(Paper No. 3315.)

"Note on the Use of 'Serve' Steel Tubes in a High-Pressure Locomotive Boiler, and their Efficiency as Compared with that of Plain Iron Tubes."

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IN 1897 the Wellington and Manawatu Railway Company procured from the Baldwin Locomotive Works of Philadelphia a "Vauclain" four-cylinder compound consolidation locomotive, No. 16, fitted with "Serve" ribbed tubes. On the advice of the New York representative of the maker of the tubes, it was decided to employ tubes $2\frac{3}{4}$ inches in diameter, reduced to $2\frac{5}{8}$ inches in diameter at the firebox end, and enlarged to $2\frac{7}{8}$ inches in diameter at the smoke-box end. The tubes were of No. 9 gauge, and were 11 feet 6 inches in length between the tube-plates, 5 inches at the front end and 4 inches at the fire-box end being plain, and the remainder ribbed. A steel fire-box was fitted, having a tube-plate $\frac{1}{2}$ inch in thickness, the front tube-plate being also $\frac{1}{2}$ inch thick, and well stayed.

The crown-staying consisted of tee-bars, 6 inches by 1 inch in cross-section, set transversely across the box and slung from tee-bars riveted to the outside shell by four sling-stays, each consisting of a flat steel bar, 3 inches by $\frac{5}{8}$ inch in cross-section, having a hole at each end through which were passed $1\frac{1}{4}$ -inch pins connecting the slings with the middle members of the tee bars; $\frac{1}{8}$ inch of slack was left in the top holes of the slings, *Figs. 1*. Button-headed stay-bolts, 1 inch in diameter and 4 inches pitch, secured the crown-sheet to the foot of the tee-bars. Between the crown-sheet and the tee-bars, which were 3 inches above the crown-sheets, these bolts passed through pieces of stout hydraulic

pipe, *Figs. 2.* It will be seen that, while the crown-sheet was well secured to withstand internal pressure, movement due to

changes of temperature was not prevented. The arrangement of stays and the spacing of the tubes are shown in *Figs. 3.*

The engine was employed in hauling trains, of about 250 tons net, over a rough undulating section of line, 27 miles in length, the boiler-pressure being alternately raised to its maximum and then allowed to die down, as the various gradients were surmounted. The maximum gradients were:—northwards bound, 5 miles at a

Figs. 3.

gradient of 1 in 40, and 3 miles at a gradient of 1 in 56; southwards bound, 3 miles and $5\frac{1}{2}$ miles at a gradient of 1 in 56. An assistant engine was used on the 1 in 40 gradient. The conditions of service demanded that the engine should stand for about 2 hours

at the end of each 27 miles run. About 120 miles were run per day.

The water used was fairly pure, and every care was taken to keep the boiler clean, it being washed out at the end of every 7 days' service, after having been allowed to cool. From the time the engine was first put in service, a considerable amount of trouble was caused by flues leaking at the fire-box end. This was improved to some extent by keeping a clear fire and an even pressure of steam whilst running downhill, and when standing at the end of a run, but there was still a good deal of leakage. It was noticed that the leaking was much worse after cleaning fires, and as the boiler was fitted with rocking-grates, advantage was taken of this to clean the fire by rocking into the ash-pan. A

great improvement resulted, and it was found that, if care was taken to prevent large quantities of cold air from entering the fire-box, the tubes could be kept fairly tight. After about 6 months' service, odd tubes began to leak, necessitating the boiler-maker expanding some tubes on every wash-out day. Leakage also began to show at the smoke-box end, and on removing some of the tubes it was found that grooving had taken place close to the inside of the tube-plate, in some cases more than half-way round the tube, and almost through the metal, *Figs. 4*. This occurred chiefly in the two bottom rows of tubes, and extended about half-way round the boiler. These tubes were replaced by new ones, but the same effect continued to recur, and after 12 months' service the Author decided to remove the Serve tubes

altogether, and to substitute plain charcoal-iron tubes, 2 inches in diameter, of No. 12 B. and S. gauge. Since this was done the boiler has given very little trouble. The heat-absorbing surface of the Serve tubes, *i.e.*, the internal surface of the tubes in contact with the hot gases, was 1,235 square feet, and the heat-distributing surface, *i.e.*, the external surface of the tubes, was 745 square feet, and the total area for the passage of gases was 2.53 square feet.

In the plain tubes afterwards substituted, the total heat-absorbing surface was 860 square feet, and the total heat-distributing surface was 945 square feet, the flue area being 2.83 square feet.

The fire-box heating-surface was in each case 92.5 square feet, and the grate-area 17 square feet. The boiler steamed freely both with the Serve tubes and with the plain tubes, but after about 500 miles had been run it was noticeably duller when fitted with the Serve tubes. The Serve tubes were "run," on an average, about twice a week, and the plain tubes once a week. The smoke-box was fitted with a deflector-plate in front of the tubes, which caused the sparks lodging in the smoke-box to be swept well forward; these were blown out when necessary by means of a spark-ejector. The smoke-box door was not opened except to run the tubes. With regard to the relative efficiency of the Serve and plain tubes, the engine, when fitted with Serve tubes, consumed, on an average, 55.4 lbs. of coal per mile, while during the 6 months after the Serve tubes were removed the consumption was 55.2 lbs. of coal per mile, and for the following year 56 lbs. per mile, or 0.272 lb. per net ton-mile. From this it appears that the 860 square feet of heat-absorbing surface of the plain tubes was as efficient as the 1,235 square feet of heat-absorbing surface of the Serve tubes, or the heat-absorbing surface of the Serve tubes has 69.6 per cent. of the efficiency of that of the plain tubes. The Author is of opinion that, owing to leaky flues, the coal-consumption was greater with the Serve tubes than it otherwise would have been.

No separate account was kept of the cost of boiler-work, but the following are particulars of the cost of all repairs on this engine:—

	Per Mile.	
For 6 months ending February, 1898 . . .	1.70d.	{ Boiler fitted with Serve tubes.
„ 12 „ „ „ 1899 . . .	3.6d.	
„ 12 „ „ „ 1900 . . .	3.2d.	{ Serve " tubes removed, plain tubes substituted.
„ 12 „ „ „ 1901 . . .	1.60d.	
		{ Boiler fitted with plain tubes.

It will be seen that for the 12 months before the Serve tubes were taken out the cost of repairs was 3·6*d.* per mile; for the first year the plain tubes were in service the cost was 3·2*d.* per mile (this included the cost of fitting the plain tubes); and for the last 12 months the cost was 1·6*d.* per mile.

The coal consumed on a compound engine of the same class, No. 13, and on the same run, might be mentioned. This engine carries steam at a pressure of 180 lbs. per square inch, has 959·4 square feet of tube heating-surface, 92·6 square feet of fire-box heating-surface, and 17 square feet of grate-area. The tubes, of charcoal-iron, are 2 inches in diameter externally, and the boiler is stayed radially, the load hauled being about 14 tons less than with engine No. 16. The coal-consumption for the past 2 years was 56·43 lbs. per mile and 55·92 lbs. per mile respectively, and the consumption per net ton-mile was 0·299 lb.

In conclusion, the Author is of opinion that the failure of the Serve tubes by grooving was caused by the ribbed portion being so rigid that all vibrations were concentrated at the front end, which is the thinnest and weakest part of the tubes, and that if, instead of the internal diameter of the tube being increased where it passes through the front tube-plate, it were kept parallel and the thickness of the metal back to the ribbed portion increased, better results would be obtained.

The Paper is accompanied by three photographs of drawings, from which the Figures in the text have been prepared.