Pennsylvania Decapod, Type I1s

PENNSYLVANIA DECAPOD SHOWS HIGH ECONOMY

Report of Tests Comparing I1s, Hand and Stoker Fired, with the Performance of the L1s Mikado

IN 1916 the Pennsylvania Railroad built a locomotive of the 2-10-0 type with cylinders working at a maximum cut-off of 50 per cent. This locomotive with minor alterations was adopted for heavy freight service and a large number of the clas I1s, as this type is designated, are now in use. The design of this locomotive was described in the *Railway Mechanical Engineer* for July, 1917, page 370. Details of the performance as disclosed by the results of test

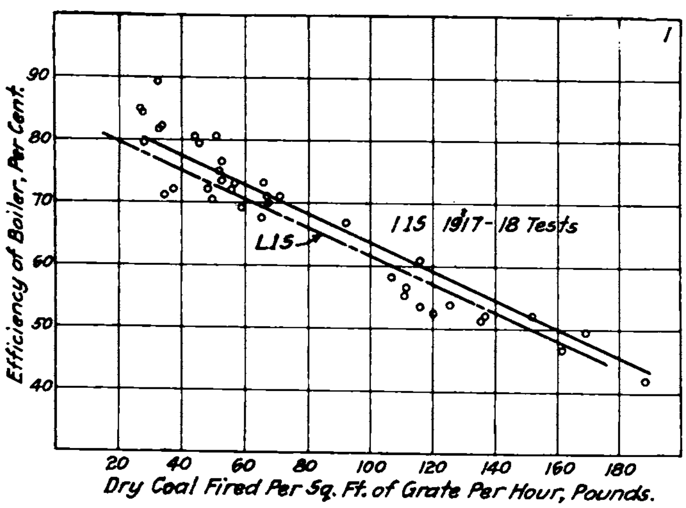

Fig. 1. Rate of Combustion and Boiler Efficiency

plant trials, are now available in Bulletin No. 31 (copyright 1919 by the Pennsylvania Railroad), from which the information in this article has been secured.

In discussing the considerations which led to the development of the I1s the bulletin points out that many locomotives, in helping service especially, are worked almost continuously with a cut-off near the end of the stroke. If they were designed so as to work at but 50 per cent cut-off when in full gear, without a sacrifice of drawbar pull, there would be gained the difference between the coal and water rates at full stroke cut-off and those at half stroke, or a saving of approximately 25 per cent. The locomotive needed at a number of points on the Pennsylvania was one having a drawbar pull 25 per cent greater than that of the class L1s, Mikado type, or one having a pull of about 75,000 lb. at 10 miles an hour. A study of such a locomotive, with a limited or restricted cut-off in a two-cylinder arrangement, indicated that the desired result could be obtained with a half stroke maximum cut-off, giving a turning moment diagram very similar to that of locomotives cutting off at full stroke.

For the purpose of developing a practical means of obtaining the economies above outlined, a locomotive was built and placed on the locomotive testing plant before going into road service, as the innovations in design made it especially desirable to have complete test results before building additional ones. As a result of the tests and the general performance of the locomotive in service, certain alterations were found advisable.

Description of the Locomotive

Locomotive No. 790, as finally arranged for these tests, is of the Decapod or 2-10-0 type with two cylinders 30½ in. in diameter and having a stroke of 32 in. The boiler pressure is 250 lb. per sq. in. and the maximum cut-off is limited to approximately 50 per cent of the stroke. In many particulars the design follows closely that of the class L1s, Mikado type, which preceded it.

The table following shows how the locomotive compares with the class L1s in certain leading dimensions. The total heating surface is about 12 per cent larger than that of the class L1s, and the total weight about 16 per cent greater. The grate areas of the two locomotives are alike.

General Dimensions of Locomotives of the I1s and L1s Classes

	Class I1s 790	Class L1s 1,752	Increase of I1s over L1s, per cent
Weight in working order, total pounds..	371,800	320,700	15.9
Weight on drivers, working order, pounds	342,050	240,200	42.4
Driving wheels, diameter, inches	62	62	...
Cylinders (simple), inches	30½ by 32	27 by 30	37.6 Vol.
Heating surface, tubes (water side), sq. ft.	4,043.94	3,715.71	8.8
Heating surface, firebox (including arch tubes), sq. ft.	290.20	301.51	3.8 Dec.
Heating surface, superheater (fireside), sq. ft.	1,478.91	1,171.63*	26.2
Heating surface, total (based on water-side of tubes), includ. superh., sq. ft.	5,810.25	5,188.85	12.0
Heating surface, total (based on fireside of tubes), including superheater, sq. ft.	5,423.12	4,847.72	11.9
Grate area, sq. ft.	70.0	70.0	0.0
Boiler pressure, pounds per square inch.	250.0	205.0	22.0
Valves	12-in. piston	12-in. piston	...
Valve motion, type	Walschaert	Walschaert	...
Firebox, type	wide, Belpaire	wide, Belpaire	...
Tubes, number	244	237	...
Tubes (outside diameter), inches	2.25	2.25	...
Flues (for superheater), number	48	40	...
Flues (outside diameter), inches	5.5	5.5	...
Tubes and flues, length, inches	228.32	228.51	...

*This is the heating surface of the 17-ft. superheater. The standard length superheater for the L1s is now the same as for the I1s or 18 ft., with a heating surface of 1.234.65 sq. ft., but the 17-ft. superheater was used in the L1s tests herein reported. The I1s superheater surface is about 20 per cent larger than that of the 18-ft. superheater for the L1s.

Tractive Force

In calculating the maximum tractive force of this locomotive the mean effective pressure reaching the drawbar cannot be taken as the usual 85 per cent of the boiler pressure, because of the limitation of the cut-off. Indicator diagrams, made in road service, at starting in full gear, show an average m.e.p. of about 75 per cent of the rated 250 lb. boiler pressure, or somewhat more, according to the time in which the first revolution is made, controlling the amount of steam passing through the auxiliary port. With 30½-in. by 32-in. cylinders, the calculated maximum tractive force may, therefore, be assumed to be that based on 75 per cent of the boiler pressure, or 90,000 lb. The ratio of weight on drivers to this calculated tractive force is 3.8. After the first few revolutions, it is expected that the drawbar pull will fall to that due to about 70 per cent of boiler pressure as m.e.p., or 84,000 lb., with a ratio of 4.07.

Boiler

The boiler is similar in design to the boiler of the class L1s, but the boiler tube surface and superheating surface are both somewhat larger. The superheater has 48 elements, where the class L1s has 40. The length of tubes and superheater flues, 19 ft., is the same as in the class L1s locomotive.

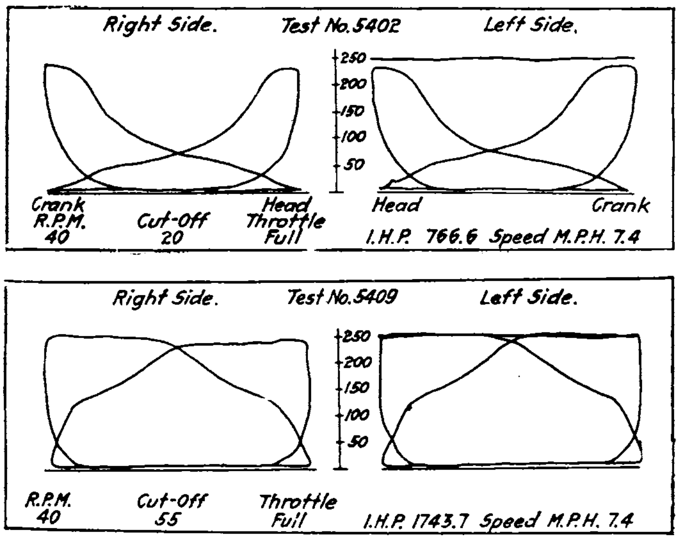

Fig. 2. Typical Indicator Diagrams

The details of the cylinders, ports and valves were described in the article referred to above. It may be well to mention that the valves have a travel of six inches in full gear and to obtain a short cut-off with this long travel, it was necessary to make the steam lap two inches. Full gear cut-off with six-inch valve travel is at 50 per cent of the stroke; however, to distinguish tests in full gear cut-off at slow speed, with allowance for steam passing through the auxiliary ports, such tests are marked 55 per cent cut-off as determined from the indicator diagrams. The lead of the valves in full gear is 3/16 in. The exhaust lap is ⅛ in.

Auxiliary ports are cut in the valve cages, 1¾ in. in advance of each of the main steam ports, and are intended to assist in starting; however, they are in action at all times when the locomotive is moving under steam. The ports are ⅛ in. by 1½ in., with a steam lap of ¼ in., and are located at each end of each cylinder at the bottom of the valve cage or bushing, making four ports in all.

Coal

Over 70 tests were made to develop the performance of the locomotive, and of these tests 39 were fired by hand with run-of-mine coal. In the 1917 tests Jamison coal was used, but on account of the difficulty in getting this coal in 1918, the tests were made with Crows Nest coal. These two coals are from the same region and vein and are alike in many respects. This is further illustrated by the average analyses, given in the following table, which have been made from all of the coal used in the hand-fired tests:

	Jamison coal 1917	Crows Nest coal 1918
Fixed carbon, percentage	56.21	56.80
Volatile combustible, percentage	31.34	29.68
Ash, percentage	11.67	12.26
Moisture, percentage	0.97	1.25
Total	100.19	99.99
Sulphur, percentage	2.15	1.41
B. t. u. per lb. dry	13,429	13,420
B. t. u. per lb. combustible	15,221	15,324

Tests with Hand Firing

Boiler Performance

Pressures and Temperatures.—An average boiler pressure within about four pounds of the rated pressure of 250 lb.

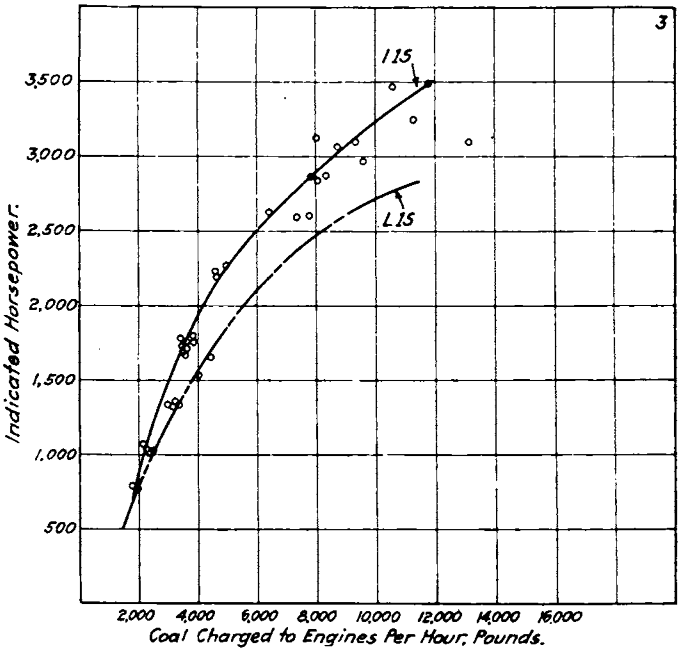

Fig. 3. Coal to Engines and Indicated Horsepower

per square inch, was maintained in all of these tests. The maximum pressure drop, or loss between the boiler and branch pipe was 18 lb., this drop being at a rate of steam flow of 58,000 lb. per hour. The exhaust steam pressure

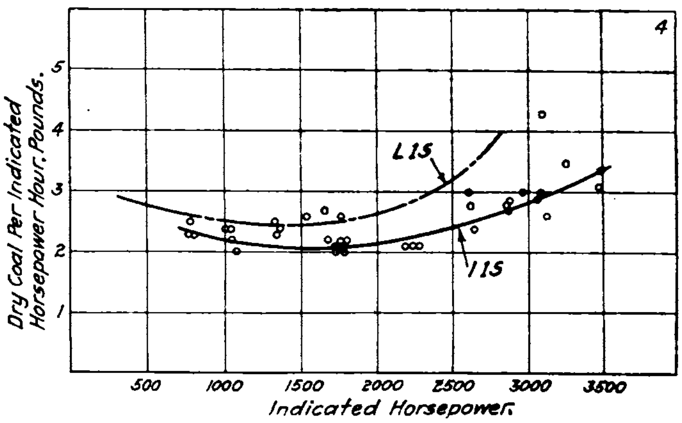

Fig. 4. Indicated Horse Power and Coal (Average for All Cut-offs)

shows a maximum of 16.3 lb. per square inch. Even with a boiler pressure of 250 lb., the maximum superheat temperature was 282.8 deg., which is nearly as high as has been obtained on any locomotive on the test plant, all of which have had a boiler pressure at or below 205 lb.

Combustion, Draft and Temperature.—In general, the draft or vacuum was higher in the Ils than in the Lls at all rates of evaporation. This is to be expected, as the exhaust nozzle area was 35.8 sq. in. for the Ils and 38.3 sq. in. for the Lls. Though not greatly different, the smokebox temperatures are somewhat higher than in tests of the Lls.

The feedwater temperature was between 37.3 and 64.9 deg. The firing was all by hand as the locomotive was not at this time equipped with a stoker. The rate of firing reached 189 lb. an hour per square foot of grate, and at this rate the evaporation per square foot of heating surface was

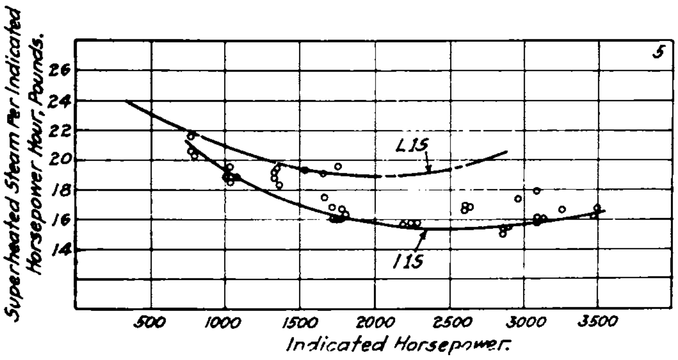

Fig. 5. Indicated Horse Power and Steam (Average for all Cut-offs)

10.3. The maximum rate of firing, in pounds per hour, was 13,226.

Evaporation.—The evaporation of this boiler appears to be less than was obtained from the smaller Lls boiler, but when the higher pressure and superheat of the Ils are considered, the maximum equivalent evaporation of the Ils is considerably above that of the Lls. The equivalent evaporation per pound of coal is illustrated by Fig. 15. The evaporation per pound of coal and the boiler efficiency results are about the same as were obtained in 1917 (see Fig. 1.). The equivalent evaporation per square foot of heating surface for the Ils reached a maximum of 14.7 lb. per hour.

Superheat.—The Ils shows a maximum superheat of about

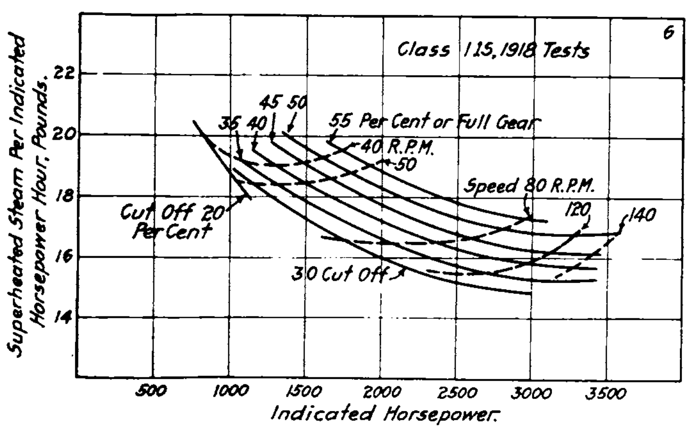

Fig. 6. Water Rates at All Cut-offs, Class I1s

280 deg. and at a rate of firing of 11,000 lb. per hour the superheat is about 15 per cent higher than for the Lls when equipped with a superheater of the same length as in the Ils, or 18 ft. When these two superheater surfaces are compared, that of the Ils is larger by about 20 per cent, on account of the larger number of elements.

The normal saturated steam temperature for the Ils is 406 deg. and for the Lls, with a boiler pressure of 205 lb., it is 389.5 deg. It would appear to be more difficult then to superheat the steam from the Ils boiler on account of its higher initial temperature, but notwithstanding this, a higher maximum superheat was obtained, although it is somewhat lower over part of the range.

The water heating surface of the Ils boiler is 8.8 per cent, the total heating surface 12.0 per cent, and the fire area through the tubes 7 per cent greater than the corresponding parts of the class Lls. For these reasons it was expected that an evaporation somewhat higher than in the case of the Lls class, over 59,000 actual, or 77,000 equivalent pounds per hour, would be possible when using an exhaust nozzle seven inches in diameter, or the same diameter as was used on the Lls.

With a seven-inch diameter exhaust nozzle (1917 tests), an evaporation of about 53,600 actual, or 72,500 equivalent pounds per hour was obtained. This was not considered sufficient, in view of the performance of the class Lls, and many changes were made in the arrangement of the diaphragm in the smokebox and different forms of stack were tried. Finally, by reducing the nozzle diameter to 6¼ in., an evaporation of 59,300 actual, or 81,900 equivalent pounds was obtained.

The tests of the 1918 series, beginning with 5401 and ending with 5416, were made with a seven-inch exhaust nozzle, and it was used again in tests 5431 to 5438. Test 5412 at 80-55-F, evaporating 51,280 lb. per hour, proved to be the limit with this nozzle and smokebox arrangement. It was found, after test 5416, that cinders were accumulating in the front end, and to overcome this the exhaust nozzle was reduced to 6¾ in. and a deflector plate, eight inches wide, put on the edge of the table plate in front of the nozzle. This deflector made the gas passage, at the smallest area, the

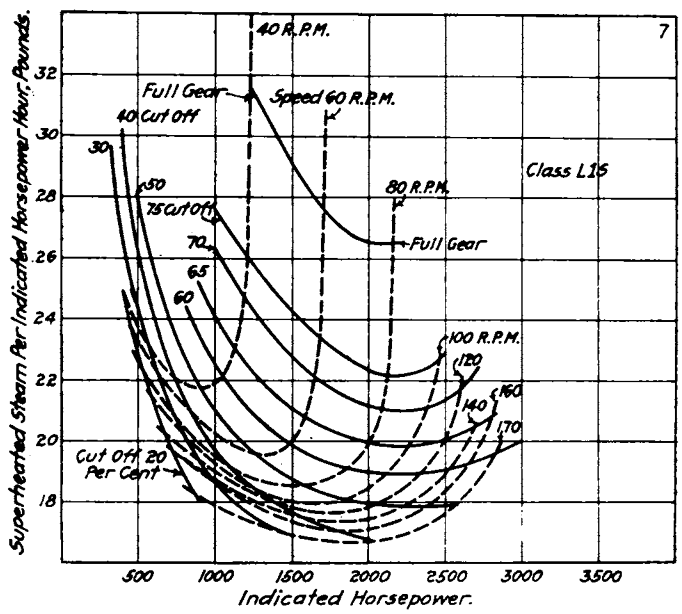

Fig. 7. Water Rates at All Cut-offs, Class L1s

same proportion of the fire area of tubes as on the classes Lls and K4s, where it is 68 per cent.

Arranged in this way, the evaporation, in test 5443 was 58,300 lb., or an increase of about 14 per cent over the evaporation that could be obtained with the seven-inch nozzle without the deflector. When equipped with a stoker in later tests, an evaporation of 60,906 lb. was obtained, showing that the expected evaporation is easily possible with this locomotive.

While in the earlier tests a 6¼-in. exhaust nozzle was used, in the final tests it was found possible to use a 6¾-in. nozzle, but not a 7-in. The boiler conditions had been improved by the changes in the stack and front end, so that the 6¾-in. nozzle gave draft conditions as good and a capacity as high as could be obtained with the 6¼-in. nozzle and the earlier arrangement of the front end.

Engine Performance

The engines of this locomotive, compared with long cut-off locomotives as to economy in coal and steam, have yielded expected results. The tests have shown that the restricting of the cut-off has had the desired effect in that, in full gear, where the bulk of the work is done, this locomotive operates much more economically than the Lls. This advantage, as expected, is reduced as the engines are cut back, but it is not until we have gone below the most economical cut-off for both locomotives that the Lls and Ils show the same economy at a given horsepower. This, moreover, is the case only at the lower horsepower (in short cut-offs at low speeds), that is, for but a small portion of the work done by the locomotive when in normal railroad service.

Indicator Diagrams and Action of Starting Ports.—Representative indicator diagrams are shown in Fig. 2. The principal point of interest in these diagrams is the action of the auxiliary starting port. It opens before the opening of the main port, having a lead of 1 15/16 in. in the tests

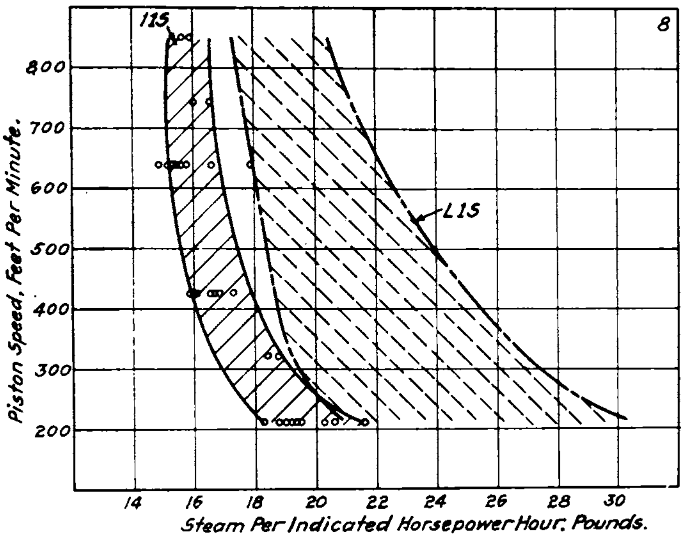

Fig. 8. Piston Speed and Water Rate

here recorded, as against 3/16 in. for the main port and, on the indicator diagrams, the effect caused thereby can scarcely be noticed. Considering the cards for full gear, there is no evidence that the auxiliary ports admit a sufficient amount of steam to hold up the admission line appreciably, after the cut-off of the main port. The testing plant conditions in starting are not the same as on the road, on account of there being little or no resistance to turning the locomotive wheels and no rolling load, in the form of the locomotive itself and the train.

Indicated Horsepower.—The test results in indicated horsepower are plotted on Fig. 3. The range of horsepower was between 766.6 and 3,486.1. The highest power was obtained at a speed of 140 r.p.m, which is equivalent to 25.3 m.p.h.

The superheated steam used per i.h.p. hour was between 14.9 and 21.6 lb. In 12 of the tests the steam used per i.h.p. hour was 16 lb. or less. On 16.6 lb. of steam per i.h.p. hour, an indicated horsepower of about 3,500 was developed.

Many tests show a coal consumption of between two and two and a half pounds per horsepower hour, while the maximum rate, neglecting test No. 5417 as abnormal, was less than three and a half pounds per i.h.p. hour. The curves as drawn for the class Ils, Figs. 4 and 5, show lower results in steam and coal per unit of power than for the class Lls at any power.

The indicated horsepower at 7.4 miles per hour, in full gear, is 1,743.7. With the Lls at the same speed in full gear it is about 1,220. This is an increase in power over the Lls of about 43 per cent. The maximum horsepower was obtained at 25 miles per hour and 45 per cent cut-off; this was 3,486. With the Lls the maximum power at this speed was 2,755, or about 80 per cent of that ot the Ils. The Lls has developed on the test plant 2,954 hp. at a speed of 29 m.p.h.

Steam Rate Curves.—In Figs. 6 and 7 curves are plotted

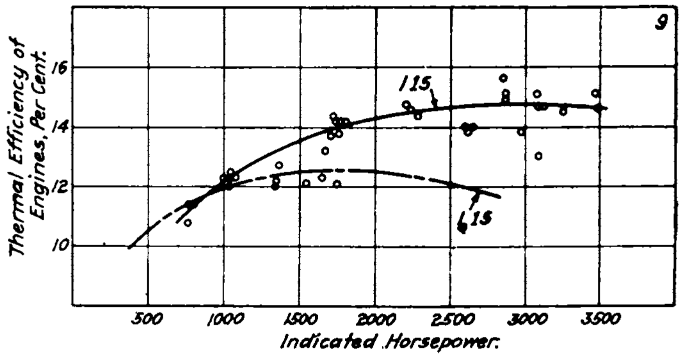

Fig. 9. Indicated Horsepower and Efficiency of Engines

showing the whole range of weight of steam per indicated horsepower hour for the locomotives, classes Ils and Lls. Considering the speed of 40 revolutions per minute or 7 m.p.h., and full gear, it is found from these diagrams that the Ils developed 1,740 i.h.p. and used about 19.5 lb. of steam per horsepower hour, while the Lls developed 1,230 hp. and used 31.5 lb. of steam per horsepower hour. At a speed of 120 r.p.m., 22.1 m.p.h., and at a cut-off of 50 per cent, for the Ils the horsepower is about 3,280, while for

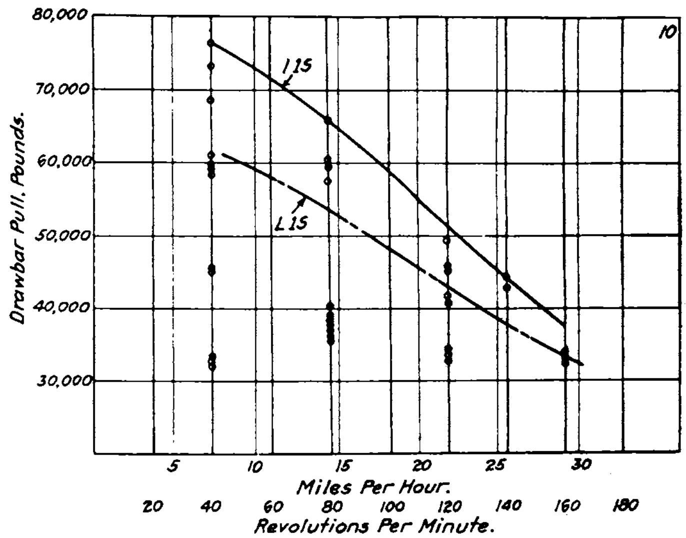

Fig. 10. Drawbar Pull of the I1s and L1s at Various Speeds

the Lls it is about 2,050, and the steam per indicated horsepower for the Ils is 16.8, while for the Lls it is 18.0. In this latter case little or no saving would be expected and the difference may be attributed to difference in quality (pressure and superheat) of the steam. In full gear, at low speed, the reduction in the steam per indicated horsepower by the Ils over the Lls is, as above indicated, approximately 38 per cent.

Piston Speed and Water Rates.—The water rate of the locomotive improves to a certain extent with an increase in piston speed, and this is shown by the plotted results in Fig. 8. The weight of steam per indicated horsepower for the Ils locomotive is in a separate zone from that of the Lls, and less steam is used when the two locomotives are tested under like conditions.

On account of the small exhaust nozzle and higher boiler pressure, the back pressure was in general somewhat greater than for the Lls.

Thermal Efficiency of Engines.—The thermal efficiency of the engines alone, referred to indicated horsepower, calculated according to the method of the A.S.M.E., is shown in Fig. 9. This efficiency is the proportion of the total heat consumed which is converted into work in the cylinders. The heat considered is that in the steam in the branch pipe, above an ideal feedwater temperature which is assumed to be that as observed of the steam in the exhaust pipe. These efficiency results show that there is much improvement in the Ils over the class Lls. The efficiencies of the locomotive are between 10 and 16 per cent, while those of the class Lls are between 10 and 14 per cent.

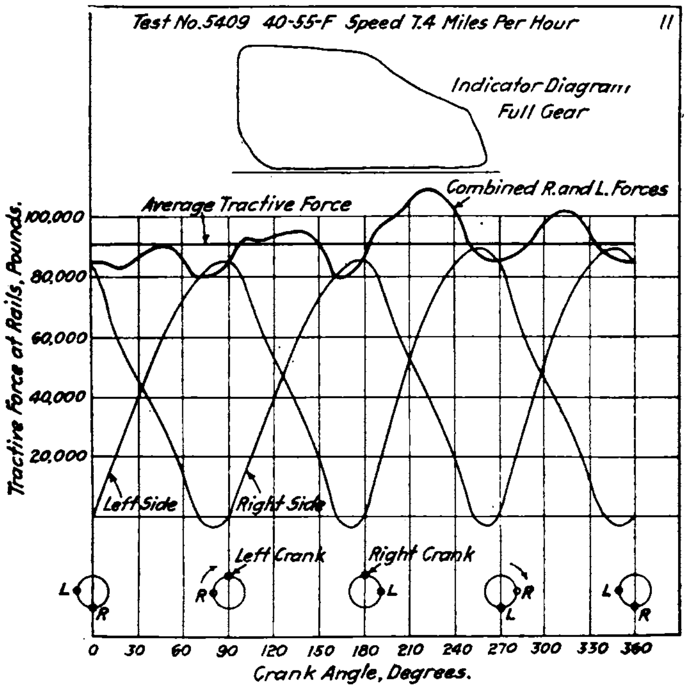

Fig. 11. Tractive Effort Curves, Full Gear, Class Ils

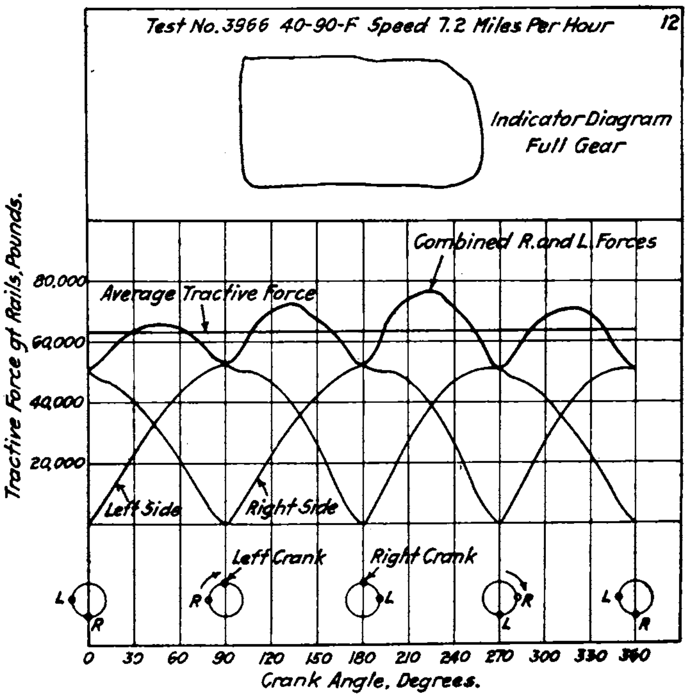

Fig. 12. Tractive Effort Curves, Full Gear, Class Lls

Locomotive Performance

The dynamometer horsepower shows increases and economies closely following those for indicated horsepower. Many tests have a coal rate of 2½ lb. (see Fig. 16) and a steam rate of less than 18 lb. The minimum rate was 16.8 lb. of steam per d.h.p. hour. Both the coal and water rates are below those of the class Lls for all dynamometer horsepowers.

The drawbar pulls obtained upon the testing plant are shown in Fig. 10. To be 25 per cent greater than the pull of the Lls at 40 r.p.m., the Ils should have a pull or about 75,000 lb., and this pull was considerably exceeded. In the tests with 30-in. cylinders at a speed of 40 r.p.m. or 7½ m.p.h., the drawbar pull on the test plant was 68,000 lb., and later on the road about 76,000 lb. With the new 30½-in. cylinders, on the test plant the pull at this speed was 76,000 lb.

Cylinder Tractive Force.—Comparative turning moment or cylinder tractive force curves for the class Ils Decapod type, and the class Lls Mikado type, are shown in Figs. 11 and 12. It will be seen from these diagrams that the turning moment in the case of the class Ils, cutting off at half stroke, forms nearly as smooth a curve as for the class Lls, cutting off at nearly full stroke, and therefore that the advantages of a favorable cut-off are obtained in this locomotive without introducing high peaks in the curve or any unusual tendency toward slipping of the driving wheels.

Machine Friction.—The machine efficiency of this locomotive is plotted in Fig. 13. The highest efficiency is 91.7 per cent. At the lowest speed of the tests, 7.4 m.p.h. in full gear, it was 85.6 per cent. In tests of the class Lls the machine efficiency was in some cases as high as 95 per cent and at 7 m.p.h., in full gear, it was 94 per cent. The thermal efficiency of the locomotive (proportion of total heat consumed converted into work at the drawbar) is shown in Fig. 14. The Ils developed a maximum efficiency of 8.1 per cent, while the highest atained by the Lls was 7.0 per cent.

Tests with Duplex Stoker

Following the hand-fired tests locomotive No. 790 was equipped with a Duplex stoker. It was then returned to the test plant and the tests continued with the stoker in use. The stoker was piped so that its exhaust steam could be turned into the base of the elevator screws to dampen the coal, the claim being made that this will reduce the smoke.

For the remaining tests the stoker was used without any hand firing and the test conditions duplicated as nearly as possible the hand-fired tests. Some of the stoker-fired tests were made to obtain the steam consumption of the locomotive only and were run for too short a time for reliable coal data. These have not been plotted on the diagrams.

The stoker speed at first was found to be too low, not over 40 strokes per minute, and in order to increase the speed changes were made in the steam ports of the stoker cylinder by enlarging and extending them. The exhaust pipe from the stoker engine was also enlarged to two inches. After these changes the stoker could be run at 48 strokes per minute, and it was possible to fire all of the coal that could be burned. The same kind of coal was used for the stoker tests as for the hand-fired tests, namely, Crows Nest run-of-mine.

The exhaust steam from the stoker cylinder was led to a condenser and the condensed steam weighed in the first nine tests. From these records it was found that about ¼ lb. of steam was used per double stroke or revolution of the stoker, and for the remaining tests the stoker exhausted to the atmosphere and the steam used was calculated. The steam used by the stoker steam jets could not be measured directly and was calculated by the Grashof formula.

Coal.—The average analyses of the Crows Nest coal used for the hand-fired and stoker tests, are shown in the following table and indicate a very small difference.

	Hand fired	Stoker fired
Fixed carbon, percentage	56.80	58.68
Volatile combustible, percentage	29.68	29.92
Ash, percentage	12.26	10.18
Moisture, percentage	1.25	1.23
Total	99.99	100.01
Sulphur, percentage	1.41	1.54
B.t.u. per lb. dry	13,420	14,130
B.t.u. per lb. combustible	15,324	15,662

Results of Tests.—The results of the stoker-fired tests are plotted in Figs. 15 and 16, and on these diagrams the hand-fired test results, made immediately before the application of the stoker, are shown for comparison.

Maximum Capacity with Stoker.—It is evident from the tests that the evaporation and rates of firing are but little more than can be obtained by hand firing, so that the capacity of the locomotive was not increased by the stoker, but of course the maximum evaporation is obtained with much less exertion on the part of the fireman, and also it is evident that the maximum evaporation can be sustained for a longer time with the stoker.

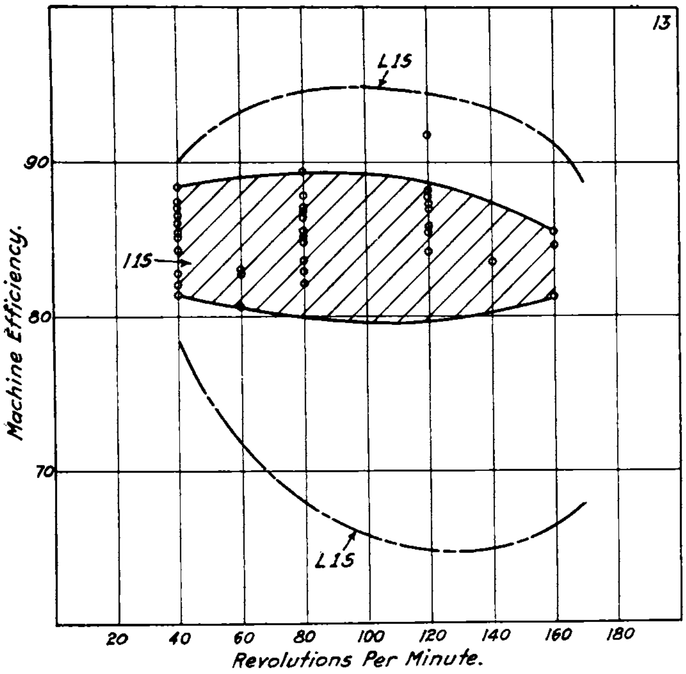

Fig. 13. Machine Efficiency

It was found that the boiler could not be forced much beyond an evaporation of 60,000 lb. per hour, indicating this to be the boiler limit for both hand and stoker firing.

Coal Economy with Stoker.—A further analysis of the stoker test results shows that hand firing is superior in evaporation per pound of coal at low rates of firing, but that this advantage decreases until, when the boiler is evaporating its maximum weight of water the stoker firing is no less economical than the expert hand firing. The advantage shown for hand firing is about 19 per cent when firing 40 lb. of coal per square foot of grate per hour, and decreases to nothing when firing 180 lb. per square foot. (See Fig. 15.) There is practically no difference in the superheat of the steam with or without the stoker. The range of the superheat is between 130 and 285 deg.

Stoker Exhaust to Conveyor.—The stoker engine ordinarily exhausts to the atmosphere, but there is also a pipe connection to the base of the elevator screws, and when this was used the coal was dampened by the exhaust steam. With this connection in use in test No. 5470 there was a marked reduction in the smoke and also a smaller coal consumption, but as there was only one test made under these conditions no very definite conclusions can be drawn, although the indications are that there is some advantage to be gained by its use. The results obtained with it, compared with both hand and stoker-fired tests without it, are shown in the following table:

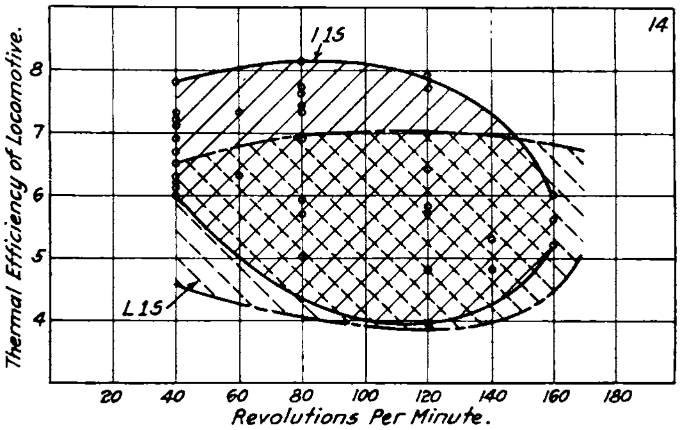

Fig. 14. Thermal Efficiency of the Locomotive

Stoker-Fired Tests

Test No.	Test designation	Coal fired, lb. per hour	Equivalent evaporation per lb. dry coal	Smoke percentage	Exhaust of stoker engine to—
5,470	120-30-F	5,505	9.1	15.6	Conveyor
5,447	120-30-F	5,783	8.7	27.0	Atmosphere
5,449	120-30-F	6,019	8.3	22.8	Atmosphere
5,456	120-30-F	6,304	7.8	32.4	Atmosphere
Hand-Fired Tests					
5,432	120-30-F	4,641	10.3	7.2	......
5,428	120-30-F	4,720	9.8	8.2	......
5,441	120-30-F	4,943	9.7	18.8	......

Steam Used by Stoker.—The estimated weight of steam used by the stoker ranged between 393 and 1,629 lb. per hour, and was about two per cent of the steam generated by the boiler. There was more hooking or leveling of the fire in hand firing than when the stoker was used. This would indicate that the stoker maintained a more nearly level fire than could be obtained by hand firing. The number of times the grates were shaken was practically the same for either hand or stoker firing.

Conclusions

With this boiler, carrying a steam pressure of 250 lb. per sq. in., no difficulty was found in superheating the steam to a high temperature. The water and superheating surfaces are larger than those of the class L1s locomotive and a greater equivalent evaporation was obtained.

The engines of this locomotive compared with long cut-off locomotives as to economy in coal and steam, have met expectations. The tests have shown that the restricting of the cut-off has had the desired effect in that, in full gear, where the bulk of the work is done, this locomotive operates much more economically than the L1s. This advantage, as expected, is reduced as the engines are cut back, but it is not until below the most economical cut-off for both locomotives that the two classes of locomotives show the same economy.

In the results of the tests which show power and steam used, the action of the stoker need not be considered, and it was found in many tests that the steam rate per i.h.p. hour was

16 lb. or less. At a rate of only 16.8 lb. of steam per hour an indicated horsepower of over 3,500 was developed. The saving in steam per indicated horsepower over the Lls is very evident and, except at low horsepower at low speed, it is not possible to operate the Lls at as good advantage as the Ils, and in full gear at low speed, the reduction in steam per indicated horsepower, over the Lls is 38 per cent.

The maximum evaporation was obtained with the stoker with very little exertion on the part of the fireman. The stoker fired a fairly level fire, and could be operated under

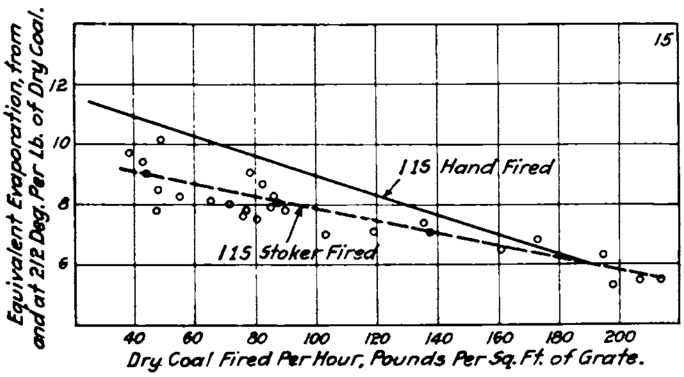

Fig. 15. Evaporation per Pound of Coal, Hand and Stoker Firing

all conditions in a satisfactory manner without any hand firing.

Except at the highest rates of firing, the stoker is wasteful in the use of coal, but appears to be no more wasteful than other stokers, and in addition has advantages over the other stokers tested, in ease of operation and in the absence of obstructions at the fire door and on the grates.

The estimated weight of steam used by the stoker was about two per cent of the steam generated by the boiler. The advantage shown for hand firing over the stoker firing in

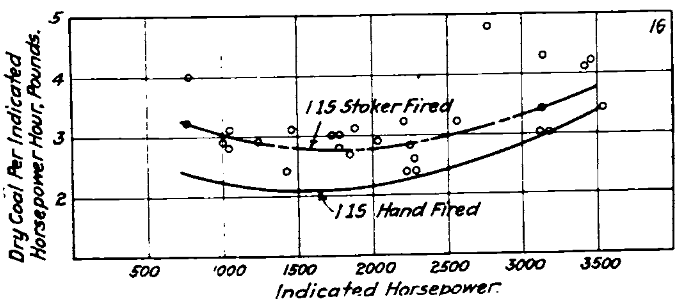

Fig. 16. Indicated Horsepower and Coal, Hand and Stoker Firing

equivalent evaporation per pound of coal is about 19 per cent when firing 40 lb. of coal per square foot of grate per hour, and decreases to nothing when firing 180 lb. per sq. ft.

With the stoker it is to be supposed that a greater number of firemen could obtain the full capacity of the locomotive than would be the case with hand firing, because of the ease of handling the stoker. Such considerations, combined with those of economy or capacity as shown by tests, in the case of locomotives of this class, must govern in deciding whether a stoker is necessary.

Labor's Share of Railroad Earnings.—Statistics of earnings and expenses of the railways in 1919 show that of the average earnings of a month of 30 days, labor received in wages the earnings of 17½ days of each month, fuel required the earnings of three days, material and supplies five days, taxes, etc., one and one half days, leaving the earnings of three days for net operating income.

ANATOLE MALLET

Anatole Mallet, the inventor of the compound locomotive which bears his name, died in Nice, France, in October, 1919. Mr. Mallet was born in 1837 at Carouge and was graduated in 1858 from the Central School of Arts and Manufactures in Paris. He was engaged in civil engineering work for several years, first with the Bureau of Direction of the General Company of Railroad Materials in France and later on the Suez Canal. In 1864 he was engineer for a company which undertook dredging operations in Italy. His first work in mechanical engineering was done in 1867, when he devoted his attention to double expansion steam engines. The first application of this system was made in 1876 on a two-cylinder compound which operated on the line from Bayonne to Biarritz. This design effected a saving of 20 per cent in fuel over the standard types and placed the inventor in the foremost ranks of locomotive designers.

The great success of the compound locomotive led to a material increase in the size of the units and to the development of three and four-cylinder compound locomotives. It became evident that the limit of size of locomotives of rigid construction, especially on lines with sharp curves, would soon be reached. In order to permit of the use of large motive power units on lines with sharp curves and light track, Mr. Mallet designed the articulated type of locomotive which was first introduced in this country on the Baltimore & Ohio and has since been adapted to use on American roads with such great success.

Among the honors conferred upon Mr. Mallet were the Schneider prize, awarded to him by the French Society of Civil Engineers in 1902, and the annual prizes of the society in 1909 and 1911. He was made a Knight of the Legion of Honor in 1885 and promoted to officer in 1905. The Institute of Mechanical Engineers of London awarded him a gold medal in 1915. He was a member of the Society of Civil Engineers of France, the Society for the Encouragement of National Industry of France, and the Franklin Institute of Philadelphia.

In addition to carrying on his engineering work, Mr. Mallet took active part in the work of the French Society of Civil Engineers from 1880 to within a few months of his death. He was editor of the Chronicle of the Bulletin of the Society, for which he wrote numerous technical notes and important memoirs. The last of these, treating of the practical evolution of the steam engine, earned for him the honors conferred by the society.

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Cars with Cans of Milk Remaining Undelivered Because of the French Railway Strike