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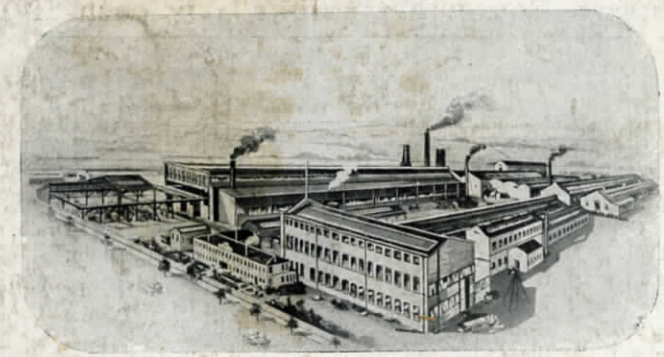

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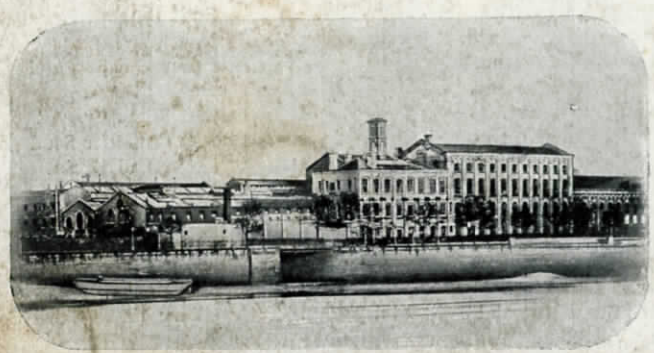

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WORTHINGTON

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QUEEN'S HOUSE, KINGSWAY,
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Bulletin 1080–A. July, 1922.

WORTHINGTON

LOCOMOTIVE BOILER FEED PUMP

AND

FEED WATER HEATER

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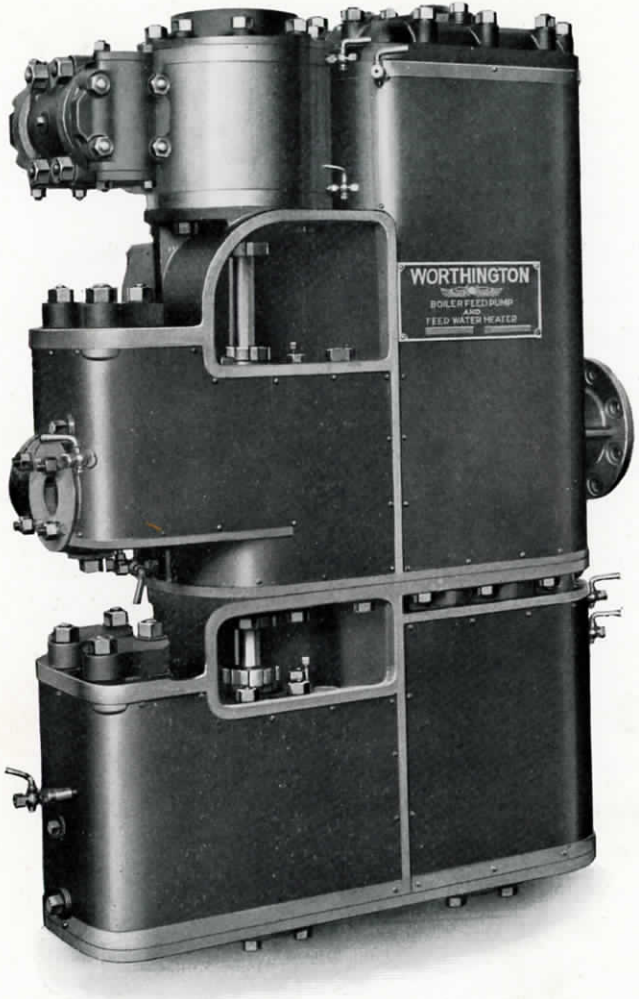

Locomotive Boiler Feed Pump and Feed Water Heater.
(Patented and Patents Pending.)

Worthington

Locomotive Boiler Feed Pump and Feed Water Heater.

(Patented and Patents Pending.)

Introduction

WORTHINGTON Locomotive Feed Pumps and Feed Water Heaters have now been in actual service on the road for three years and have proved themselves to be reliable for railroad service. They are easier to operate than injectors and are preferred by the engine drivers. They can be operated continuously at low capacities and can be kept in operation without any attention from the driver in spite of very low steam pressures due to boiler or other trouble. They effect a material reduction in coal and water consumption all the time and may be used to obtain increased steaming capacity when needed. They offer the peculiar advantage of being of greatest assistance to the locomotive when the locomotive most needs their assistance. Feed water temperatures obtained are not influenced by winter temperatures, reduced boiler pressure or superheat, but the coal and water saving or increased steaming capacity is proportionately greater under these conditions.

The Worthington Locomotive Feed Pump and Feed Water Heater is a unit complete in itself, and can be attached to the locomotive at a minimum expense. It offers advantages in fuel and water saving or increased steaming capacity at a first cost that is small compared

with other means of obtaining these advantages, and in most cases will earn its first cost and cost of attachment in from one to two years.

Fig. 2.
Worthington Locomotive Boiler Feed Pump and Feed Water Heater. Size No. 3.
Front View showing Exhaust Steam Inlet.
(Patented and Patents Pending.)

The advantages obtained from feed water heating on the locomotive are so much greater than in the stationary plant that the time must come when feed water heating will be as nearly universal on the locomotive as it is in the stationary plant.

The locomotive is a power plant that is necessarily subject to space and weight limitations and is obliged to carry its coal and water supply with it. For this reason economy and capacity increasing devices are of particular interest for the locomotive.

The Feed Water Heater is one of the most effective of these devices. By recovering part of the heat necessary to generate the steam it renders unnecessary the burning and carrying of an equivalent amount of coal, and by recovering part of the feed water it reduces the amount of water that must be carried. Both the heat and the water are recovered from the exhaust steam, an otherwise waste product. Since part of the work of the boiler is accomplished in the heater, the capacity of existing boilers is increased or smaller boilers may be used. Unlike most other economy and capacity increasing devices, the feed water heater need not be an integral part of the locomotive, but can be made a replaceable attachment, easily removable for major repairs when necessary without laying up the locomotive.

Some of the earliest locomotives were provided with feed water heaters. In fact, they appear to have been more generally used in the earliest days of the locomotive than later. All sorts and types of heaters have been tried, some recovering heat from the hot gases and others from the exhaust steam, but only in the last few years do we find any general adoption of locomotive feed water heaters, and then only in some few countries in Europe, where it is reported as many as 15,000 are in service.

These heaters are practically all of the closed or surface type, deriving their heat from the condensation of part of the exhaust steam from the locomotive, but they waste to the track the condensate from this exhaust

steam as well as its heat, are seriously affected by small amounts of scale and require enough exhaust steam to heat all of the feed water.

The locomotive feed water heater manufactured by Worthington Simpson, Ltd., is of the open type. The heater is built under the Thos. C. McBride patents and was formerly known as the McBride Locomotive Feed Water Heater and Boiler Feed Pump.

The Worthington Locomotive Feed Water Heater uses part of the exhaust steam from the locomotive to heat the feed water. This exhaust steam first passes through an oil separator which removes any lubricating oil from it.

The Worthington Heater, because it is of the open type, automatically and without complication recovers the condensate from the exhaust steam used in heating and all of its heat. Since part of the feed water, about 15 per cent., is recovered from the exhaust steam, the scale-forming matter entering the heater and the boiler with the feed water is reduced by this amount. In addition to this, actual experience on the road in bad water districts has proved that Worthington heaters can be operated for months without cleaning and with accumulations of scale from $^1/_8$ to $^1/_4$ in. in thickness without in the least affecting the feed water temperatures obtained or the operation of either the heater or the pump.

That part of the feed water which is recovered from the exhaust steam by the Worthington heater does not need heating. Only the balance of the feed water, about 85 per cent., which is taken from the tender, requires to be heated. For this reason, the Worthington heater uses less exhaust steam than other heaters and leaves more exhaust steam available for the draught, a most important feature on the locomotive.

The open type heater has now been universally adopted for stationary power plants. Its use with the oil separator to remove the oil from the exhaust steam on its way to the heater applies to the locomotive principles which years of development have proved best in stationary power plant practice.

Description.

The Worthington Locomotive Boiler Feed Pump and Feed Water Heater combines in a single unit all the elements necessary for:

(*a*) The heating of the feed water by direct contact with exhaust steam from the locomotive.

(*b*) The recovery of the water resulting from the condensation of this exhaust steam, as well as all of its heat.

(*c*) The delivery of the hot feed water, together with this water of condensation, direct to the boiler.

These units are built in four sizes having capacities of 2,000, 3,200, 4,425, and 6,000 gallons per hour respectively. One of these units having a maximum capacity of 4,425 gallons of feed water per hour is shown in the illustration on page 6 of this bulletin.

The illustrations throughout this bulletin show the application of these heaters to various types of locomotives. It will be noted that the units are designed for convenient attachment to the side of the locomotive boiler as is customary with air brake compressors.

The general construction of the heater and pump is shown in sectional view on page 30. The preferred location on the locomotive and the piping connections are shown on page 11. The heater is a simple cast-iron box, to one side of which the pump is attached. The large opening in the side of the heater (marked engine exhaust pipe) is connected by a pipe to the exhaust ports of the locomotive through holes cut into these ports through the back of the cylinder exhaust chest, as is shown in

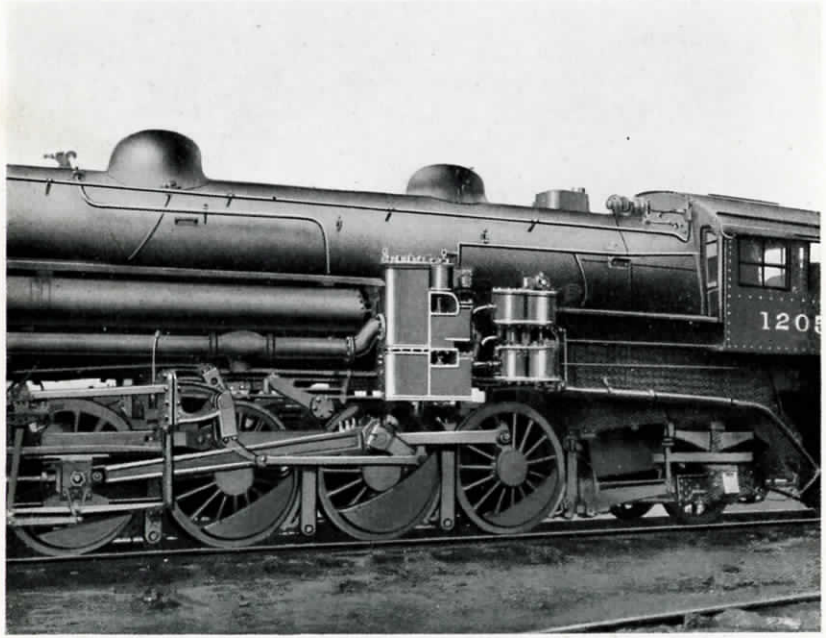

Fig. 3.
Worthington Locomotive Feed Pump and Feed Water Heater on Mikado Type Locomotive.

the illustration of the piping on page 11. The open space in the top of the heater is, therefore, supplied with exhaust steam from the locomotive at practically exhaust port pressure. This pipe leading the exhaust steam to

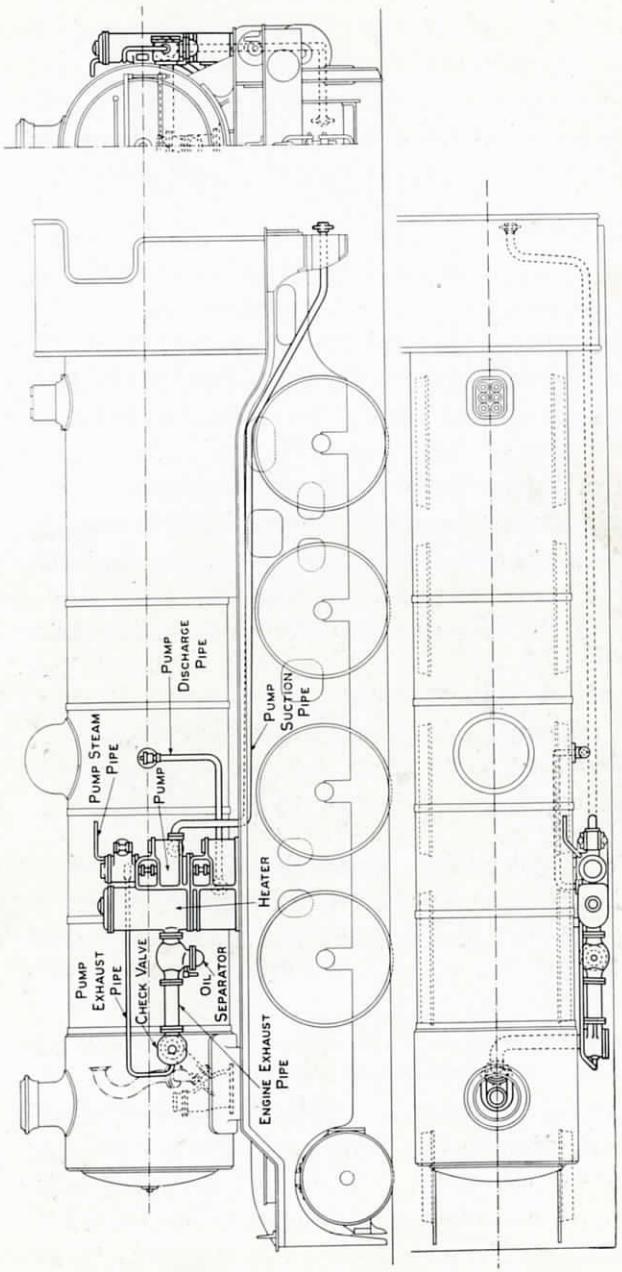

Fig. 4.
Diagram showing Application and Piping of Worthington Locomotive Feed Pump and Feed Water Heater.

the feed water heater has in it a check valve and an oil separator. A small hole in the bottom of the oil separator provides a continuous drip for the oil which is separated from the exhaust steam from the locomotive, effectually preventing this oil from entering the heater and reaching the boiler.

The feed pump is of the vertical, direct-acting piston type, with the steam cylinder above and two water cylinders below. The upper or cold water cylinder takes cold water from the tender through the usual hose and pipe and delivers it to a spray valve in the top of the heater which sprays the water into the exhaust steam filling this part of the heater. This cold water condenses as much of the exhaust steam as is necessary to heat it, and, mixing with the water resulting from the condensation of this exhaust steam, drops to the bottom of the heater. The lower pump cylinder takes this heated water from the heater and delivers it to the boiler.

A small vent in the rear of the heater is provided to relieve it of any air that might accumulate in it. A pipe is provided leading this air to a point of convenient discharge between the tracks or to the ashpan.

The exhaust steam from the pump is led into the main exhaust pipe leading to the heater, where it mixes with the exhaust steam from the locomotive and passes with it through the oil separator and into the heater, and is useful in helping to heat the feed water.

The amount of exhaust steam taken from the locomotive by the heater is controlled automatically, the cold water entering the heater condensing only as much steam as is necessary to heat it, refusing any more. However, this amount necessarily varies with the steam and cold water conditions, and consequently some means

of regulating the water level in the heater must be provided. The desired regulation is effected by so proportioning the pistons of the two pump cylinders as to cause a tendency for a slight excess of water to accumulate in the heater and the return of this slight excess of water, under control of a bucket in the heater, to the cold pump cylinder and thence to the heater.

The bucket shown is part 79 in the sectional view of the heater on page 30. When there is too much water in the heater the bucket fills and sinks. In its low position the bucket opens ports in the central stem, 78, allowing the excess water to reach an extra suction valve, 55, in the cold water cylinder. The water thus returned to the cold water pump meets a correspondingly reduced amount of water coming from the tender through the main suction valve, 60, and is delivered with it to the heater through the spray valve, 130. After the excess of water has been pumped from the heater and the bucket is partly emptied, the bucket rises, closing the return passage so that the return valve, 55, is then out of commission and all of the water is taken from the tender through the main valve, 60.

The pump is driven by steam from the locomotive boiler through a pipe provided with a throttle valve placed within convenient reach of the driver's left hand. By a slight turn of the hand wheel of the throttle valve the driver can start his pump, stop it, or adjust its speed to maintain the desired water level in the boiler without taking his attention from the road or even looking inside the cab.

A single-feed lubricator or an extra connection from the main lubricator is provided for the lubrication of the steam cylinder of the pump.

The heater is provided with convenient plugs through which sediment can be washed from it, and cocks through

which it can be drained to prevent freezing when the locomotive is laid up.

Fuel and Water Saving.

The Worthington Locomotive Feed Water Heater will recover from 10 to 12 per cent. of the heat required by the superheated steam locomotive boiler under usual operating conditions, and from 11 to 13 per cent. of the heat required by the boiler of the saturated steam locomotive. In this it does not differ from the feed water heater of the stationary power plant. In the case of the locomotive, however, there is a greater saving of fuel due to the fact that the locomotive boiler is generally overloaded, as compared with stationary practice. This reduction in the amount of heat required results in a higher boiler efficiency due to the decreased amount of heat that must be transmitted to generate a given amount of steam.

For example: A certain large goods locomotive which had been very carefully tested showed a boiler efficiency of 63 per cent. when fed with the injector and evaporating 40,000 lbs. of water per hour. When the amount of heat required from the fire and transmitted through the heating surface was reduced 10.4 per cent. because of the heater, the efficiency of the boiler was increased to 66 per cent. Injector operation required the burning of 100 parts of coal at 63 per cent. efficiency. Heater operation required 100—10.4 or 89.6 per cent. of the heat, but from coal burned at 66 per cent. efficiency. The actual amount of coal required was, therefore:

$$\frac{63}{66} - (100-10.4) = 85.5 \text{ per cent.}$$

On this basis the coal saving was 14.5 per cent. Therefore, whereas the fuel saving in the stationary power plant would have been but 10.4 per cent., the fuel saving on this particular locomotive at this capacity was 14.5 per cent.

This characteristic of the feed water heater on the locomotive is shown in Fig. 5 (see Proceedings American Society of Mechanical Engineers, "Locomotive Feed Water Heating," by Thos. C. McBride, May, 1920). The curve marked "D" (Heat Saving) shows the amount of heat actually recovered by the feed water heater. The upper solid curve marked "E" (Coal Saving) shows the actual coal saving. The distance between these two curves is the saving in fuel in addition to that obtained from the feed water heater alone due to the better efficiency of the boiler at the lower firing rate.

The Worthington Locomotive Feed Water Heater recovers from 13 to 16 per cent. of the feed water from the exhaust steam, the larger figure with the lower water temperatures of winter operation. This water saving is in effect an equivalent increase in tender water capacity, and where it renders unnecessary a stop for water, results in a still further saving of fuel as well as time.

Steaming Capacity.

As part of the work of the boiler is effected in the feed water heater, an increase in steaming capacity for the same amount of coal burned results from its use. With 200 lbs. steam pressure, 150 degrees superheat, and 40-degrees tender water temperature, the steaming capacity is increased 13.5 to 14.5 per cent., depending on the exhaust steam pressure available. With 70-degrees tender water temperature, from 11 to 12 per cent. increase is obtained.

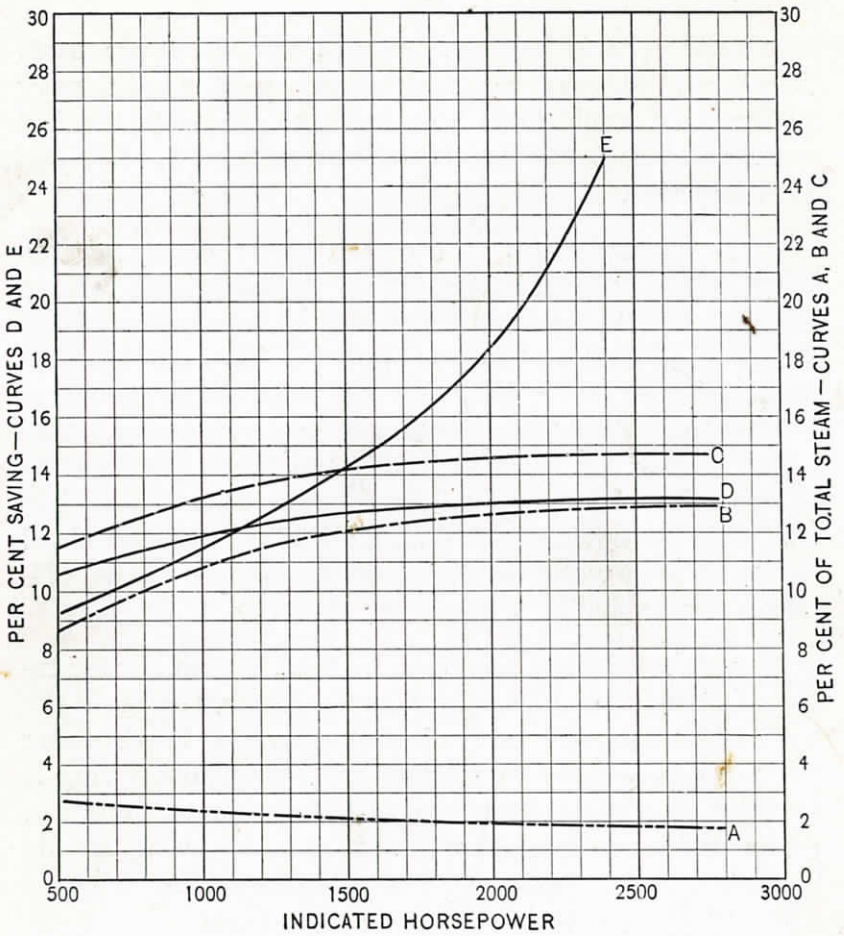

Fig. 5

INDICATED HORSEPOWER

Fig. 5. Analysis of coal saving based on indicated horsepower. Total exhaust steam taken by heater, the amount furnished by the feed pump and the amount taken from the exhaust ports of the locomotive.

A—Exhaust steam furnished by feed pump, per cent. of total.
B—Exhaust steam taken from exhaust ports, per cent. of total.
C—Total exhaust steam utilized by heater, per cent. of total.
D—Heat saving, per cent.
E—Coal saving, per cent.

An inspection of the coal-saving curve of Fig. 5 shows that the coal saving increases very rapidly with increased capacity of the locomotive. For this reason the feed water heater is of particular value on locomotives which must be operated at or near their maximum capacity and on older locomotives, generally small for the work they are called upon to do.

Draught.

The Worthington Locomotive Feed Water Heater, because of its type, is particularly applicable to the locomotive. Closed heaters require enough exhaust steam to heat all of the feed water. The Worthington heater recovers part of the feed water, approximately 15 per cent. from the exhaust steam, and only the balance of the feed water, approximately 85 per cent., remains to be heated. Since only part of the feed water needs to be heated, a minimum amount of steam is taken from the locomotive exhaust by the heater and more is left available for the draught, while the amount of fuel burned is always reduced at a greater rate than is the amount of steam available for the draught. This feature is well shown in the curves of Fig. 5, which have been taken from actual test plant results. The upper dotted curve "C" shows the total amount of exhaust steam taken by the feed water heater. The lower dotted curve "B" is drawn below the upper one at a distance representing the amount of exhaust steam furnished to the heater by the feed pump. The lower dotted curve, therefore, shows the amount of exhaust steam taken from the blast nozzle by the heater. It will be noted that this curve is entirely below the coal-saving curve. The ratio of the amount of steam left available for the draught to the amount of coal that must be burned will therefore always

be greater with the Worthington heater than it will be with the injector. For instance, at 2,000 I.H.P., the Worthington heater reduced the amount of steam available for the draught $12\frac{1}{2}$ per cent., as compared with injector operation, whereas the amount of coal burned was reduced to $18\frac{1}{2}$ per cent. Eighty-seven and one-half parts of exhaust steam were left to burn $81\frac{1}{2}$ parts of coal and there was an excess of draught as compared with burning the same amount of coal with injector feeding. Numerous trials of locomotives with Worthington heaters running alternate runs with the injector and the heater have demonstrated that there is no necessity for any reduction in the size of the blast nozzle because of the heater.

On the other hand, the curves, Fig. 5, show that there is a possibility of slightly increasing the size of the blast nozzle with the Worthington heater, with the consequent

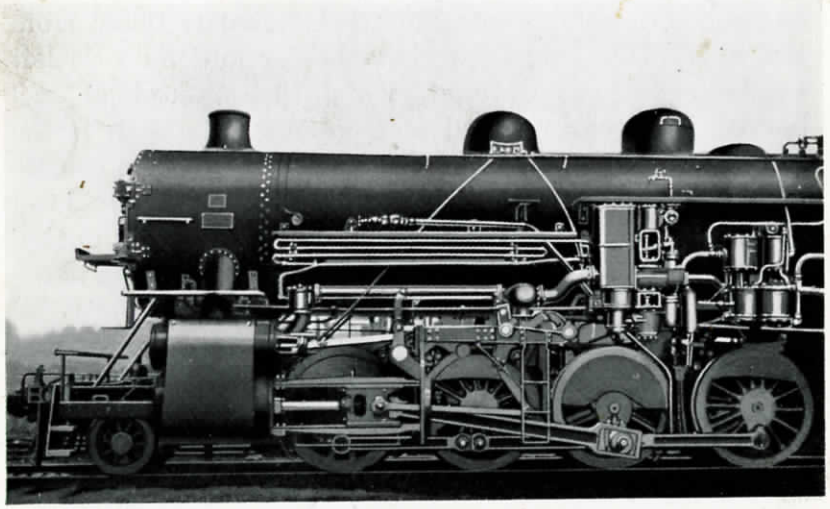

Fig. 6.
Worthington Locomotive Feed Pump and Feed Water Heater on Mikado Type Locomotive.

advantage of an additional reduction in back pressure in the locomotive cylinders. While it is difficult to measure the reduction in back pressure in the locomotive cylinders, because of the feed water heater, drivers operating locomotives equipped with Worthington feed water heaters have noted and commented on the very considerable reduction in the sound of the exhaust of the locomotive.

Since the use of the Worthington Locomotive Feed Water Heater results in such a considerable reduction in the amount of coal burned to generate the same amount of steam, there must necessarily be some reduction in the flue gas temperatures and in the degree of superheat, and, consequently, a slight increase in the steam consumption per I.H.P. This loss is small and is compensated for by the reduction in back pressure in the locomotive cylinders, due to the exhaust steam taken by the feed water heater. In the case of new locomotives built with Worthington heaters it would probably be advisable to so modify the superheaters that there would be no reduction in superheat because of the feed water heater.

Scale.

Since the Worthington Locomotive Feed Water Heater is of the open type, and not dependent on the transfer of heat through heating surfaces, scale has no influence on the feed water temperatures obtained. Worthington heaters, after having been in service in bad water districts for months, show accumulations of soft scale $\frac{1}{8}$ in. or more in thickness with no influence whatever on the heating of the feed water or the operation of the feed pump. The scale which forms at feed water heater temperatures is usually not hard, but of a soft slimy nature. The Worthington Feed Water Heater is provided with wash-out plugs, through which this sludge

can be washed out by means of the ordinary boiler wash equipment. An examination of a number of Worthington heaters in service in bad water districts shows that the scale accumulates mainly on the upper part of the heater where the heating takes place, with almost no scale whatever in the lower part of the heater or in the pump.

Since the Worthington Locomotive Feed Water Heater recovers approximately fifteen per cent. of the feed water from the exhaust steam, the total amount of scale-forming material entering the boiler is necessarily reduced by this amount, with a proportionate increase in the mileage obtained from flues and fireboxes and a corresponding reduction in the necessity for blowing off, with its attendant loss of heat and water.

Oil Separator.

The Worthington Locomotive Feed Water Heater is installed with an oil separator to remove the lubricating oil from the exhaust steam entering it. This separator is of a type that has been approved by long years of use and provides for the continuous elimination of the oil, with practically no attention in the way of cleaning. Worthington Locomotive Feed Water Heaters have been in service three years, and very careful tests have shown only a trace of oil in the boiler. Much has been said as to the danger resulting from the presence of oil in the locomotive boiler, but the practice of using large quantities of crude oil in locomotive boilers on some railways to assist in cleaning them and to prevent foaming demonstrates that this danger has been unduly magnified. The general adoption of the oil separator in stationary power plants, using generally types of boilers where oil might give trouble, has warranted the selection of this means of oil separation as the most perfect.

Protection Against Freezing.

The position of the Worthington Locomotive Feed Pump and Feed Water Heater on the side of the locomotive boiler and the complete lagging of both pump and heater effectually prevents their freezing while there is steam in the locomotive boiler. For very cold climates it is recommended that the bracket attaching the pump and heater to the boiler be completely closed in, the back of the pump and heater being designed to facilitate this closing as is shown in the view of the rear of the heater below. When the bracket is so closed in, the

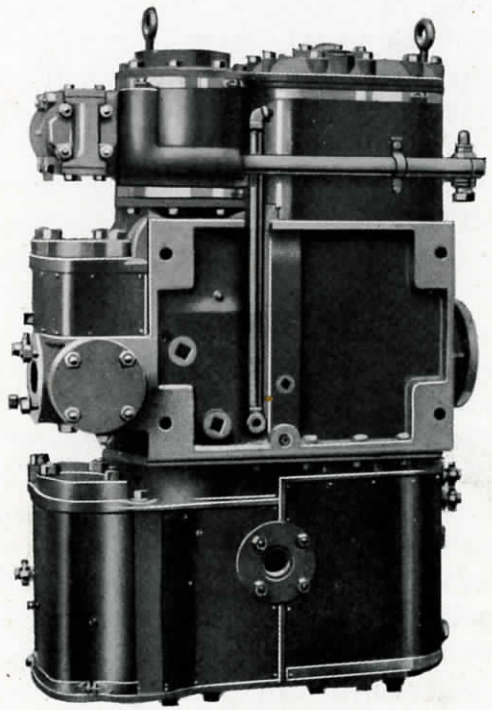

Fig. 7.
Rear View of No. 3 Worthington Locomotive Feed Pump and Feed Water Heater, showing Edge Finished Flush with Four Supporting Feet to meet similar Finished Edge on Supporting Bracket, enclosing space within the Bracket to prevent Freezing.

heat radiated from that part of the boiler shell within the bracket reaches the back of the pump and heater and effectually overcomes any danger from freezing. This leaves only the suction pipe from the tender to the pump and the tender hose to be protected from freezing. Foreign practice provides a small live steam line from the dome to the lowest part of this pump suction pipe by means of which the water in it can be kept slightly heated when the locomotive is standing during very low temperatures. In some installations a small circulating pipe has been used, presuming that the pump would be operated very slowly when the locomotive is standing during periods of very low temperature, discharging water through the slightly open valve in this circulating pipe to the rear end of the pump suction pipe just forward of the tender hose. This water is slightly heated in the heater by the exhaust steam from the pump, and, being circulated backwards through the circulating pipe and then forward through the pump suction pipe, will prevent the latter from freezing.

Installation.

The Worthington Locomotive Feed Pump and Feed Water Heater is designed for attachment to the side of the locomotive boiler, as is customary with air brake compressors. A typical installation is shown in the illustration, page 11. The suction line from the tender is led to the heater and the discharge line to the boiler check valve instead of to the injector. The main feature of the piping system is the exhaust steam take-off from the exhaust passages in the cylinders, the right and left-hand connections of which are brought together by a manifold on which is fixed the exhaust check valve ; the exhaust steam is thus conveyed by a single pipe to the heater. This low resistance check valve is of special design and

serves to trap the steam blown through it at each exhaust impulse, thus preventing its expansion backwards and escape through the blast nozzle at low speeds. At the same time, it compels the exhaust from the boiler feed pump to pass to the heater when the engine is not using steam, at which time the pump exhaust would otherwise be free to escape out of the blast nozzle. Where conditions appear to make it advisable, the oil separator, referred to above, is also incorporated in this line.

Steam for the operation of the boiler feed pump is supplied from the dome through a pipe having a throttle valve placed within convenient reach of the driver. By means of this throttle valve the feed pump is stopped and started and its speed controlled to meet the water requirements of the boiler. The exhaust from the pump is conveyed into the main exhaust pipe to the heater.

Operation.

The Worthington Locomotive Feed Pump and Feed Water Heater should be operated similarly to the feed pumps in a stationary power plant, running the pump as nearly continuously as possible while the locomotive is steaming and adjusting the pump throttle valve as may be necessary to maintain the desired water level in the boiler. From $^1/_2$ to $^3/_4$ turn of the throttle valve will generally be sufficient to give an ample supply of water to the boiler. When using the heater it is not necessary to fill the boiler while standing to be ready for starting or to fill the boiler on the down grade to be ready for the up grade. The smaller steam requirements of the boiler feed pump, as compared with the injector, renders it possible to operate the pump without loss of steam pressure when the locomotive is started. This method of operation gives the best results, both from the heater and from other features of the locomotive.

Storing Locomotives.

When locomotives are to be stored in freezing weather the pump should be stopped at the top end of its stroke, the tender hose connections broken and all drain cocks on the pump and heater opened, and it is advisable to run a wire through these drain cocks to make sure that they are not stopped up with sediment.

Maintenance.

A number of outstanding features that will tend to keep down the cost of maintenance of the Worthington Combined Locomotive Feed Water Heater and Boiler Feed Pump to an absolute minimum will have been detected in the foregoing. They may be enumerated as follows :

FIRST.—The Worthington Locomotive Feed Water Heating unit, as far as any mechanically operated parts are concerned, is essentially a steam actuated pump, experience in the manufacture of which Worthington Simpson, Ltd., have been accumulating for the past eighty years. The thousands of successful boiler feed pumps in stationary and marine service all over the world are ample testimony of this company's ability to produce a satisfactory apparatus for locomotive use.

SECOND.—The Worthington Locomotive Feed Water Heater is mounted as a unit on the outside of the locomotive boiler. Complete inspection and testing is a matter of minutes only. There is no occasion for opening front ends, dumping fires, or taking down arch brick, as is sometimes required in the case of other essential features of locomotive equipment. Its corresponding accessibility for adjustment and repair is an even greater advantage.

THIRD.—The simplicity of the installation is such that a minimum of pipe maintenance is involved. Condensate recovery being inherent in the open feed heating process, not a single pipe joint or a single inch of pipe is required in order to realise this very decided advantage.

FOURTH.—The fact that the apparatus is free from the deleterious effects of scale in both its mechanical and its thermal functions obviate the necessity of opening the heater for washing or cleaning purposes at more frequent intervals than from three to six months, even under the worst water conditions. Under favourable water conditions these heaters have been used for three years without requiring cleaning in a single instance.

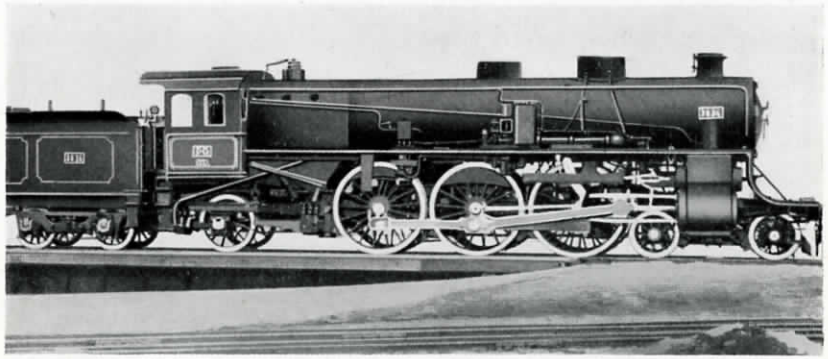

Fig. 8.
Worthington Locomotive Feed Pump and Feed Water Heater on Pacific Type Locomotive.
Size No. 2. Capacity, 3,200 Gallons per Hour.

FIFTH.—The Worthington Locomotive Feed Heating System is a *low pressure* system. The heater proper is subjected to a pressure somewhat less then the back pressure in the cylinders, while the heater supply pump is required to work against only a sufficient pressure to spray the water into the heating chamber.

SIXTH.—Adequate protection against freezing is assured by the heat radiated from the boiler to the back of the pump and heater, and the complete covering of the pump and heater.

Service.

Worthington Simpson, Ltd., maintain a Service Department, from which they furnish competent and experienced men to instruct users in the installation, operation and maintenance of the Worthington Locomotive Feed Pump and Feed Water Heater. In addition to this, they have offices in the principal cities of the United Kingdom and other countries, with their own engineering and maintenance organizations, which give immediate attention to the needs of their customers and products.

The Worthington Locomotive Feed Water Heater is so simple that it calls for little, if any, attention in the way of maintenance, cleaning, or otherwise. However, in order that the best results may be obtained in the shortest possible time, this Special Department is maintained and the services of experienced instructors offered to users of the Worthington Locomotive Feed Pump and Feed Water Heater.

Properties of Steam.

A table of the properties of steam is given on the next page. The total heat of steam stated is the heat in B.T.U. in the steam above that in water at 32 degrees Fahrenheit; that is, it is the heat necessary to generate steam at the pressure and temperature considered from water at a temperature of 32 degrees Fahrenheit. The corresponding

heat of water at any temperature is obtained practically exactly by subtracting 32 from the temperature. Thus, the total heat of water at 70 degrees temperature is 38 B.T.U.

At Exhaust Pressure			At Boiler Pressure						
					Total Heat of Steam.				
Press. Lbs. Gauge	Temp. Degs. Fahr.	Total Heat of Steam	Press. Lbs. Gauge	Temp. Degs. Fahr.	Saturated	Superheated. 50°	100°	150°	200°
0	212	1150.4	180	379.6	1197.7	1229.2	1256.4	1282.0	1307.0
1	215.3	1151.6	181	380.1	1197.8	1229.3	1256.5	1282.1	1307.1
2	218.5	1152.8	182	380.5	1197.8	1229.4	1256.7	1282.2	1307.2
3	221.5	1153.9	183	380.9	1197.9	1229.6	1256.8	1282.4	1307.3
4	224.4	1154.9	184	381.3	1198.0	1229.7	1256.9	1282.5	1307.5
5	227.2	1155.9	185	381.8	1198.1	1229.8	1257.1	1282.6	1307.7
6	229.8	1156.8	186	382.2	1198.2	1229.9	1257.2	1282.8	1307.8
7	232.4	1157.8	187	382.6	1198.2	1230.0	1257.3	1282.9	1307.9
8	234.8	1158.6	188	383.0	1198.3	1230.1	1257.5	1283.1	1308.1
9	237.1	1159.4	189	383.4	1198.4	1230.3	1257.6	1283.2	1308.2
10	239.4	1160.2	190	383.9	1198.5	1230.4	1257.7	1283.3	1308.3
11	241.6	1161.0	191	384.3	1198.5	1230.5	1257.8	1283.5	1308.5
12	243.7	1161.7	192	384.7	1198.6	1230.6	1258.0	1283.6	1308.6
13	245.8	1162.4	193	385.1	1198.7	1230.7	1258.1	1283.7	1308.8
14	247.8	1163.0	194	385.5	1198.8	1230.9	1258.2	1283.8	1308.9
15	249.7	1163.7	195	385.9	1198.8	1231.0	1258.4	1284.0	1309.0
16	251.6	1164.3	196	386.3	1198.9	1231.1	1258.5	1284.1	1309.2
17	253.5	1164.9	197	386.7	1199.0	1231.2	1258.6	1284.3	1309.3
18	255.3	1165.5	198	387.1	1199.1	1231.3	1258.7	1284.4	1309.4
19	257.0	1166.1	199	387.5	1199.1	1231.5	1258.8	1284.5	1309.6
20	258.7	1166.6	200	387.9	1199.2	1231.6	1259.0	1284.6	1309.7

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As an illustration of the use of this table in calculating the reduction in the amount of heat required to generate the steam, also the amount of steam required for heating and the amount of water saved by the Worthington Locomotive Feed Water Heater, the following examples are submitted:

Reduction in Amount of Heat Required to Generate the Steam.

Assumed temperature of water in tender, deg. Fahr.	40	70
Assumed steam pressure in branch pipe, lb. per sq. in. ...	200	200
Assumed superheat, deg. Fahr.	150	150
Heat content per lb. of steam as generated, B.T.U.	1284.6	1284.6
Heat content per lb. of water at 40 deg., B.T.U.	8	
Heat content per lb. of water at 70 deg., B.T.U.		38
Heat required to generate one lb. of steam, B.T.U.	1276.6	1246.6
Reduction in heat required when water is heated from 40 to 215 deg., B.T.U. ...	175	
Reduction in heat required when water is heated from 70 to 215 deg., B.T.U. ...		145
Reduction in heat required, per cent.	13.7	11.6
Total heat required by locomotive with feed pump, as compared with injector operation, per cent.	101.75	101.75
Reduction in heat required by locomotive with heater, this being the product of the last two figures, per cent. ...	13.94	11.80
Heat required, per cent.	87.81	89.95
Reduction in heat required, as compared with 100 per cent. required for injector operation, per cent.	12.2	10.05

The amount of steam required for the operation of the feed pump is two per cent. of the weight of the water delivered by the pump, but as the pump uses saturated steam and the locomotive superheated steam, the pump uses but 1.75 per cent. of the heat from the fire of the locomotive.

While the heater reduces by 10 to 12.2 per cent. the amount of heat required to generate a certain amount of steam at the assumed conditions, **a much greater reduction in the amount of fuel burned is obtained.** From 10 to 12.2 per cent. of the work of the boiler is done in the heater. Correspondingly less heat is transmitted through the heating surface and needed from the fire, and their efficiency is increased. Depending on the steaming capacity at which the locomotive is working, the quality of the fuel, &c., the percentage of fuel saving while running may easily be twice as much as is the percentage of heat recovered by the heater. This feature of the feed water heater on the locomotive has been discussed on pages 14 and 15 and is shown graphically in Fig. 5 on page 16.

EXHAUST STEAM REQUIRED FOR HEATING.

Assumed tender water temperature	40	70
B.T.U. required to heat one lb. of feed water to assumed temperature of 215 deg. from 40 deg.	175	
from 70 deg.		145
Heat content of one lb. of exhaust steam assumed at 7 lbs. pressure and to be saturated because of the use of the feed pump exhaust in the heater ... ...B.T.U.	1157	1157
Heat content of one lb. of water condensed from this exhaust steam at assumed 215 deg. ... ...B.T.U.	183	183
Heat given up by this pound of exhaust steam in condensing from 7 lbs. pressure to water at 215 deg., ... B.T.U.	974	974
Exhaust steam required to heat cold feed water, this being the heat taken up by one lb. of cold feed water divided by the heat given up by one lb. of exhaust steam, per cent....	18	15
Exhaust steam to heater from feed pump, per cent.	2	2
Exhaust steam taken from exhaust ports of locomotive, per cent. of cold water	16	13
The Worthington Heater adds the water condensed from the exhaust steam to the cold water delivered to the heater from the tender, so that with the Worthington Heater the exhaust steam required for heating is 16 divided by 116, and 13 divided by 113, respectively, and the exhaust steam taken from the exhaust ports is, per cent.	13.8	11.5

WATER SAVED DUE TO FEED WATER HEATER.

Steam for locomotive cylinders, per cent.	100	100
Steam required for feed pump, per cent.	2	2
Steam required from boiler by heater locomotive, as compared with injector operation, per cent.	102	102
Exhaust steam condensed in heating feed water, per cent., 0.18×102 ...	18.4	
0.15×102 ...		15.3
Water required by locomotive, per cent.	83.6	86.7
Water saving, as compared with injector operation, per cent.	16.4	13.3

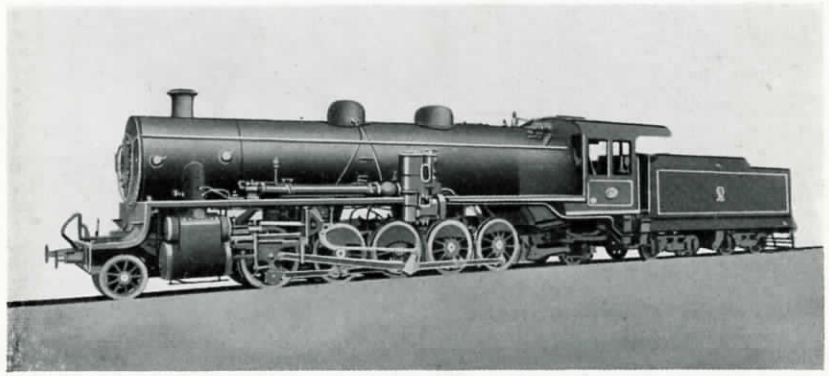

Fig. 9.
Worthington Locomotive Feed Pump and Feed Water Heater on Santa Fe Type Locomotive.
Size No. 2. Capacity, 3,200 Gallons per Hour.

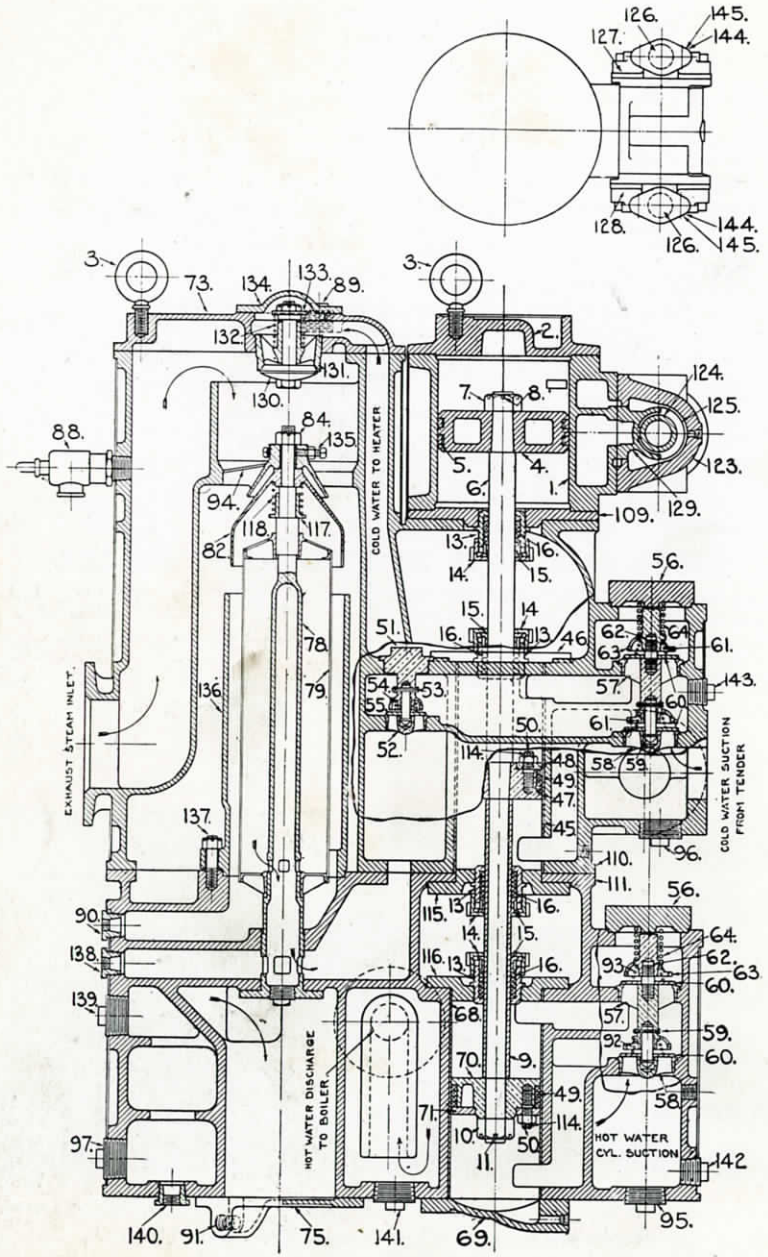

Fig. 10

Sectional View of Worthington Locomotive Feed Pump and Feed Water Heater

LIST OF PARTS.

No.	Name of Part.
1.	Steam Cylinder.
2.	Steam Cylinder Head.
3.	Eye Bolt.
4.	Steam Piston.
5.	Steam Piston Rings.
6.	Piston Rod.
7.	Piston Rod Castellated Nut.
8.	Piston Rod Split Pin.
9.	Piston Rod Tube.
10.	Piston Rod Castellated Nut.
11.	Piston Rod Split Pin.
13.	Piston Rod Stuffing-box.
14.	Piston Rod Stuffing-box Cap.
15.	Piston Rod Stuffing-box Gland.
16.	Piston Rod Stuffing-box Packing.
45.	Pump Cylinder Lining.
46.	Upper Pump Cylinder Head.
47.	Pump Piston.
48.	Pump Piston Follower.
49.	Pump Piston Packing.
50.	Pump Piston Collar Stud and Nut.
51.	Return Valve Plug.
52.	Return Valve Seat.
53.	Return Valve Bolt and Split Pin.
54.	Return Valve Spring.
55.	Return Valve.
56.	Pump Cylinder Valve Chest Cap.
57.	Discharge Valve Seat.
58.	Suction Valve Seat.
59.	Suction Valve Bolt and Split Pin.
60.	Valve.
61.	Valve Spring.
62.	Discharge Valve Stud.
63.	Discharge Valve Guard.
64.	Holding Down Spring.
68.	Pump Cylinder Lining.
69.	Lower Pump Head.
70.	Pump Piston.
71.	Pump Piston Follower.
73.	Heater Cover.
75.	Lower Heater Cover.
78.	Bucket Stem.
79.	Bucket.
82.	Lower Baffle.
84.	Bucket Stem Nut and Split Pin.
88.	Safety Valve.

No.	Name of Part.
89.	Filling Plug.
90.	Washout Plug and Drain.
91.	Washout and Drain.
92.	Spring (light).
93.	Spring (heavy).
94.	Spindle Guide.
95.	Washout Plug.
96.	Washout Plug.
97.	Washout Plug.
109.	Lower Steam Head.
110.	Pump Cylinder and Heater Shell (upper).
111.	Pump Cylinder and Heater Shell (lower).
114.	⅛″ Copper Wire.
115.	Lower Pump Head (cold cylinder).
116.	Upper Pump Head (hot cylinder).
117.	Bucket Stop.
118.	Bucket Stop Spring.
123.	Auxiliary Steam Cylinder.
124.	Auxiliary Plunger.
125.	Auxiliary Plunger Rings.
126.	Auxiliary Valves.
127.	Auxiliary Valve Chests (right-hand).
128.	Auxiliary Valve Chests (left-hand).
129.	Main Steam Valve.
130.	Spray Valve.
131.	Spray Valve Seat.
132.	Spray Valve Spring.
133.	Spray Valve Spring Guard and Split Pin.
134.	Spray Valve Cover.
135.	Adjusting Bolt and Nut for Bucket Stem.
136.	Bucket Chamber.
137.	Bucket Chamber Stud and Nut.
138.	Washout and Drain.
139.	Washout Plug.
140.	Washout and Drain.
141.	Washout Plug.
142.	Washout Plug.
143.	Washout Plug.
144.	Auxiliary Valve Chest Covers.