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* indicates illustrated article.
§ indicates editorial comment.
‡ indicates communication.
† indicates a short non-illustrated article or note.

A

MALLET ARTICULATED COMPOUND LOCOMOTIVE

SOUTHERN PACIFIC COMPANY.

The Baldwin Locomotive Works has recently completed two Mallet articulated compound locomotives for the Southern Pacific Company, which are the heaviest locomotives in the world. They will be used on the Sacramento Division of that railroad between Roseville and Truckee, where the maximum grade is 116 ft. per mile, and will have a rating of 1212 tons, exclusive of engine and tender, over that division. The locomotives have a total weight of 425,900 lbs, of which 394,150 lbs. is on drivers. The calculated tractive effort is 94,640 lbs. They are of the 2-8-8-2 type, the front truck carrying 14,500 lbs. and the back truck 17,250 lbs.

The most notable departure from previous locomotive practice in this case is found in the incorporation of the feed water heater forming a part of the boiler and in the introduction of the reheater between the high and low pressure cylinders. This, of course, is the largest number of wheels ever put under a single locomotive and the arrangement for removing the forward section of the boiler is entirely new.

The accompanying table has been prepared to permit a comparison between the four most notable examples of Mallet articulated compound locomotives that have been built in this country. From this it will be seen that while the Southern Pacific engine is by far the largest in total weight, it has not quite the tractive effort, working compound, that is given by the Erie locomotive, which carries all of its weight on drivers, and as a result has a higher factor of adhesion. The increased tractive effort of the Erie,

Road	S. P.	Erie	G. N.	B. & O.
Type	2-8-8-2	0-8-8-0	2 6 6-2	0-6-6-0
Builder	Baldwin	Amer.	Baldwin	Amer.
Total Wgt., lbs.	425900	410000	355000	334500
Wgt. on Drivers, lbs.	394150	410000	316000	334500
Tractive effort (comp.), lbs.	94640	94800*	71600	70000*
Diam. Cylinders, in.	26 & 40	25 & 39	21½ & 33	20 & 32
Stroke, in.	30	28	32	32
Steam Pressure, lbs.	200	215	200	235
Diam. Drivers, in.	57	51	55	56
Diam. Boiler, in.	84	84	84	84
Total Heating Surface	6393†	5313.7	5703	5600
Wgt. on Drivers ÷ Tractive Effort	4.18	4 32	4.4	4.75
Total Wgt. ÷ Tractive Effort	4.51	4.32	4.95	4.75
Tractive Effort × Diam. Driv. ÷ Heating Surf.	843	910	690	700
Heating Surface ÷ Grate Area	93.4	53.14	73	77.3
Wgt. Drivers ÷ Heating Surface	61.0	76.9	59.2	59.5
See American Engineer	—	1906 p429	1906 p371	1904 p237

*This is not the maximum tractive effort of these locomotives, since they are fitted with an intercepting valve and separate exhaust pipe, allowing them to be worked simple and thus increase the tractive effort given by 20%.
†Includes Feed Water Heater.

however, is largely due to the smaller diameter of drivers and increased steam pressure, it being designed altogether for pushing service and not for regular road work, which, we understand, the Southern Pacific is intended for.

The illustrations on the following pages show the general design and the boiler arrangement of the Southern Pacific locomotive, and in a later issue will be given some of the more interesting details of this design.

Oil is to be used for fuel, but it is evident from the construction of the firebox that coal can be burned, although probably not fast enough to develop the full power of the locomotive. The boiler is of the straight type, 84 in. in diameter at the front end. Ahead of the firebox is the barrel of the boiler proper, having 401 2¼-in. flues, 21 ft. long, and a heating surface of 4,941 sq. ft. These flues terminate in a combustion chamber 54 in. long, occupying the full section of the boiler in front of which is a feed water heater. The tubes in this feed water heater are of the same number and diameter as in the boiler and are set in alignment with the boiler tubes. They terminate in a front end of the usual form. The combustion chamber is provided with a man hole, so that the tube ends therein are readily accessible and a further provision for facilitating repairs is made by separating the boiler shell at the rear end of the combustion chamber. This joint is made by riveting a heavy ring to each boiler section, which rings are butted with a V-shaped fit and secured together by 42 1¼-in. bolts.

Two non-lifting injectors discharge on either side into the feed water heater, which is kept constantly filled with water. The boiler feed passes out from the top of this chamber and is delivered into the main barrel through two checks, one on either side, located just back of the front tube sheet.

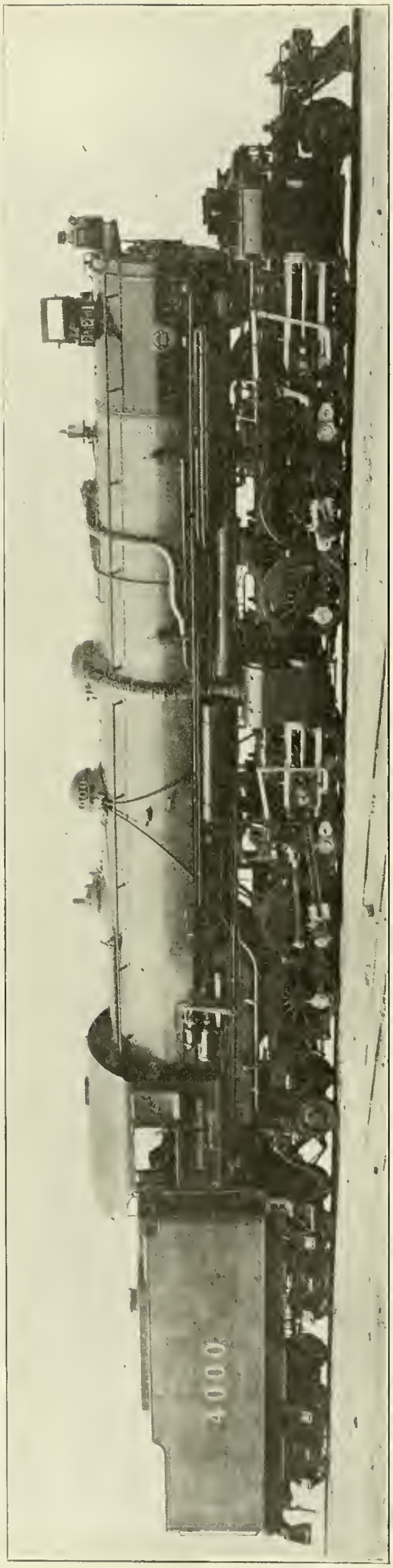
A Baldwin type of superheater is placed in the front end and connected in the piping system between the high and low pressure cylinders, thus forming, in this case, a reheater. It will no doubt be found that the addition of heat to the steam at this point will prove to be of great advantage from an operating standpoint as well as thermodynamically.

The waist-bearer under the combustion chamber is bolted in place, while the front waist-bearer and the high-pressure cylinder saddle, are riveted to the shell. The longitudinal seams in the barrel are placed on the top center line, and have diamond welt strips inside. Flexible staybolts are liberally used in the sides, back and throat of the firebox, while the crown sheet is stayed with tee irons hung on expansion links, in accordance with Associated Lines practice.

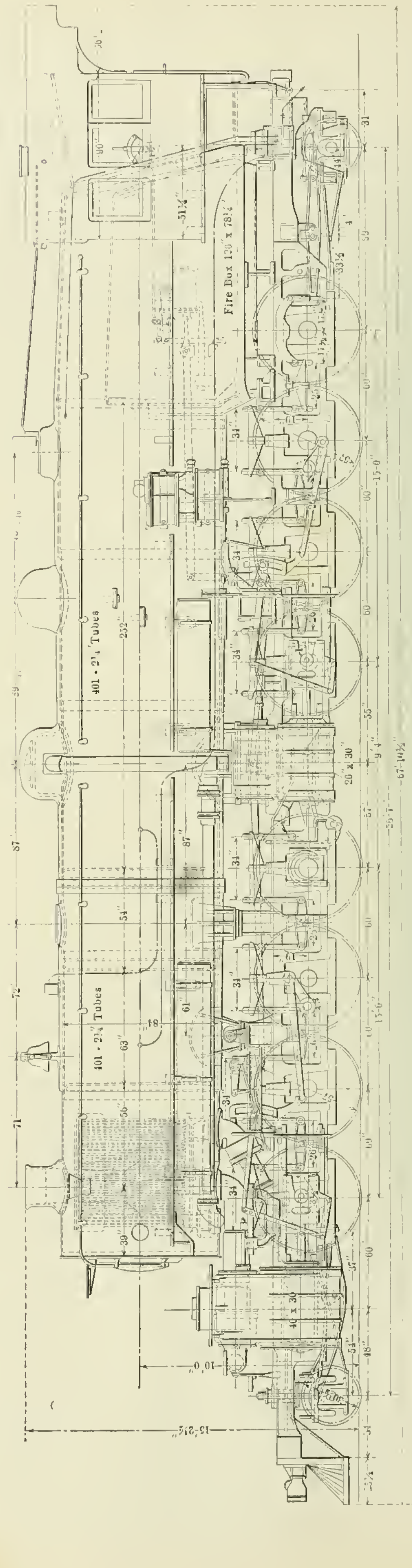
The dome, which is of cast steel, is placed immediately above the high-pressure cylinders, and the arrangement of the throttle and live steam pipes is similar to that used on heavy articulated locomotives previously built by this company. The exhaust from the high-pressure cylinders passes into two pipes which lead to the reheater in the front end. These pipes are of steel, and each is fitted, at the back end, with a slip joint made tight with a packed gland. The steam enters the reheater at the front end of the device, and passes successively through six groups of tubes. It then enters a T-connection, from which it is conveyed to the low-pressure cylinders through a single pipe having a ball joint at each end and a slip joint in the middle. Each low-pressure cylinder is cast separately, and is bolted to a large steel box casting, which is suitably cored out to convey the steam from the receiver pipe to a pair of short elbow pipes, making final connection with the low-pressure steam chests. The distribution is here controlled by 15-inch piston valves which are duplicates of those used on the high-pressure cylinders. The final exhaust passes out through the front of each casting, into a T-connection, which communicates with a flexible pipe leading to the smoke-box. The slip joint in this pipe is made tight by means of snap rings and leakage grooves. At the smoke-box end, the ball joint is fitted with a coiled spring which holds the pipe against its seat. The valves for both the high and low-pressure engines are set with a travel of 5½ inches and a lead of 5-16 inch. The steam lap is 1 inch, and the exhaust clearance 1-16 inch. Reversing is effected by the Raggonet power gear,* which is operated by compressed air and is self-locking. The gear is directly connected to the high-pressure reverse shaft. The reach rod connection to the low-pressure reverse shaft, is placed on the center line of the engine, and is fitted with a universal joint located immediately above the articulated frame connection. The joint is guided between the inner walls of the high-pressure cylinder saddle. In this way the reversing connections are simplified, and when the engine is on a curve the angular position of the reach rod has practically no effect on the forward valve motion. This arrangement has been made the subject of a patent.

One of the locomotives is equipped with vanadium steel frames, and the other with frames of carbon steel. The connection between the frames is single, and is effected by a cast steel radius-bar which also constitutes a most substantial tie for the rear end of the front frames. The fulcrum pin is 7 inches in diameter;

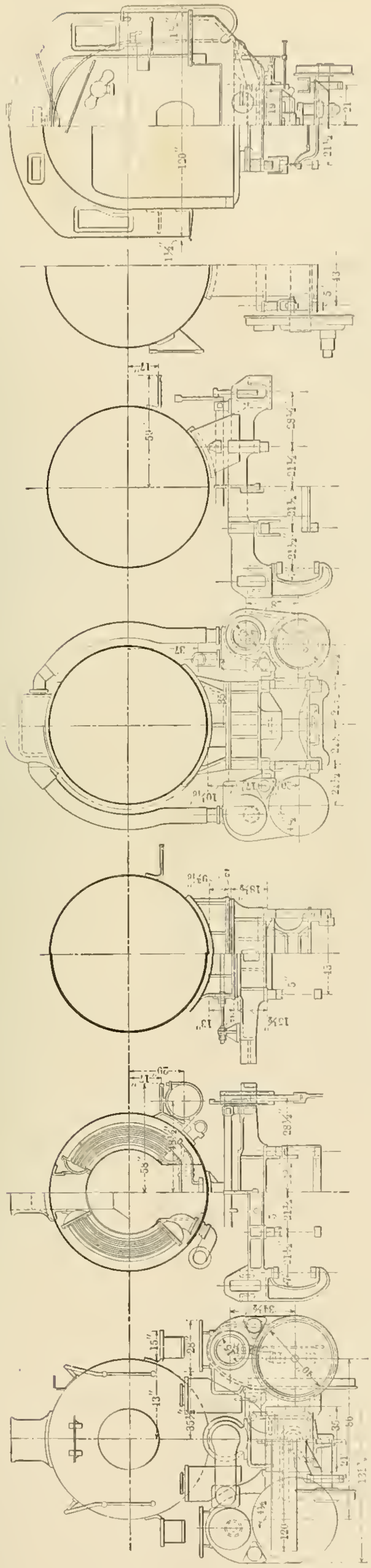
* See AMERICAN ENGINEER, July, 1908, page 260.



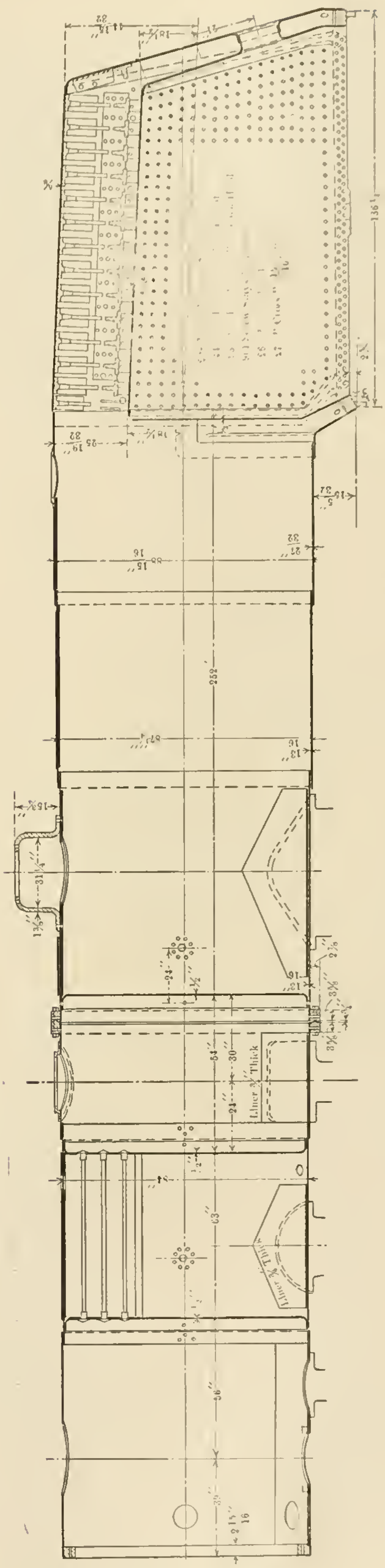
GENERAL VIEW OF THE LARGEST LOCOMOTIVE IN THE WORLD—SOUTHERN PACIFIC 2-8-8-2 TYPE.



ELEVATION OF MALLET ARTICULATED COMPOUND, 2-8-8-2 TYPE LOCOMOTIVE—SOUTHERN PACIFIC COMPANY.



END ELEVATION AND SECTIONS OF SOUTHERN PACIFIC 2-8-8-2 TYPE LOCOMOTIVE.



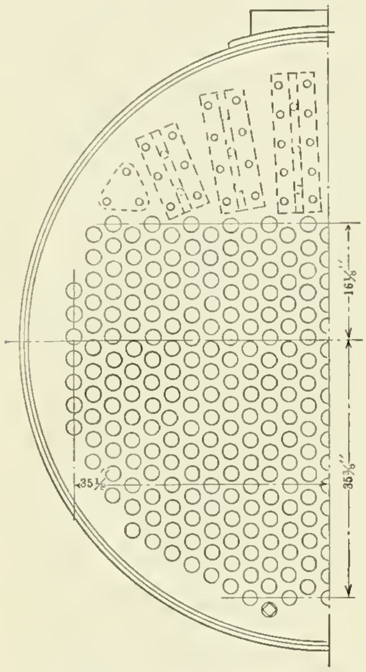
LONGITUDINAL SECTION OF BOILER AND FEED WATER HEATER—SOUTHERN PACIFIC 2-8-8-2 TYPE LOCOMOTIVE.

it is inserted from below, and held in place by a plate supported on a cast steel crosstie, which spans the bottom rails of the rear frames between the high-pressure cylinders. The weights on the two groups of wheels are equalized by contact between the front and rear frames, no equalizing bolts being used in this design.

The front frames are stopped immediately ahead of the leading driving pedestals, where they are securely bolted to a large steel box casting, previously mentioned, which supports the low-pressure cylinders. The cylinders are keyed at the front only. The bumper beam is of cast steel, 10 feet long, while the maximum width over the low-pressure cylinders is approximately 11 feet.

The boiler is supported, on the front frames by two bearings, both of which have their sliding surfaces normally in contact. The front bearing carries the centering springs, and the wear is taken, in each case, by a cast iron shoe 2 inches thick. Both bearings are fitted with clamps to keep the frames from falling away when the boiler is lifted.

This locomotive naturally embodies in its design many smaller details of interest which will be illustrated later. The cylinder



ELEVATION OF FRONT FLUE SHEET.

and steam chest heads are of cast steel, the low-pressure heads being dished and strongly ribbed. The low-pressure pistons are also dished; they have cast steel bodies, and the snap rings are carried by a cast iron ring which is bolted to the body, and widened at the bottom. The links for the low-pressure valve gear are placed outside the second pair of driving wheels, and are supported by cast steel bearers which span the distance between the guide yoke and the front waist bearer. The low-pressure valve stems are connected to long crossheads, which slide in brackets bolted to the top guide bars. The locomotive is readily separable, as the joint in the boiler is but a short distance ahead of the articulated frame connection, and all pipes which pass the joint are provided with unions. The separable feature has been tested and proved entirely feasible. Sand is delivered to the rear group of driving wheels from a box placed on top of the boiler, and to the front group from two boxes placed right and left ahead of the leading drivers. The high pressure cylinders are lubricated from the cab in the usual manner, while the low pressure are lubricated by means of a force feed pump driven from the forward valve motion. This arrangement avoids the use of flexible oil piping.

The tender is designed in accordance with Associated Lines standards, and is fitted with a 9,000 gallon water-bottom tank. The capacity for oil is 2,850 gallons.

The detail parts of this locomotive have, where possible, been designed in accordance with existing standards of the Associated Lines. The engine is practically equivalent, in weight and capacity, to two large consolidation type locomotives, and in spite of its great size, presents a pleasing and symmetrical appearance.

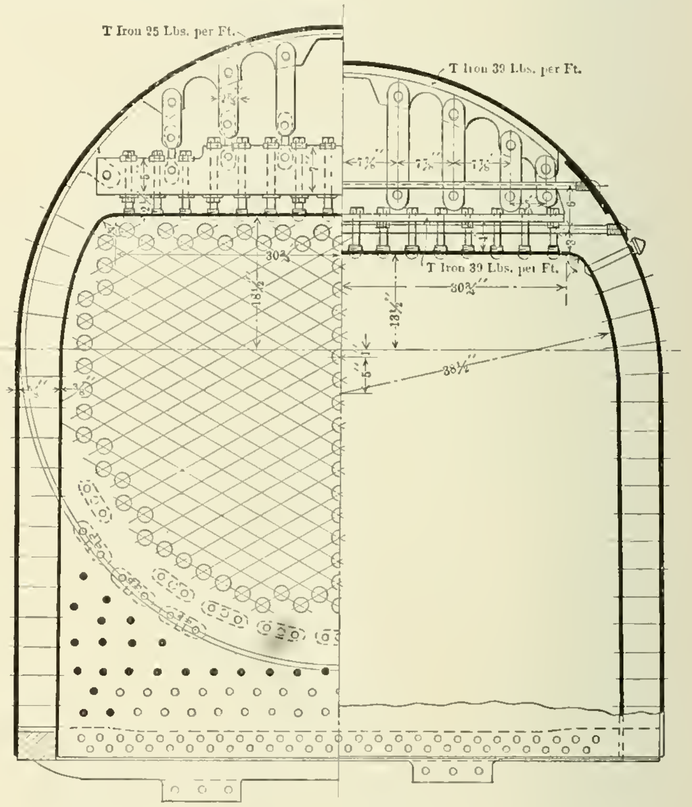
The general dimensions are given below:

GENERAL DATA.

Gauge	4 ft. 8½ in.
Service	Freight
Fuel	Oil
Tractive effort	94,640 lbs.
Weight in working order	425,900 lbs.
Weight on drivers	394,150 lbs.
Weight on leading truck	14,500 lbs.
Weight on trailing truck	17,250 lbs.
Weight of engine and tender in working order	596,000 lbs.
Wheel base, driving	39 ft. 4 in.
Wheel base, total	56 ft. 7 in.
Wheel base, engine and tender	83 ft. 6 in.

RATIOS.

Weight on drivers ÷ tractive effort	4.18
Total weight ÷ tractive effort	4.51
Tractive effort x diam. drivers ÷ heating surface	843.00
Total heating surface ÷ grate area	93.40
Firebox heating surface ÷ total heating surface, %	3.63
Weight on drivers ÷ total heating surface	61.00
Total weight ÷ total heating surface	67.00
Volume equiv. simple cylinders	28.8?
Total heating surface ÷ vol. cylinders	220.00
Grate area ÷ vol. cylinders	2.38



SECTION THROUGH FIREBOX—SOUTHERN PACIFIC MALLET.

CYLINDERS.

Kind	Compound
Diameter	26 & 40 in.
Stroke	30 in.

VALVES.

Kind	Piston
Diameter	15 in.
Greatest travel	5½ in.
Outside lap	1 in.
Inside clearance	1/16 in.
Lead, constant	5/16 in.

WHEELS.

Driving, diameter over tires	57 in.
Driving, thickness of tires	3½ in.
Driving journals, main, diameter and length	11 x 12 in.
Driving journals, others, diameter and length	10 x 12 in.
Engine truck wheels, diameter	30½ in.
Engine truck, journals	6 x 10 in.
Trailing truck wheels, diameter	30½ in.
Trailing truck, journals	6 x 10 in.

BOILER.

Style	Straight
Working pressure	200 lbs.
Outside diameter of first ring	84 in.
Firebox, length and width	126 x 78¼ in.
Firebox plates, thickness	⅜ & ½ in.
Firebox, water space	5 in.
Tubes, number and outside diameter	401—2¼ in.
Tubes, length	21 ft.
Heating surface, tubes	4,941 sq. ft.
Heating surface, firebox	232 sq. ft.
Feed water heater tubes, number and diam	401—2¼ in.
Feed water heater tubes, length	5 ft. 3 in.
Feed water heater, heating surface	1,220 sq. ft.

Heating surface, total	6,393 sq. ft.
Reheater heating surface	655 sq. ft.
Grate area	68.4 sq. ft.
Smokestack, height above rail	15 ft. 2½ in.
Center of boiler above rail	120 in.

TENDER.

Wheels, diameter	33½ in.
Journals, diameter and length	6 x 11 in.
Water capacity	9,000 gals.
Oil capacity	2,850 gals.

RAILROAD MACHINE SHOP PRACTICE.

II.—DRIVING BOXES.

George J. Burns.

If any one class of locomotive repair work more than another justifies a study of comparative costs and results it is locomotive driving boxes. With but few exceptions each shop is strenuous in claiming that its own particular practice is the best. If the cost happens to be high it is contended that the additional expense is more than offset by superior efficiency. If the job is somewhat roughly done it is claimed that it is all sufficient for its purpose, and that unnecessary exactness is extravagant. The object of this article will, therefore, be to lay before the reader comparative processes and costs and not to undertake to advise which practice should be adopted. The cost and time for doing the same work with the same class of tools in different shops varies so greatly as to justify any one in doubting the accuracy of some of the observations. To simplify comparisons, cast steel boxes only will be considered.

Facing—Exclusive of Recess or Channel on Hub Side.—This work is done on planers, milling machines, boring mills, shapers, and to a limited extent on lathes. The practice is determined by the character of work and by the equipment of the shop. If the recess on the hub side is machined, the facing, on that side at least, can be done most economically on a boring mill. The shortest facing time observed was 30 minutes per box on a powerful milling machine. That time is easily possible on a modern planer. The longest time observed was a three hour job on a planer.

Recess on Hub Side.—The practice is so varied that comparisons are almost out of the question. In some shops the recesses are machined and in others they are dovetailed in addition with more or less elaboration. This was particularly observed in a shop where a brass plate was used instead of casting babbitt on the box. The tendency seems to be in the direction of not machining the recess. The contention is that not only is the machining expensive, requiring the facing to be done on a boring mill, but that the rough surface holds the babbitt better than the machined surface. In most shops the babbit is held in place by tapping brass plugs into the box. In some shops the plugs are staggered with view of securing a continuous brass bearing. The best practice for holding the babbitt seems to be to have the sides of the recess slightly eccentric with each other.

Crown or Shell Fit.—This work is done on planers, shapers and slotters. The planer seems to give the poorest efficiency, and a special draw stroke shaper the best. The wide variation in time of doing this work on the same class of tools emphasizes the necessity of profiting by comparison. The shortest time was one hour per box, and the longest time was 7½ hours per box.

Cellar Fit.—In some shops the legs are machined at the time the crown fit is made and any variation resulting from pressing in the brass is allowed for by fitting the cellar to caliper measurement. In other shops the legs of the box are machined to standard after the brasses are pressed in; sometimes they are simply surfaced and squared, each cellar being fitted to its box.

The practice in coring the legs of the box also varies greatly. Some roads do not core at all, deeming the support the full width of the leg on the cellar to be of more importance than the shop time saved by coring. Some legs are cored in the center, leaving a band on four sides. The advantage of such coring is doubtful, as in machining the tool is required to make full stroke and where the coring is shallow there is a liability, as noted in one shop, that the tool will run in the scale. The most common practice in coring the leg is to core across, leaving a band at the top and the bottom. On some roads the coring is up and down, leaving a band at each side. That form is of doubtful advantage, especially as the coring is crosswise on most cellars. On some roads there is no uniformity as to coring, all forms being more or less in use. The time for machining the legs for the cellar fit varies all the way from 45 minutes to 3 hours per box.

Shoe and Wedge Fit.—The most universal practice is to back off or taper the side of the shoe and wedge fit. On one road, at least, the sides are not tapered and equally good results are claimed to be secured. The shoe and wedge fit is made on planers, milling machines, and shapers. The shortest time observed was one hour per box on a milling machine. That time ought to be possible on a modern planer. The longest time observed was four hours; the usual time was about two hours—all taper work.

Replaning.—Here again there is such a wide range in time and such a wide variation in practice that attempts at comparison are confusing. If the least expensive practices are sufficient, the most expensive are inexcusable.

Most roads in replaning follow the taper of the sides. Some few roads replane straight, relying upon the fillet to compensate for the taper. The practice seems to be tending toward one tool work, roughing and finishing in one cut.

Is there a necessity for a brass bearing between the box and the shoes and wedges? One important road, at least, does not deem such a bearing a necessity. The mechanical department, after carefully observing results and considering all arguments pro and con, contend that the advantage of the brass bearing is not commensurate with its cost. They claim that the brass bearing offers no advantage whatever, providing the surfaces are kept reasonably well lubricated. Other roads claim that the brass bearing is necessary and that lubrication will not offset it.

In shops where a brass bearing is deemed necessary, the following practices have been observed:

1. Brass shoes and wedges.
2. Shoes and wedges with brass facing.
3. Brass liners on first repairs.
4. Brass liners when boxes become so thin they cannot be safely further replaned.
5. Most brass liners are fitted and riveted to the box.
6. On some roads the brass liner is cast in position in the box.

The shortest time observed for replaning was 25 minutes per box, and the longest 1½ hours per box. The usual time was about one hour.

Power Plant Efficiency.—H. G. Stott, Mem. of the Am. Soc. of Mech. Engrs., estimates the average heat distribution in the power house as shown in the following table:

	Per cent.	Per cent.
Heat in the coal		100
Loss in ashes	2.4	
Loss in stack	22.7	
Loss from boiler radiation and leakage	8.0	
Returned by feed water heater		3.1
Returned by economizer		6.8
Loss in pipe radiation	0.2	
Delivered to circulator	1.6	
Delivered to boiler feeder	1.4	
Leakage and high pressure drips	1.1	
Heating	0.2	
Loss in engine friction	0.8	
Delivered to small auxiliaries	0.4	
To house auxiliaries	0.2	
Radiation from engine	0.2	
Rejected to condenser	60.1	
Electrical losses	0.3	
Totals	99.6	109.9
Delivered to bus-bar	10.3	

We may assume that with a good steam generating station we convert but ten per cent. of the heat stored in the coal into electricity, on the bus-bars. Further losses due to distribution and conversion, in various ways, to light and power occur so that we get but little of the potential energy provided for our use by a wise and beneficent nature. Surely, if our ecclesiastical brethren maintain that the storage of coal is a manifestation of Divine Providence, the present inventions for utilizing it must have emanated from his Satanic Majesty.—*From President M. L. Holman's address before the A. S. M. E.*

In some cases they have been known to hire halls and secure a young engineer or some one familiar with the subject to lecture to or quizz them. This practice is all wrong and cannot produce the best results. Some arrangement should be made so that the work and study of each individual fireman can be followed through the year. It has been suggested that correspondence school methods could be adopted. The firemen could be required to send in papers covering the answers to certain of the subjects at more or less regular intervals; these could be corrected and returned to him with suggestions and criticisms; in case the fireman desired information on any topic in connection with his work he could write in for it, if he could not conveniently get it in other ways. The yearly examination would be held as at present, but the men would be much better prepared.

INCREASING THE FIREMAN'S OUTPUT.

Again the limits for size and weight of locomotives have been exceeded and we have a new, "largest locomotive in the world" in the Southern Pacific 2-8-8-2 type, two of which have recently been finished by the Baldwin Locomotive Works. A study of the design of this locomotive, which is illustrated on page 181 of this issue, shows, however, that it is deserving of attention for reasons more important than those of mere size and weight.

It has truthfully been contended that the capacity of a locomotive is limited by the physical capacity of the fireman and it was felt, when Mallet compounds were first introduced, that they would be impracticable because of the impossibility of a fireman being capable of developing so large an amount of power. Such, however, did not prove to be the case as it was found that the economy of the compound cylinders, combined with the other advantageous features of the design, permitted one man to furnish steam enough for the full capacity of the locomotive. It did seem though that, in the B. & O. engine, the limit had been reached and probably as a matter of fact it had been reached for continuous service, but later the Erie locomotive, with over 30 per cent. more tractive effort, after a long trial has been found to require the services of but one fireman; this, however, in pushing service with short periods of maximum power requirement.

By burning oil, the Southern Pacific locomotive has escaped this limiting feature, but nevertheless there has been incorporated in its design features which probably with a coal burning locomotive would allow one fireman to develop the full capacity of the engine in regular service. This, of course, refers to the feed water heater and re-heater, both being originally intended for money savers in smaller locomotives, but in this case being far more valuable as permitting the decided extension of the limits of one fireman's capacity.

It looks as if American locomotive development had reached a stage where refinements for increasing the steam and water economy are absolutely essential, not to save money as they were originally designed to do, but to permit continual progress along the line of increased size and power.

In studying the design from this standpoint, however, it is hard to harmonize the application of front and rear truck wheels. In this case we have a locomotive which has a total weight about 16,000 lbs. greater than the Erie and is evidently more powerful in every respect, but still has not as large a tractive effort. In other words, instead of increasing the fireman's capacity it would seem as if, in this feature, it has been directly decreased. Of course, locomotive building companies will build whatever a railroad company wants and there are probably operating reasons in this case which make truck wheels desirable, but it is known that locomotives of this type without trucks will operate under severe conditions of curvature with entire safety and with a surprisingly small amount of flange wear, the latter being less than on consolidation locomotives in the same service. With these facts in mind and viewing the design from the standpoint of capacity it is to be regretted that unusual conditions exist which make it desirable to apply truck wheels to this type of locomotive.

AN IMPORTANT DEVELOPMENT IN ENGINEERING AND INDUSTRIAL EDUCATION.

The introduction of co-operative engineering courses at the University of Cincinnati marks a most distinct and important advance in engineering education. It is greatly to the credit of the Cincinnati machine tool builders and manufacturers that they were foresighted enough to grasp the significance of Prof. Schneider's scheme and to lend their aid and support in order that it might be given a fair trial. Briefly the idea is to combine practical and theoretical instruction by having the students spend alternate weeks in the engineering college of the University and in the manufacturing shops of the city. Each class is divided into two sections so that one part is in the University while the other is in the shops.

The course is six years long; the entrance requirements are the same as for the regular four-year engineering course at the University. The latter statement possibly requires some modification—the co-operative course has become so popular that many times more applications are received than the number of students that can be accommodated; it is therefore possible to carefully select those who seem best adapted for following engineering pursuits. Except for two or three weeks' vacation the students must work in the shop during the summer months, although this work need not necessarily be in Cincinnati.

As far as possible the student in his shop work follows the progress of the material from the raw state to the finished product, including, for instance, work in the shops, test department, drafting room and sales department. This work is just as carefully planned as that at the University and is intended to give the student a good shop and business training. The manufacturers take a great interest in the co-operative students and since they unite with the University authorities in planning and developing the shop courses the best possible results are obtained. Ask most of the Cincinnati machine tool builders if they have co-operative students in their shops, or if they know Prof. Schneider, and you will be surprised at the hearty and enthusiastic response.

It will be found that the students who enroll in the average college engineering department do not in most cases have a clear idea of what their work after leaving college is really to be. It is comical to hear some of the reasons why students select the course in which they are entered. The work at college, at least during the early part of the course, does not tend to enlighten them very much in this respect. The college shop work is a kind of a farce—it is true one gets some idea of the way things are done, a kind of smattering, but from a practical standpoint it is not of much value compared to gaining the experience under actual shop conditions.

It costs money to give young men an education. Is the money spent to the best advantage when young men entirely unsuited to follow or make a success of a profession, and having mistaken ideas as to what it really is, enter a course and drop out one by one during the four years or discover after graduation that it does not suit their tastes? It is surprising to note the small number of men who graduate and take up engineering work as compared to the number that entered in the freshman year for the same class. Are those in charge spending the money of the State economically and efficiently when this condition exists, and is it fair to the misguided young man to have him use his time in this way.

Is it logical to have a young man spend four years at an important period of his life, digging away at theory, and under conditions far removed from practical work, and at the end of that time, at the age of 22 or more, don overalls and start in at the bottom in the shop as an apprentice? Unfortunately college life at many institutions unfits a man to go into the shop and get on the same plane as the workman, whose work, habits, ideals and manner of living he must understand if he is to become a successful manager of men. Is it not much better to study theory and practice together, as in the co-operative courses, so that he will realize at the beginning something of what his life work is to be? (He will have a pretty good idea before he