac{17239}{25.9} = 664$	$\frac{19491}{25.1} = 777$	$\frac{20515}{25.2} = 814$	$\frac{21552}{26.1} = 826$	$\frac{21998}{28.5} = 771$
Corresponding Tractive Effort	$\frac{329 \times 33000}{440}$ = 24675 lbs.	$\frac{517 \times 33000}{880}$ = 19400 lbs.	$\frac{670 \times 33000}{1320}$ = 16750 lbs.	$\frac{777 \times 33000}{1760}$ = 14568 lbs.	$\frac{814 \times 33000}{2200}$ = 12210 lbs.	$\frac{826 \times 33000}{2640}$ = 10325 lbs.	$\frac{771 \times 33000}{3080}$ = 8260 lbs.
Internal Resistance of Engine (lbs. per ton) (Fig. 2)	14	15.25	18	20.5	23	26	28.2
Total Internal Resistance of Engine ... ... Weight of Engine only = 53.75 tons (p. 276) ...	14 × 53.75 = 752 lbs.	15.25 × 53.75 = 820 lbs.	18 × 53.75 = 968 lbs.	20.5 × 53.75 = 1102 lbs.	23 × 53.75 = 1236 lbs.	26 × 53.75 = 1398 lbs.	28.2 × 53.75 = 1515 lbs.
The Resistance of the Engine and Tender as a vehicle (Fig. 3, Lawford Fry Curve)	11.5 lbs./ton	12.5 lbs./ton	13.5 lbs./ton	14.5 lbs./ton	16 lbs./ton	17 lbs./ton	18 lbs./ton
Total Resistance of Engine and Tender as a vehicle... Weight of Engine and Tender = 95.75 tons (p. 276)	11.5 × 95.75 = 1101	12.5 × 95.75 = 1196	13.5 × 95.75 = 1293	14.5 × 95.75 = 1388	16 × 95.75 = 1532	17 × 95.75 = 1628	18 × 95.75 = 1723
Total Resistance of Engine and Tender	752 + 1101 = 1853 lbs.	820 + 1196 = 2016 lbs.	968 + 1293 = 2261 lbs.	1102 + 1388 = 2490 lbs.	1236 + 1532 = 2768 lbs.	1398 + 1628 = 3026 lbs.	1515 + 1723 = 3238 lbs.
Effective Pull at Drawbar—Tractive Effort *less* Resistance of Engine and Tender + Internal Resistance	24675 — 1853 = 22822 lbs.	19400 — 2016 = 17384 lbs.	16750 — 2261 = 14489 lbs.	14568 — 2490 = 12078 lbs.	12210 — 2768 = 9442 lbs.	10325 — 3026 = 7299 lbs.	8260 — 3238 = 5022 lbs.
Drawbar H.P.	$\frac{22822 \times 440}{33000} = 305$	$\frac{17384 \times 880}{33000} = 463$	$\frac{14489 \times 1320}{33000} = 579$	$\frac{12078 \times 1760}{33000} = 638$	$\frac{9442 \times 2200}{33000} = 629$	$\frac{7299 \times 2640}{33000} = 584$	$\frac{5022 \times 3080}{33000} = 468$
Coal Consumption per Drawbar H.P.	$\frac{988}{305}$ = 3.24 lbs.	$\frac{1692}{463}$ = 3.65 lbs.	$\frac{2223}{579}$ = 3.84 lbs.	$\frac{2670}{638}$ = 4.17 lbs.	$\frac{3017}{629}$ = 4.79 lbs.	$\frac{3241}{584}$ = 5.54 lbs.	$\frac{3374}{468}$ = 7.21 lbs.


LANCASHIRE AND YORKSHIRE RAILWAY 0-8-0 GOODS ENGINE
CYLINDERS 20" DIA x 26" STROKE
WHEELS 4'-6" DIA
COAL CONSUMPTION PER DRAWBAR H.P. HOUR LBS
1
2
3
4
5
6
7
5
10
15
20
25
30
35
40
MILES PER HOUR
SPEED
100
200
300
400
500
600
700
800
900
1000
1100
FEET PER MIN.
PISTON SPEED

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