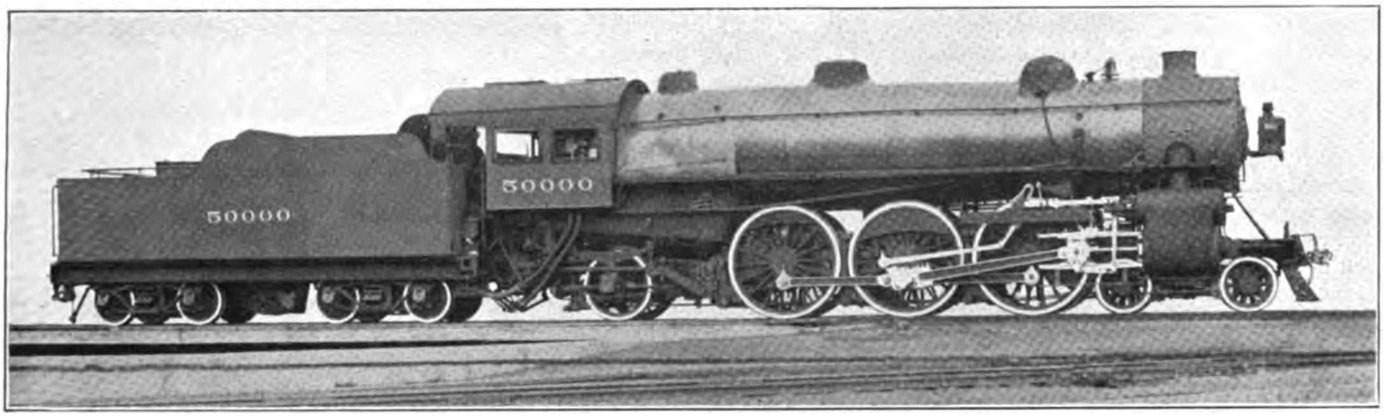


Experimental Pacific Type No. 50000, Which Established New Records for Power per Unit of Weight

Avoidable Waste in Locomotive Operation as Affected by Design*

BY JAMES PARTINGTON

Estimating Engineer, American Locomotive Company

IT SEEMS advisable to consider this subject from the constructive standpoint of indicating what constitutes good design as demonstrated by locomotives in actual service, rather than to attempt to point out the defects in locomotives which do not show maximum efficiency. If any power plant or engine is not properly proportioned for the work it has to do, the most expert skill in operation can reduce only in part the waste resulting from having such equipment in service.

First, considering the design of steam locomotives from the standpoint of new equipment, when a railroad company is in the market for new locomotives its requirements may be met sometimes by duplicating locomotives in service on their road, but adding newly developed attachments which make for increased efficiency and economy. More frequently, however, it will be found that increased traffic, change from wooden to steel cars, improvement in track, roadbed and bridges, etc., will justify and make advisable the adoption of locomotives of a larger and more powerful type.

Then careful consideration must be given to service requirements—maximum loads to be hauled, capacity of cars, approximate proportion of loaded to empty cars per train, grades, curves, running time over divisions, maximum allowable load per axle, location of coal chutes and water tanks, clearances, conditions under which trains must be started, and any other special requirements of the service.

Having determined the drawbar pull necessary, it remains to design a locomotive that will have the following efficiency requirements:

1 A drawbar horsepower for the minimum amount of fuel.
2 A drawbar horsepower for the minimum amount of weight of locomotive and tender.
3 A drawbar horsepower for the minimum cost of repairs.

Fuel Economy

As standard practice in modern locomotives, a sectional brick arch in the firebox and a fire-tube superheater should be applied as a means of saving fuel in any class of service. A sectional brick arch is low in first cost, easily applied and easily renewed. It usually accomplishes a fuel saving of from 10 to 12 per cent in coal-burning engines, and about 5 per cent in oil-burning engines.

The very general use of superheaters has gradually brought about improved conditions of cylinder lubrication which now make it possible and desirable for the greatest economy to use a high degree of superheat, 250 to 300 deg. F. now being considered the best practice. A saving of 25 to 30 per cent can be obtained.

The use of feedwater heaters will further conserve fuel, and these are now in general use in continental Europe and are gradually being applied to locomotives in the United States. The saving that can be realized is as much as 12 per cent. The initial cost is considerable, but the effect of the feedwater heater in operation, aside from fuel economy, will be to help reduce other boiler-maintenance charges.

The general proportions of the boiler should also receive careful consideration. For the best results with bituminous coal, the length of the boiler tubes should be approximately within the following limits:

Size of tube, in.	Distance over tube sheet
2	18 ft. 0 in. to 19 ft. 6 in.
2¼	22 ft. 6 in. to 24 ft. 6 in.
2½	28 ft. 0 in. to 30 ft. 0 in.

For many designs of locomotives, a combustion chamber can be provided, and this will help further in the economical production of steam. A generous steam space should be provided, and the throttle designed and located to secure dry steam. The evaporative capacity of the boiler should be as nearly 100 per cent of the maximum steam requirements of the cylinders as the type of locomotive will permit. Based on 100-per cent boiler, the grate area should be sufficient to prevent the maximum coal consumption per sq. ft. of grate per hour from exceeding, for bituminous coal, 120 lb., and for anthracite coal, 55 to 70 lb., depending on size.

When the total coal consumption exceeds 6000 lb. per hr., it is generally necessary to apply an automatic stoker. These have now been so adapted to locomotive requirements that a properly designed stoker will show economy over hand firing, aside from the necessity of its use on account of the coal consumption being greater than the physical capacity of one fireman if the boiler were hand-fired.

The arrangement of deflector plates and netting in the

*A paper to be presented at the meeting of the Railroad Division of the American Society of Mechanical Engineers, New York, December 9.

smoke-box should be carefully adapted to the fuel and combustion conditions, to provide minimum fuel waste and minimum back pressure in the cylinder-exhaust passages with proper provision against fire hazards which might obtain by the throwing of sparks.

The boiler being designed to produce steam at a minimum cost, it is now necessary to design the engine to use this steam with maximum economy.

The cylinder proportions and diameter of the drivers should be such as will develop maximum horsepower at the ruling speeds for train movements. The greatest horsepower of locomotive cylinders will usually be developed within a piston speed ranging from 700 to 1000 ft. per min. Therefore, if other traffic conditions will permit, the operation of trains within these limits should show the greatest operating economy.

Minimum Weight of Motive-Power Equipment

The weight on the locomotive drivers gives an engine friction, independent of other factors, of 22 lb. per ton. The desirability of avoiding excess weight on the drivers from this standpoint alone is therefore readily apparent. When the type of engine will permit, this weight should not exceed what is necessary to give a satisfactory factor of adhesion; this is usually 4¼ times the maximum tractive power. All weight in excess of this and all other excess weight and excess tender weight should be eliminated, as far as this can be done without detriment to the design of engine and tender. This applies with particular force to the machinery parts of the engine, especially those parts which affect the counterbalance. All saving in weight in these parts usually produces a similar saving in counterbalance weights and a reduction in the dynamic augment, which is very desirable from the standpoint of track and roadbed maintenance.

The use of special materials to keep down weight is often amply justified if repair parts can be obtained promptly when required. This, in the past, has often been the cause of delay, but it can be guarded against by carrying a few spare parts in stock ready for renewals. High-tensile alloy steel can frequently be used to advantage for driving axles, crank pins, main and side rods, piston rods, etc.

Occasional steep grades or hard starting conditions at stations may cut down the hauling capacity of locomotives over a division to a serious extent. In such cases, the utilization of the weight on trailer trucks for additional tractive power in starting and at slow speeds may increase the capacity of the locomotive from 10 to 25 per cent, depending on the number of driving wheels and working pressure. It has been demonstrated that a separate steam engine or booster geared to the trailing axle will give this additional traction, and that it can be cut in or cut out very satisfactorily as occasion may require.

This is an item in economical operation worthy of consideration where hauling capacity is restricted by such limitations, and the use of an independent booster may often permit the satisfactory operation of considerably lighter locomotives for service of this character.

Within the limits of this paper, only the major features of design can be outlined briefly, and only such devices as have been carefully tried out and are in successful operation are cited. The writer believes the savings mentioned are well within what may be obtained in practice.

Many other improvements promising further economy in the generation and use of power in the steam locomotive are contemplated and are now in the experimental stage, but these do not properly come under the scope of our subject as here treated.

Cost of Repairs

It has been pointed out that locomotives and tenders should be designed to produce the required drawbar horsepower with as little excess weight as possible. In this connection, however, due consideration must be given to the question of repairs.

The design of boilers from the standpoint of weight is practically fixed by existing boiler regulations, which provide that locomotive boilers must be operated with a factor of safety of not less than four. Practically all boilers at the present time are designed with a factor of safety of 4½, which leaves a comfortable margin between this and the minimum allowable operating factor.

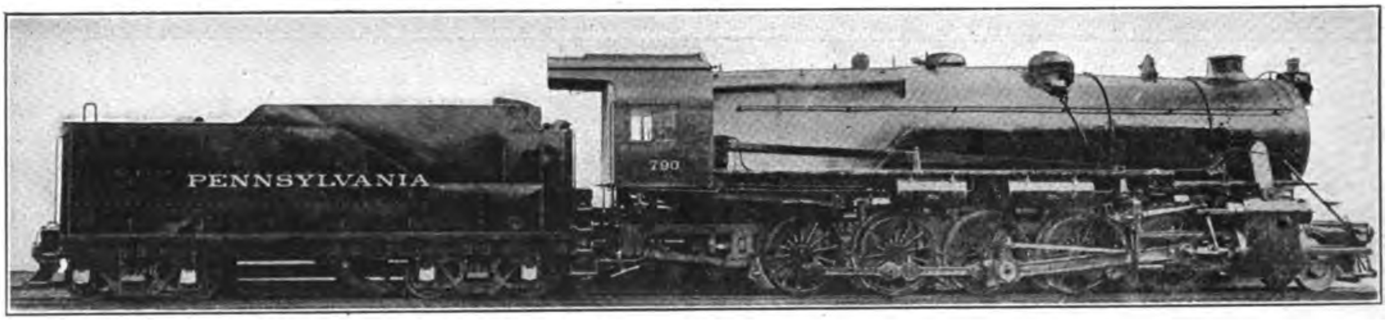
The maximum stresses in other parts of the locomotive must also be carefully considered, and the parts must be designed to keep these stresses within limits which will eliminate costly failures in service.

Aside from the consideration of stresses, much repair cost can be avoided by adopting designs which reduce the number of parts, as far as reasonably may be, especially where these parts must have bolted connections. Here, however, care must be taken to avoid construction which cannot readily be removed for repairs or renewals or repaired in place with reasonable facility.

Many roads today are giving a great deal of thought to locomotive design along these lines, having especially in mind the desirability of making the engine parts accessible for oiling and inspection; easily removable with proper shop facilities; of the minimum number of pieces and interchangeable with equipment now in service.

The repair-shop facilities must, of course, be kept abreast of the requirements; *i.e.*, as new and larger locomotives are put in service, turntables, cranes, machine tools, etc. must be of sufficient capacity to handle the larger equipment economically.

The repairs of locomotives can often be facilitated and the necessary shop equipment kept down to the minimum by securing from the locomotive builder many parts which he is able to turn out more accurately and more economically than the average railroad shop would be equipped to do. Such parts include: flanged sheets for boiler repairs; flexible and ordinary staybolts; finished bolts and nuts; drop forgings; packing rings for pistons and piston valves and



Pennsylvania Decapod With Short Maximum Cut-Off, Which Shows Remarkable Economy Over a Wide Range special equipment which requires special tools for its production.

Without attempting to pursue further the design of new locomotives it may be remarked that a study of the special conditions of individual railroads is necessary to secure equipment best suited to the needs of each.

Old Motive-Power Equipment

Much waste in locomotive operation can be avoided by making a careful survey of present motive-power equipment which is not giving as economical or efficient service as could be obtained if the engines were modernized. This applies particularly to locomotives where the service conditions demand more power than the present equipment can economically produce. All the suggestions made in regard to the design of new equipment are applicable to a greater or less degree to old equipment, providing the old equipment is not meeting the demands of the service from a power standpoint, or is not furnishing this power economically.

In making a survey of this character care should be taken to determine accurately whether the old equipment will warrant the additional cost of changes and betterments necessary to convert it into up-to-date power. This can be decided by taking the number of years the engines will be retained in service and the increased net return or saving for this period as against the cost involved for changes, interest on the additional investment, increased maintenance, etc.

A comparison should also be made with the results that could be realized by the purchase of new equipment best adapted for the service, as against the cost of contemplated changes in the old equipment. If these comparisons show a saving in favor of modernizing the old equipment or the purchase of new equipment, every month that the engines are kept in service without doing this will result in a loss that is not recoverable.

A few concrete examples of what has been accomplished in service by locomotives designed to yield maximum efficiency may be of advantage. Notable designs, for which data is available, are as follows:

Pacific type passenger locomotive No. 50000 built by the American Locomotive Company; Decapod type freight locomotive, Class I1s, built by the Pennsylvania Railroad and heavy Mallet special service locomotive built for the Virginian by the American Locomotive Company.

American Locomotive Company Engine No. 50000

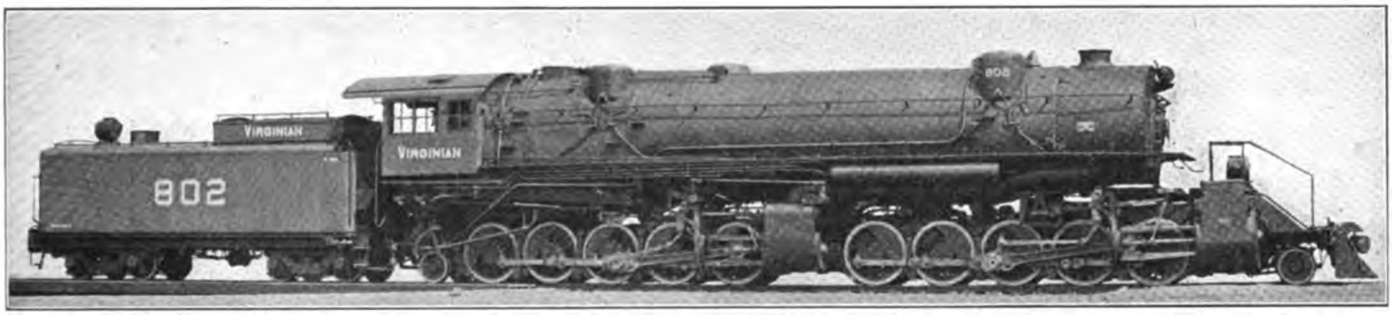
Locomotive 50000 was built by the American Locomotive Company in 1910. It was designed and constructed at the builder's expense to demonstrate the maximum tractive power with adequate boiler capacity that could be obtained while keeping the adhesive weight below 60,000 lb. per driving axle.

Untrammeled by any outside specifications or the necessity of conforming to any railroad's existing standards, the builders had a free hand to embody in this design their ideas of the best engineering practice. To accomplish the purpose of the design—the maximum capacity per pound of weight—the largest boiler capacity within the predetermined wheel loads was the essential feature.

This end was obtained by eliminating every pound of weight in all the parts that was not necessary to strength and durability, utilizing the weight thus saved to provide a larger boiler, and by increasing the capacity of the boiler thus secured by combining in one design the most approved fuel saving devices to obtain the utmost economy in boiler and cylinder performance.

Many of the large Pacific type locomotives with drivers 75 in. in diameter and over in operation today greatly exceed locomotive 50000 in total weight.

An average of all of the important engines of this type including locomotive 50000 shows approximately 1,000 lb. less tractive power with an increase of 17,400 lb. in weight with the very slight advantage of only 1½ per cent in boiler capacity. (See table appended).



Virginian 2-10-10-2 Type, the Most Powerful Locomotive in the World

Locomotive 50000 delivers one cylinder horse power for every 110.8 lb. of weight and one boiler horse power for every 120.3 lb. of weight.

In actual tests it developed:

An average rate of 2.21 lb. of coal per i.h.p. hour.

A low rate on one test of 2.12 lb. of coal per i.h.p. hour.

An average rate of 16.85 lb. of steam per i.h.p. hour.

A low rate on one test of 16.5 lb. of steam per i.h.p. hour.

A maximum indicated horse power of 2,216 or one horse power for every 121.4 lb. of weight.

The thought occurred that possibly 50000 was built too light and that later on, in order to keep the engine in service, many of the parts might require strengthening.

Locomotive 50000 was purchased by the Erie Railroad and numbered 2509. Wm. Schlafge, Mechanical Manager of the Erie, states that since the locomotive was received it has been necessary to make very few changes. The guide yoke was reinforced on account of working. Guide yoke blocks were also made solid on the guide yokes. The trailer spring sliding block was changed to the same type as used on the railroad's K-4 Pacific type locomotives. No other changes or alterations have been made. Yet from the time this locomotive was placed in service on the Erie up to March 1, 1920, it had made a total mileage of 351,800.

Ten years of service coupled with 350,000 miles of running demonstrate the strength of the design and the figures given indicate remarkable performance.

Pennsylvania Railroad Class I 1s

While the design of engine 50000 represents the best practice of the present day as measured by the economical operation of passenger locomotives, the development of heavy freight power involves the consideration of other factors that materially affect the design. In 1915 the Pennsylvania Railroad found that for the economical operation of their line a tractive power about 25 per cent in excess of the Mikados then in use was desirable. In working on the design for such an engine, an attempt was made to obtain better economy in performance by a radical departure in cylinder proportions. The accepted practice in proportioning cylinders is to arrange for a cut off of nearly 90 per cent of the stroke, so that the starting torque may be as uniform as possible.

As the adhesive weight limits the cylinder diameter if excessive slipping is to be avoided, it is obvious that on long grades, where the maximum tractive effort is required, the long cut offs use steam in a most uneconomical manner. As the Pennsylvania has several such long grades on its line, the new design adopted involved a limitation of the cut off to about 50 per cent in place of 90 per cent and an increase in the cylinder diameter to give sufficient torque at this cut off to fully utilize the adhesive weight. The expected increase in economy of coal and water due to the shorter cut off has been fully realized. Not only has the engine shown remarkable efficiency, but the economy under wide ranges of load is especially remarkable.

We are fortunate in having available a very complete test of this engine, made on the testing plant at Altoona. (Bulletin 31, P. R. R. Testing Plant 1919, copyrighted). This test shows a water rate of 15.4 lb. per i.h.p. hour with a total i.h.p. of 3,080 at 40 per cent cut off and a coal consumption 2.9 lb. The lowest coal consumption recorded is 2.00 lb. per i.h.p. hour, obtained at an output of 1,777 i.h.p. and a cut off of 30 per cent.

The thermal efficiency of the locomotive is also high and well sustained over a large range, a maximum of 8.1 per cent being attained at an output of 1,777 i.h.p., and the range being from 6.1 per cent at 776 i.h.p. to 5.3 per cent at 3,486 i.h.p. with an average of over 7 per cent for the usual operating conditions.

The highest drawbar pull recorded in these tests is 76,211 lb. at a speed of 7.4 m.p.h., but in road service a pull of 80,640 lb. has been recorded at 7.2 m.p.h. The indicated tractive effort plotted from a card taken at 7.4 miles per hour at 55 per cent cut off is slightly over 90,000 lb.

This design gives a calculated figure of 88.9 lb. per cylinder horse power, the lowest on record. During the tests an indicated horse power of 3,486 was developed, giving a weight of 106.2 lb. per horse power. The weight per boiler horse power does not compare as favorably, however, as it is 145.4 lb. The Belpaire firebox contributes materially to this excess.

Virginian 2-10-10-2 Type Locomotives

The large 2-10-10-2 Mallet engines for the Virginian were designed to meet their unique conditions. This road was built as an outlet to certain bituminous coal fields of West Virginia. Practically the entire revenue business is confined to hauling coal to the shipping docks at Sewall's Point, the west-bound revenue freight being negligible in amount, as only one town of any importance, Roanoke, is located on the line. As the development of the coal fields proceeded the tonnage to be handled increased rapidly, rising from 2,141,009 in 1911 to 7,621,555 in 1920, and in order to handle the business at a profit the maximum attainable capacity in motive power was demanded. Having fixed on 100 cars as the maximum number that could safely be handled in a single train, the car capacity increased to 120 tons, it was estimated that a locomotive of 147,000 lb. tractive power would be needed to haul the train from Princeton to tidewater, a helper being used for a grade of .6 per cent ten miles long over the Alleghenies. The 2-10-10-2 Mallets were designed to meet these conditions and their operation has been very successful. They have handled trains of 16,000 tons on a .2 per cent grade with the lowest consumption of coal per ton mile ever recorded. Unfortunately, accurate tests of coal and water per dynamometer horse power are not available owing to the fact that there is no dynamometer of adequate capacity to be had at present. However, on May

LARGE PACIFIC TYPE LOCOMOTIVES NOW IN OPERATION IN THE UNITED STATES

													Average
Engine	50,000												
Cylinders	27 in. by 28 in.	27 in. by 28 in.	25 in. by 28 in.	25 in. by 30 in.	27 in. by 28 in.	26 in. by 28 in.	26 in. by 28 in.	23½ in. by 26 in.	26 in. by 28 in.	25 in. by 28 in.	25 in. by 28 in.	25 in. by 28 in.	25.6 in. by 28 in.
Drivers—dia.	79	80	79	75	77	79	75	79	75	77	80	75	77.5
Boiler—dia.	76⅜	78½	76⅜	79⅞	75 1/16	78	78 9/16	70⅝	76	74	72	69	....
Pressure	185	205	210	200	185	210	200	200	190	200	200	185	197.5
Firebox, length....	114⅛	126	126	111⅛	114 1/16	126¼	114⅝	108⅛	110	120⅝	126¼	108⅛	....
Firebox, width.....	75¼	99	108¼	84⅜	84	108¾	84¼	75¼	72	84	108¼	70¼	....
Tube, length	22-0	19-0	17-3	18-6	22-0	19-0	20-6	21-6	20-0	22-0	19-0	20-0	....
Wheel base driving.	14-0	13-10	14-0	13-2	14-0	13-10	13-0	14-0	13-0	13-4	13-10	13-6	....
Wheel base engine.	35-7	36-6	36-0	34-9	36-2	35-8	34-11	36-6	34-4	35-8	35-7	34-9	....
Weight on drivers..	172,500	201,800	192,500	181,500	178,000	181,400	194,000	184,500	169,500	165,000	176,900	168,500	180,500
Weight of engine..	269,000	308,900	302,000	299,000	295,000	291,400	287,000	282,000	280,000	279,500	273,600	269,000	286,400
Heat. surf. tubes and flues	3,808	3,746.8	2,830	3,232	3,534.7	3,454	3,939	3,193	3,386	3,720.9	2,644	2,970	....
Heat. surf. firebox.	248	288.6	351	297.6	239.8	303	259.6	231	240	266.4	282	230	....
Heat. surf. total...	4,056	4,035.4	3,181	3,529.6	3,774.5	3,757	4,198.6	3,424	3,620	3,987.3	2,926	3,200	3,640.8
Superheating surface	897	1,154	645	803	962	816	970	838	830	783.5	652	778	....
Grate area	59.8	70.0	95.0	65.0	66.5	94.8	67	56.5	55	70.4	94.5	52.7	{61.6* / 70.6
Tractive power.....	40,600	41,845	39,500	42,600	41,700	42,770	42,900	30,900	40,700	38,600	37,200	36,700	39,670
Cyl. h.p.	2,427	2,690	2,365	2,252	2,427	2,556	2,434	1,990	2,312	2,252	2,252	2,083	2,336
Boiler h.p.	2,235	2,467	2,244	2,282	2,104	2,311	2,398	1,958	2,112	2,267	1,950	1,869	2,186
Weight per cyl. h.p.	110.8	114.8	127.7	132.8	121.5	114.0	117.9	141.7	121.1	124.1	121.5	129.1	122.8
Weight per boiler h.p.	120.3	125.2	134.6	131.4	140.2	126.1	119.7	144.0	132.6	123.3	140.3	143.9	131.8
Boiler percentage..	92.0	91.7	95.0	101.0	86.7	90.5	98.5	98.2	91.5	109.5	86.8	90.0	93.5

***Is an average of the soft coal burning engine only. The figure 70.6 is the average for all the engines, including the hard coal burners.**

25, a train of 15,725 tons behind the tender was hauled from Princeton to Roanoke at a rate of 26.9 lb. of coal per 1,000 ton miles, and on May 27 a 75 car train of 12,070 tons showed the same figure for coal per thousand ton miles.

One of these engines has hauled a train of 110 cars weighing 17,250 tons from Victoria to Sewall's Point, which is believed to be the heaviest train ever handled by one engine. The ruling adverse grade was .2 per cent.

The principal dimensions of the three locomotives cited and a comparison of the horse power characteristics—calculated by the American Locomotive Company's method—are embodied in the following table:

MODERN MAXIMUM EFFICIENCY LOCOMOTIVES

	No. 50000		
Road	Erie	Virginian	Pennsylvania
Type	4-6-2	2-10-10-2	2-10-0
Fuel	Bituminous coal	Bituminous coal	Bituminous coal
Boiler, type	Conical connection	Extended wagon top	Conical connection
Boiler, diameter	76¼ in.-87 in.	105½-118½ in.	87-90½ in.
Weight on drivers, lb.	172,500	617,000	342,050
Weight on truck, lb.	49,000	32,000	29,750
Weight on trailer, lb.	47,000	35,000	....
Weight, total, lb.	269,000	684,000	371,800
Driving wheel diam.	79 in.	56 in.	62 in.
Cylinders	27 in. by 28 in.	30 in. and 48 in. by 32 in.	30½ in. by 32 in.
Boiler pressure, lb. per sq. in.	185	215	250
Tractive power, lb.	40,600	147,200	90,000
Factor of adhesion	4.25	4.08	3.80
Cylinder horse power	2,427	5,040	4,182
Grate, length and width	114 in. by 75¼ in.	144 in. by 108¼ in.	126 in. by 80 in.
Grate area, sq. ft.	59.7	108.7	70.01
Tubes, number	207	381	244
Tubes, length	22 ft. 0 in.	25 ft. 0 in.	19 ft. 1 in.
Tubes, spacing	¾ in.	⅞ in.	⅝ in.
Tubes, thickness	No. 11 B. W. G.	No. 11 B. W. G.	.125
Tubes, diameter	2¼ in.	2¼ in.	2¼ in.
Flues, number	36	70	48
Flues, diameter	5½ in.	5½ in.	5½ in.
Flues, thickness	3/16 in.	No. 9 B.W.G.	.18
Combustion chamber—length	None	36 in.	42 in.
Brick arch	Security	Gaines	Security
Heating surface—firebox, sq. ft.	248	532	290
Heating surface tubes—water side, sq. ft.	2,672	5,592	2,731
Heating surface flues—water side, sq. ft.	1,136	2,511	1,313
Heating surface total, sq. ft.	4,056	8,635	4,334
Boiler horse power	2,250	4,800	2,553
Steam rate, lb. per hp. hour	20.8	19.7	20.8
Coal rate, lb. per hp. hour	3.25	3.1	3.25
Superheater, number of units	36	70	42
Superheater, diameter	1½ in.	1½ in.	1½ in.
Superheater, heating surface	879	2,120	1,418
Tender weight in running order, lb.	161,500	214,300	182,000
Tender capacity coal, tons	14	12	17½
Tender capacity water, gallons	8,000	13,000	9,000
Weight of locomotive in lb. per cylinder hp.	110.6	135.7	88.9
Weight of locomotive in lb. per boiler hp.	119.6	142.5	145.4
Best actual performance—			
Steam rate—lb. per hp. hour	16.5	....	15.4
Coal rate—lb. per hp. hour	2.12	....	2.0

Drop Pits at Terminals on the South African Railways

BY JOHN D. ROGERS*

The question of drop pit facilities should receive the most careful consideration of American railway motive power officers who at this time are striving to reduce costs of operation and increase the earning capacity of locomotives. The practice of jacking engines for replacing wheels is as obsolete as the tallow candle, yet it still prevails at many terminals. Modern motive power represents enormous invested capital, in addition to which heavy overhead charges are accruing whether the engine is idle or in service. Railway executives should heed the recommendations of their motive power officers for improved facilities, one of the most important of which should be efficient drop pit arrangements. The engineering and motive power departments should co-operate when terminal plans are prepared. There should be no difference of opinion concerning the advantages of drop pits—the principal feature to be considered is the number and arrangement. Drop pits inconveniently placed will often cause delays in the turning of power and compel the roundhouse foreman to "take a chance," the risk of which is too well known for comment here.

It may seem strange to the American railway man to have his attention called to South Africa for an illustration of what has been accomplished in equipping engine terminals with drop pits. The writer had many years' experience in

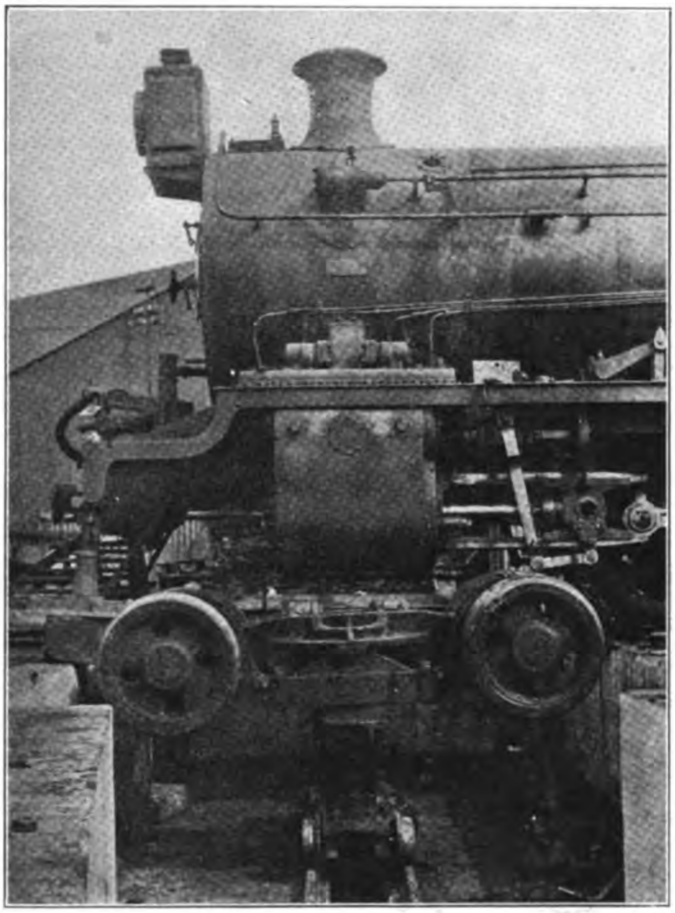


Fig. 1—Engine Truck Drop Pit at Bloemfontein

operating roundhouses on some of the important American railways and has in mind many terminals where today the heaviest engines are jacked to a critical height to run out the truck for changing wheels or other repairs; in addition to the excessive loss of time serious damage often results to the engine frame and spring rigging. Practically every terminal on the South African Railways, including those on the outlying districts, is equipped with modern drop pits for truck and driving wheels. These pits are invariably arranged to give the most flexible service for all wheels, including those of the tender. All pits are equipped with an efficient hydraulic jack which is manufactured by the railway company in its shops at Uitenhage.

Pits are always clean and dry; they are constructed of concrete, the walls being whitewashed. The question of drainage has been given most careful attention as many of the pits are in the open and South African rainfalls are ex-

*Mr. Rogers, who was formerly a mechanical department officer on a number of American railroads and later a captain in the Russian Railway Service Corps, is now technical representative of the Baldwin Locomotive Works at Johannesburg, South Africa.