Oct. 12, 1937. J. S. COFFIN, JR., ET AL 2,095,239

LOCOMOTIVE FEED WATER HEATING SYSTEM AND APPARATUS

Filed May 14, 1935 3 Sheets-Sheet 1

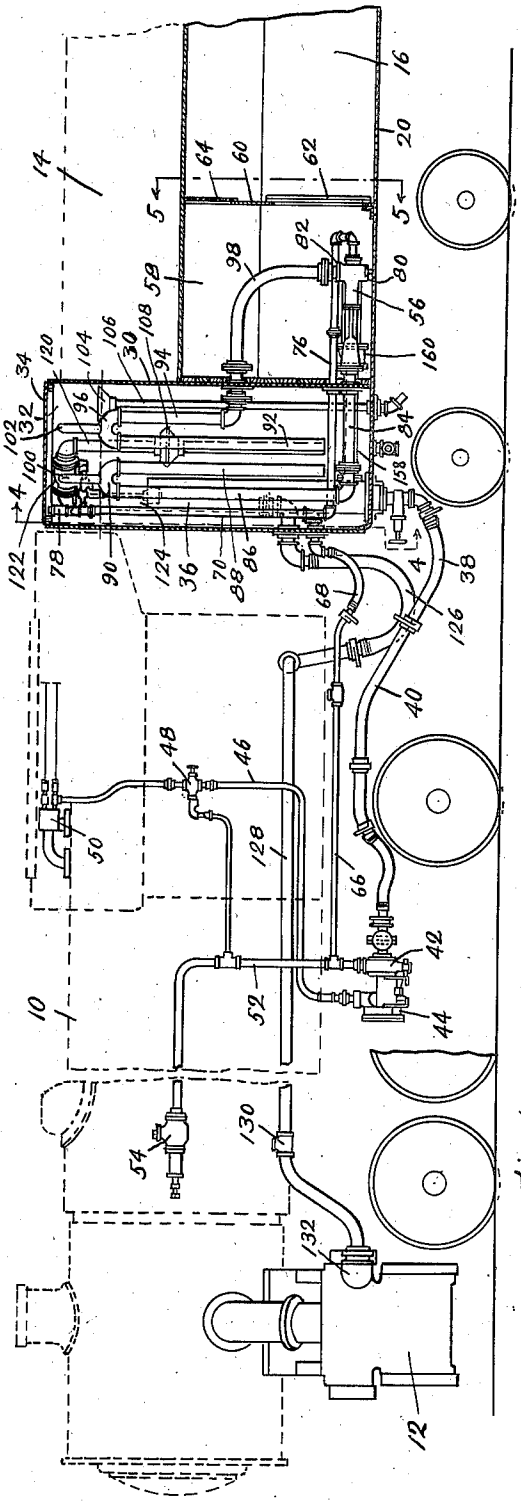

Fig. 1.

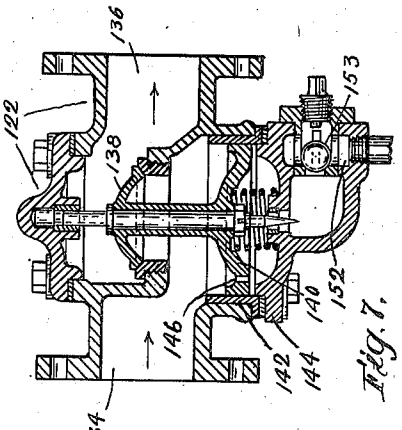

Fig. 7.

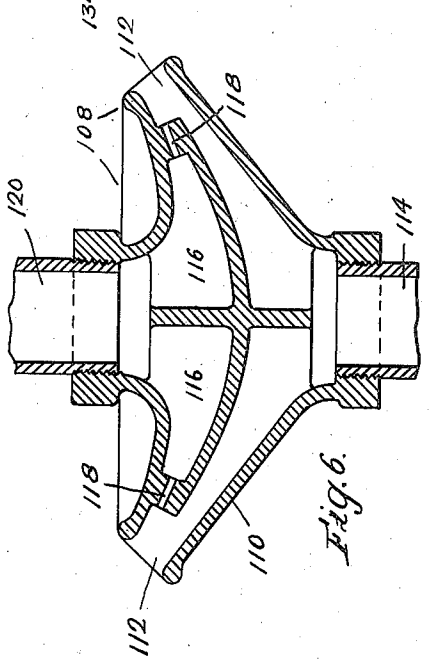

Fig. 6.

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LOCOMOTIVE FEED WATER HEATING SYSTEM AND APPARATUS

Filed May 14, 1935 3 Sheets-Sheet 2

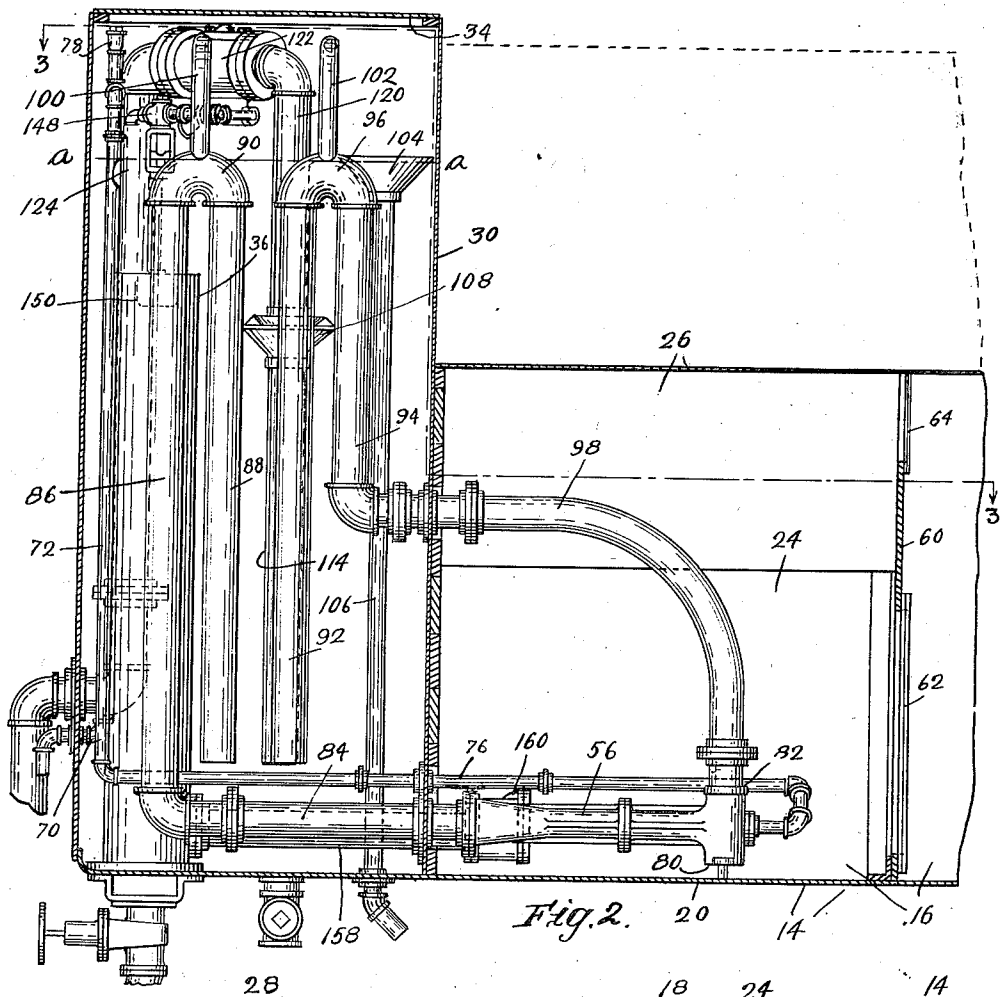

Fig. 2.

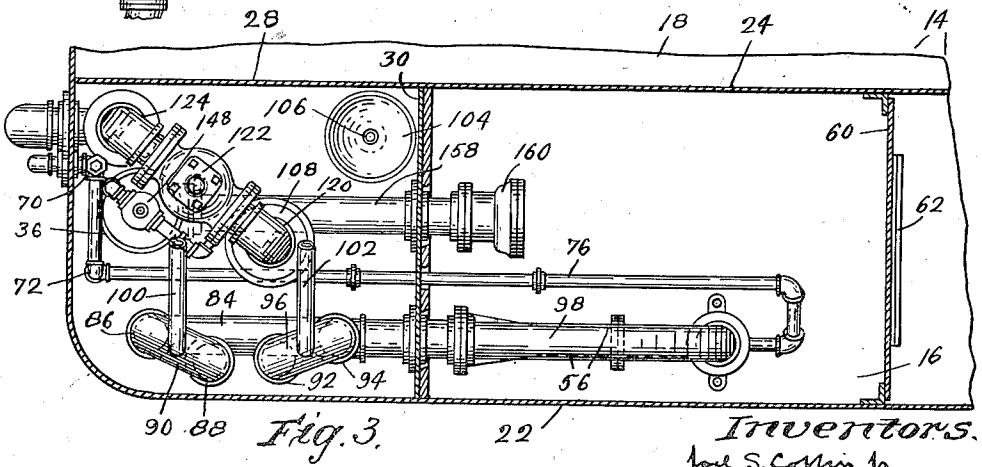

Fig. 3.

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LOCOMOTIVE FEED WATER HEATING SYSTEM AND APPARATUS

Filed May 14, 1935 3 Sheets-Sheet 3

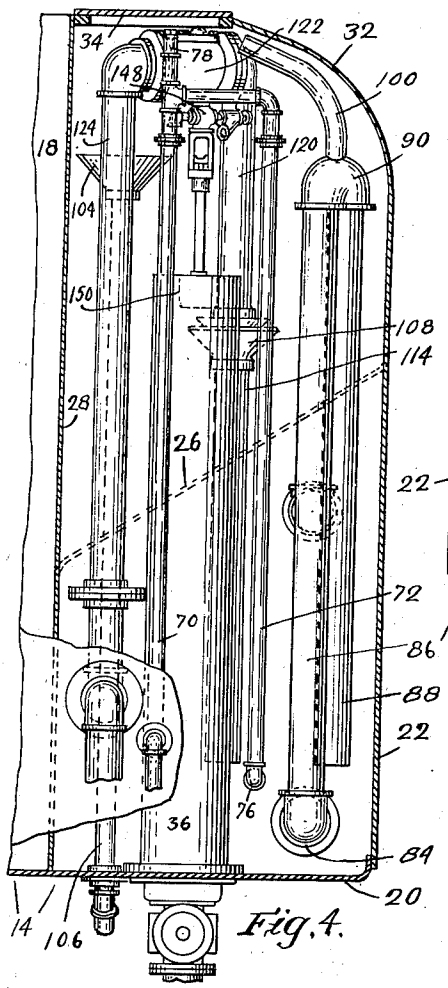


Fig. 4.

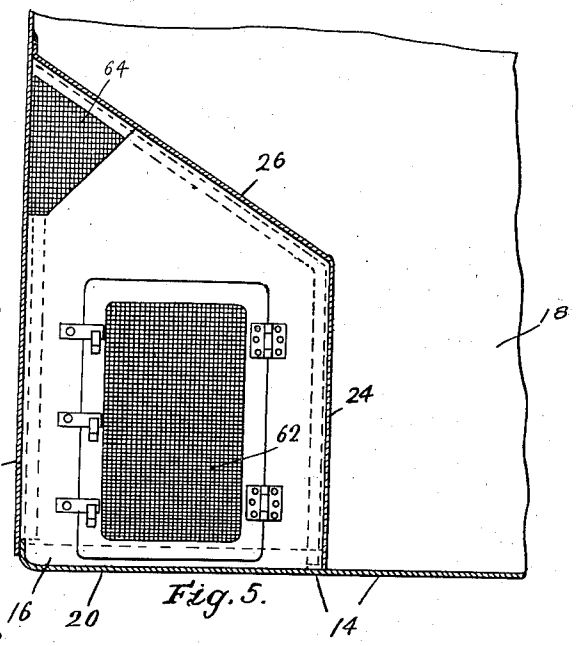


Fig. 5.

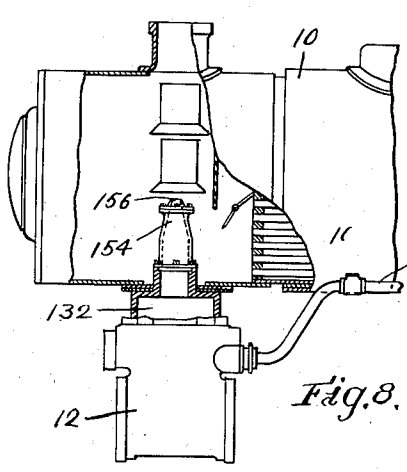
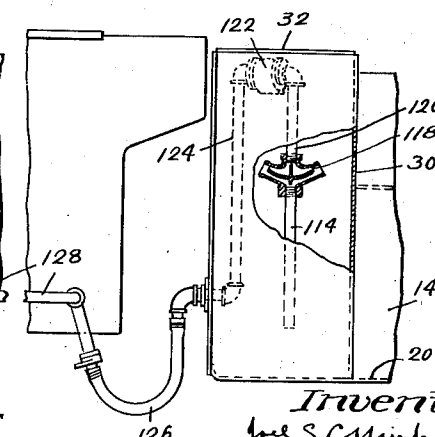


Fig. 8.



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Patented Oct. 12, 1937 2,095,239

UNITED STATES PATENT OFFICE

2,095,239

LOCOMOTIVE FEED WATER HEATING SYSTEM AND APPARATUS

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Application May 14, 1935, Serial No. 21,394

28 Claims. (Cl. 122—434)

This invention relates to a system and apparatus for heating the feed water supplied to a boiler and has particular reference to locomotive boilers wherein the feed water heating apparatus is located on the tender of the locomotive.

One of the objects of the present invention is an improved form of locomotive boiler feed water heating apparatus arranged to provide a constant supply of hot feed water sufficient at all times when the locomotive is in service to meet the demands of the boiler for water.

In a feed water heating system with which this invention is particularly concerned the locomotive boiler is supplied with feed water by a pump, usually although not necessarily a turbine driven centrifugal pump, which receives hot water from a heating compartment of the tender, the heating compartment being at atmospheric pressure and being heated usually by steam exhausted from the locomotive cylinders and receiving water from the cold water compartment of the tender. From the standpoint of economy it is desirable that the boiler feed water temperature be as high as possible which, with a feed water heating compartment at atmospheric pressure, is limited to the normal boiling point of the water. In ordinary practice, however, the temperature of the feed water must be kept considerably below the maximum possible temperature because of the inability of the feed water pump to handle hot water, it being understood that the pressure on the water is necessarily reduced at the pump inlet not only by the intake velocity of the water but to the action of the pump impeller on the water. If the water is exceedingly hot a sufficient reduction of pressure, commonly experienced, causes the water to boil or to flash into steam at the pump inlet and thereby stop or at least seriously interfere with the pumping action. Because of this action of the hot water in the pump the feed water temperature of atmospheric heaters, the water level in which corresponds with the cold water level of the tender, cannot utilize a high temperature of the heated water.

It is an object of the present invention to maintain a level of hot water above the inlet of the suction pipe of the pump, constantly as high as is practicable from the standpoint of space limitations above the maximum level of cold water in the tender, thereby increasing the pressure on the hot water at the pump inlet to such an extent that the water pressure is definitely above the boiling pressure of water at that temperature and consequently permitting that water of a higher temperature can be handled by the pump. With this arrangement and with a pump located below the bottom of the cold water space of the tender, as is usually the case, it is possible to have the temperature of the water in the water heating compartment of the tender at approximately the boiling point of water at atmospheric pressure since the head of water at the pump inlet can maintain the pressure on the flowing hot water therein at, or above, atmospheric pressure and thus the pump can handle the hot water without its flashing into steam.

A further object of the invention is the provision of a water heating compartment so arranged that the hot water is located in the top portion of the compartment and the suction pipe of the pump opens into the heating compartment in the top portion only thereof and above the maximum water level of the cold water in the tender so that under normal conditions of operation the cold water of the tender cannot find its way into the pump inlet. For emergency purposes as, for instance, when the elevated water level in the heating compartment cannot be maintained, it is desirable for the pump to draw cold water directly from the cold water space of the compartment and, for this purpose, the suction pipe of the pump is provided with a branch communicating directly with the cold water space, the branch having a check valve therein that is normally maintained closed by the elevated level of water in the heating compartment and suction pipe, but the valve being free to open when the water level in the suction pipe drops materially below the level of water in the cold water compartment. This arrangement constitutes a further object of the invention.

Another object of the invention is to maintain the elevated level of water in the heating compartment by a pump operated concurrently with the operation of the feed water pump to force water into the hot water compartment from the cold water space of the tender, any excess water overflowing from the heating compartment into the cold water space, but through the pump inlet, so that the overflowing water together with what additional cold water is required to make up the full capacity of the pump, can be returned to the heating compartment. When the pump is an injector operated by a part of the hot boiler feed water under pressure of the feed water pump the heat of the pumped water is thereby conserved. Furthermore, the overflow is so arranged that the overflowing water is always relatively cold water, that is to say, it is water that has not been heated by the heater in the heating

compartment and hence there is no loss of hot water from the compartment.

Under certain normal conditions of operation hot water is drawn from the heating compartment, cold water is forced into the compartment and at the same time the water in the compartment is being heated. In order to maintain a maximum temperature of hot water under these conditions it is highly desirable that there be relatively no commingling of the hot and cold water in the heating compartment and means for accomplishing this result constitutes a further object of this invention.

In carrying out this object of the invention the heating compartment is vertical, that is to say, its greatest dimension is vertically disposed and it has relatively small horizontal dimensions, and the outlet for the hot water is at the upper part thereof and the inlet for the cold water is at the bottom part thereof. The heater preferably is of the injector type operated by exhaust steam from the locomotive cylinders and preferably is disposed as nearly as practicable in the middle of the cross section of the heating compartment, and in the upper part thereof. According to well known principles the hot water introduced into the compartment tends to remain on top. The heater discharges hot water slowly and evenly throughout the cross-sectional area of the compartment, thereby in effect laying down the hot water in a hot water stratum that is relatively sharply segregated from the cold water.

Inasmuch as the direction of water flow through the compartment is vertical the effect is to maintain a zone of hot water of uniform or varying depth depending on the relative rates of heating and feed and a zone of cold water underneath it, the two zones being relatively sharply segregated so that only hot water flows into the entrance of the suction pipe of the pump. When the heater is operating with no water being drawn from or forced into the heating compartment the hot water stratum is of a constantly increasing depth until the entire contents of the heating compartment become heated. Such an arrangement constitutes a further object of the invention.

Heretofore atmospheric water heating systems have necessitated thermostatic control of the heating steam. It is an object of the present invention to provide a simple arrangement of water heating such that the amount of steam supplied to the water for heating it to the required temperature when taken over a substantial period of time is proportional to the water consumption of the locomotive boiler during this time so that the temperature of the boiler feed water can be maintained practically constant independently of thermostatic control devices, notwithstanding variable rates of steam discharged by the locomotive, caused by different loads or different throttle and cut-off settings, in relation to the arbitrary and sometimes intermittent rate of feed selected by the operator.

The exhaust steam from the locomotive is discharged through a draft nozzle into the locomotive stack. The draft nozzle can have a considerable range of dimensions that are suitable for drafting. Exhaust steam for heating the boiler feed water is taken from the exhaust steam cavity of the locomotive cylinders, from which cavity exhaust steam also passes through the draft nozzle. Thus the flow of heating steam at all times can be made a definite part of the total exhaust steam. In accordance with the present invention the flow of heating steam is so proportioned to the flow of steam through the draft nozzle, as by proper dimensionings of the draft nozzle and the steam orifice of the exhaust steam water heater, or the pipe conducting steam from the exhaust steam cavity to the heater, or the like, that the heat content of the steam supplied to the heater and available for heating the boiler feed water is such as to heat to the desired temperature an amount of water that will at all times be equivalent to the amount of water, represented by steam, discharged from the locomotive cylinders. Such an arrangment constitutes a further object of the invention.

A further object is generally to improve upon feed water heating systems and apparatus.

The invention herein described is in the nature of an improvement on the invention of Joel S. Coffin, Jr., Serial No. 722,498, filed April 26, 1934.

Fig. 1 is a diagrammatic side elevation of a locomotive and its tender in association with the feed water heating and supply system embodying the present invention.

Fig. 2 is an enlarged side elevation partly in section of the feed water heating compartment and associated apparatus illustrated in Fig. 1.

Fig. 3 is a plan view of the structure of Fig. 2 taken along line 3—3 of Fig. 2.

Fig. 4 is an end elevation taken along line 4—4 of Fig. 1.

Fig. 5 is a section taken along line 5—5 of Fig. 1.

Fig. 6 is a sectional detail of the water heater in the heating compartment.

Fig. 7 is a sectional detail of a temperature responsive valve controlling the flow of steam to the heater.

Fig. 8 is a diagrammatic view of the locomotive and heating compartment and illustrating the relation between the blast nozzle of the locomotive and the steam nozzle of the feed water heater.

The invention is herein shown applied to a locomotive having the boiler 10, the cylinders 12 and the tender 14. The tender 14 is provided with a forwardly extended cold water leg 16 located on one side of the coal pocket 18, see Fig. 5, and formed by the bottom wall 20, the outer wall 22, the inner wall 24 and the inclined top wall 26. The maximum water level in the cold water space of the tender in the form of tender shown in the drawings is represented by the junction of the inclined wall 26 and the outer side wall 22.

The feed water heating compartment comprising a part of the present invention is located at the forward end of the water leg 16 and is formed by the aforesaid bottom wall 20, the outer side wall 22 and the inner side wall 28, the rear wall 30, and the curved top wall 32, which has an opening at the top of the heating compartment removably closed by a cover 34, see Fig. 4.

In accordance with the present invention the heating compartment is vertical, that is to say, its vertical dimension is materially greater than its transverse dimension so that the compartment is relatively high and narrow. Preferably the heating compartment is as high as space and clearance limitations will permit so that the top of the compartment and the normal water level in the compartment is much above the maximum height of cold water in the tender.

Hot water is drawn from the top portion of the heating compartment into the open upper end of a pump suction pipe 36 which upstands in the heating compartment from the bottom wall thereof

and is terminated below the normal water level of the compartment and materially above the maximum cold water level of the tender. The lower end of the pipe **36** communicates through a hose bag **38** and other piping **40** with the inlet of a pump **42** herein illustrated as a centrifugal pump carried by the locomotive preferably below the bottom of the tender and driven by a turbine **44** supplied with steam through a steam line **46** and control valve **48** from the auxiliary turret **50** of the locomotive. High pressure hot water is delivered from the pump into a pipe **52** and through a boiler check valve **54** into the boiler.

Water pumping means operated concurrently with the boiler feed water pump **42** is utilized to deliver cold water from the cold water space of the tender into the feed water heating compartment. Said pumping means comprises an injector **56** located in the bottom part of an intake compartment **58** formed in the forward end of the water leg **16** by a transverse wall plate **60**. Said wall plate has a screened doorway **62** through which water can flow from the cold water space of the tender and the door of which can be opened to obtain access to the interior of the intake compartment. The uppermost part of the partition wall **60** is provided with a screened vent opening **64** to vent the intake compartment of air that might otherwise be entrapped in the upper portion thereof.

The injector **56** is operated by the hot pressure boiler feed water supplied by the boiler feed water pump **42** through a pipe **66** that communicates with the feed water delivery pipe **52** and through a hose bag **68** with the lower end of the leg **70**, see Figs. 1 and 4, of a siphon disposed within the heating compartment. Said siphon has its upper end located above the normal water level of the heating compartment and a lower leg **72** that extends into the bottom portion of the heating compartment and connects with a pipe **76** leading to the water nozzle of the injector. The uppermost portion of the siphon is provided with a vacuum breaking valve **78** which is normally closed under the influence of water pressure in the siphon but it opens when the feed water pump is idle and the pressure drops to or below atmospheric to allow air to enter the siphon and thereby to prevent water from flowing in the reverse direction through the pipe from the injector.

The injector is provided with a lower water inlet **80** and an upper water inlet **82** and delivers water through a pipe **84** and into the lower leg **86**, see Figs. 1 and 2, of a vacuum breaking siphon located in the water heating compartment and having another vertical leg or pipe **88**, the two pipes being connected in the top portion of the heating compartment by the connecting member **90**. The lower end of the pipe or leg **88** terminates close to the bottom of the heating compartment so that the cold water is delivered to the bottom of the compartment where there is little likelihood of its commingling with the hot water of the upper portion of the compartment.

Overflow water of the compartment passes into another vacuum breaking siphon comprising the vertical legs **92** and **94** connected at the top by the connecting member **96**, the connecting members of the two siphons **90**, **96**, being preferably at the same level. The leg **94** communicates with a pipe **98** that opens into the upper inlet **82** of the injector so that the overflowing water passes into the injector and can be re-introduced into the heating compartment, thereby conserving the heat of the overflow water. The lower end of the leg **92** terminates close above the bottom of the heating compartment so that the water that overflows is cold water except as it may be slightly heated by the hot pumping water.

The connecting members **90**, **96** of the vacuum breaking siphons are provided with vent pipes **100**, **102**, respectively, of substantial cross-sectional area that extend upwardly and are open to the uppermost part of the heating compartment. The dimensions of the pipes **86**, **88** through which the incoming cold water is passed are sufficiently great so that there is no material water pressure in the interior of the connecting member **90** and hence no water flows out of the vent pipe **100** when the injector is in operation, and the water issues quietly and without any material disturbance out of the pipe and into the bottom of the heating compartment. When the injector ceases to operate and the water level in the heating compartment descends below the bottom of the water passage in the connecting member **90** air passes through the vent pipe **100** into the interior of the siphon and thus prevents the siphoning of the water out of the heating compartment into the cold water space of the tender. A similar action takes place with respect to the siphon for the overflowing water.

The water level in the heating compartment can vary slightly depending upon whether or not the injector is operating. When the injector is operating the water passages in the connecting members **90**, **96** can flow more or less full of water so that the water level may be as represented by the line *a*—*a* Fig. 2. This level will be the maximum water level. When the injector is not operating and the feed water pump also is idle cold water will flow out of the heating compartment until the water level is at the bottom of the water passage in the connecting member **96**. This variation in water level is of no particular moment and can if desired be reduced by making the water passages in the connecting members **90** and **96** shorter in vertical height and correspondingly longer horizontally. The water level, however, is at all times materially above the maximum water level of the cold water space of the tender.

An oil skimmer in the shape of a funnel **104** has its large open upper end disposed slightly above the water level in the heating compartment so that oil that is introduced into the water through the exhaust steam used for heating and rises to the surface of the water, can be skimmed off the surface when the water in the compartment surges due to change of speed of the locomotive, the oil flowing downwardly through the pipe **106** to the underside of the tender where it is discharged on the track. The pipe may also constitute the vent for the heating compartment that maintains the interior of the compartment at atmospheric pressure.

The water in the heating compartment is heated preferably by a heater **108** of the steam ejector type. This heater, as shown in cross section in Fig. 6, includes an inverted conical casing **110** having an annular hot water discharge orifice **112** in communication with a vertical cold water intake pipe **114** opening into the bottom part of the heating compartment in the cold water zone. The ejector is also provided with a steam chamber **116** communicating with an annular or substantially annular steam orifice **118** which discharges into the water orifice **112** and induces a flow of water, the steam condensing and thereby heating the water.

The heater is located in the middle of the cross section of the heating compartment somewhat below the water level. The construction and arrangement of the heater is such that hot water flows relatively slowly therefrom so as not deleteriously to agitate the water in the compartment and the hot water is distributed as a sheet or layer across the compartment. With this arrangement definite stratification or segregation of the hot and cold water zones in the compartment can be obtained when water is being drawn from and flows into the compartment. The direction of water movement in the compartment is upward so that when water is fed into and drawn from the compartment, a good separation of the hot and cold water zones is obtained. When the locomotive is not working and no steam is passing into the compartment as hot water is drawn from the upper portion, the zone of hot water at the top is constantly diminishing in depth. When the heater is operating without water being drawn from the heating compartment the hot water zone progressively increases in depth until the entire contents of the compartment are ultimately brought to maximum temperature. In the meantime the water level in the locomotive boiler has been drawn down to a level at which it is necessary to withdraw water from the compartment for feed and in order to restore the boiler water level to its original value feeding will have to be continued after the locomotive ceases working or will have to be carried on at a greater rate than steam is being evaporated. During this time the hot water zone progressively contracts in depth until the locomotive boiler is full when the above cycle may be repeated.

The ejector heater operates to deliver hot water at a more or less constant temperature irrespective of the exhaust steam pressure. That is to say, a higher steam pressure, for instance, induces a proportionally higher flow of cold water so that the water temperature in the upper part of the heating compartment tends to remain approximately uniform, and a storage of heat, which occurs when the boiler feed water pump is shut off, manifests itself by a deepening of the hot water zone rather than by an increase of temperature of the hot water.

If on the other hand water is evaporated at about the same rate at which water is being fed the depth of the hot water zone remains substantially constant. The present invention contemplates proportioning the volume of the hot water compartment in a more or less defined ratio to the volume of water in the locomotive between the high and low gauge glass levels depending on whether the feed and working of a particular locomotive is alternating as in switching service or coordinated as in road service, the switching service requiring a larger compartment.

Steam is supplied to the heating ejector by a pipe **120** which communicates with the steam chamber **116** of the ejector at its lower end and with the outlet of a thermostatically operated control valve **122** illustrated in cross section in Fig. 7. Steam enters the valve **122** through a vertical pipe **124**, the pipes **120** and **124** together with the valve **122** forming a vacuum breaking siphon functioning in an obvious manner. The lower end of the pipe **124** receives steam through a hose bag **126**, see Fig. 1, piping **128**, and a check valve **130** from the exhaust steam cavity **132** of the locomotive cylinders so that steam is available for operating the heater whenever the locomotive cylinders are supplied with steam.

The valve **122** is constructed essentially as described in the copending application of Joel S. Coffin, Jr., Serial No. 744,298, filed April 26, 1934, and as described and claimed in the copending application of George W. Emery, Serial No. 742,257, filed August 31, 1934, both applications and the present application having a common assignee. Said valve **122** has a steam inlet passage **134** and an outlet passage **136**, the flow of steam between which is controlled by a valve member **138** responsive to pressure differences on opposite sides of a piston **140** operating in a cylinder **142**, the upper end of which is open to the inlet passage **134** and the lower end of which is closed by a cover **144**. The arrangement is such that when the pressure difference on opposite sides of the piston **140** acts in a downward direction it effects the closing of the valve **138**. A resultant pressure on the piston in the opposite direction effects the opening of the valve. Pressure fluid in the inlet passage **134** can leak into the cylinder on the underside of the piston through a suitable leak passage **146**. Thus if the valve **138** is initially closed and the space beneath the piston is closed and at a lower pressure than that existing in the inlet passage **134**, steam can flow into the closed lower end of the cylinder and more or less equalize the pressure on both sides of the piston so that the pressure acting directly on the underside of the valve **138** can open the valve. The operation of the valve is controlled by a pilot valve **148**, see Fig. 2. This valve is of common construction and is open and closed in response to the temperature of the water in the heating compartment by a thermostatic bulb **150**. The valve **148** controls the opening and closing of the vent passage **152** of the lower part of the cylinder **146** of the main valve **122**. The arrangement is such that when the temperature of the water in the heating compartment reaches a selected high point the pilot valve **148** is caused to be opened to allow the cylinder on the underside of the piston **140** of the valve to vent freely into the atmosphere in the top of the heating compartment, thereby to effect the closing of the valve. When the temperature of the water drops to a selected low point the valve **148** is caused to be closed thereby permitting pressure to be built up on the underside of the piston **140** of the main valve to effect the opening of the main valve and allow steam to flow into the heater. A siphon breaking check valve **153** is in the vent passage **152**.

With the present invention the use of the thermostatically controlled valve **122** while perhaps desirable for some installations is not imperative for all installations. As a part of this invention the arrangement of the heater and its steam supply is such that the heat supplied to the water is so proportioned to the amount of water, discharged as steam, consumed by the locomotive boiler that the water passing to the feed water pump is heated to approximately a constant temperature. The exhaust steam cavity **132** of the locomotive cylinders, see Fig. 8, discharges exhaust steam into the draft nozzle **154** of the locomotive boiler. Thus when the engine cylinders are taking steam the total steam exhausted from the engine cylinders is discharged through the orifice **156** of the draft nozzle and the orifice **118** of the water heater. Hence each orifice passes a certain definite proportion of the total exhaust steam, which proportion depends mainly upon the relative cross-sectional areas of the

orifices. This proportion is constant regardless of variations of amount of exhaust steam except as the proportion may be varied slightly with different amounts of exhaust steam due to pipe friction and the like. Since the weight of exhaust steam exhausted at any given time ultimately has to be made up by an equal weight of water delivered into the boiler and since the water heating effect obtained by condensing the steam is greater than the heat required to raise an equivalent weight of water to approximately the boiling point at atmospheric pressure, it follows that by passing a definite proportion of the total amount of exhaust steam into the feed water heater the feed water required to make up for boiler water consumed as steam can be heated automatically to the desired temperature by the time it is needed in the boiler. To this end the cross sectional area of the steam orifice 118 of the water heater bears a certain definite relation to the cross sectional area of the orifice 156 of the draft nozzle as to effect the desired result with any particular locomotive with which the feed water heating system is associated. This relation can also be obtained by suitable dimensioning of the exhaust steam pipe to the heater, and the like.

The water capacity of the heating compartment when the locomotive service is such that evaporation and feed take place alternately is intended to be approximately equal to the volume of water contained in the locomotive boiler between the high and low water level marks on the gauge glass. With this intermittent operation of the feed water system there will be a time when the boiler is filled with water to the high water level and the heating compartment is filled with cold water. With the ratio of orifice areas in the water heater and in the draft nozzle above referred to by the time the water in the boiler has descended to the low water level the amount of steam that has been passed into the water heater will be just sufficient to heat the water in the heating compartment to the desired temperature regardless of the variableness of the rate at which the water in the boiler has been converted into steam and exhausted from the engine cylinders and, of course, assuming no heat losses in the heating compartment due to radiation and the like which can be suitably compensated for. The feed water pump can then be set in operation to discharge the hot water into the boiler and replenish the water supply therein. The same heating effect takes place even though the pump is started say when only half the water between high and low water level marks of the boiler gauge glass has been consumed and the locomotive continues working. In this case the heating compartment will be approximately half full of heated water, the hot water being in the upper portion of the compartment. The pump takes water from the heating compartment but the steam heater lays down a constantly replenished strata of hot water so that the pump always receives the hot water discharged from the heater free from any material commingling with the cold water that may occupy the lower portion of the compartment. Thus the boiler is at all normal times supplied with hot water so that the use of the thermally controlled valve 133 is not imperative.

By having the water level of the heating compartment a substantial distance above the maximum water level of cold water in the tender the pressure on the pump inlet is increased so that water at a higher temperature can be handled by the pump. Furthermore, since the water level in the heating compartment is at all normal times at a practically constant amount above the maximum cold water level of the tender the temperature of the water that can be effectively handled by the pump can be at some constant high value since it is not influenced by and does not have to decrease with the decreasing cold water level of the tender.

In the event of failure of the injector 56 to maintain the normal high water level in the heating compartment and the water level therein drops below the top of the pump suction pipe 36 and materially below the cold water level in the tender, means are provided to permit the pump to draw cold water directly from the cold water space of the tender. For this purpose a pipe 158, see Figs. 1, 2 and 3, is connected with the bottom part of the suction pipe 36 at the bottom of the heating compartment and passes through the rear wall 30 thereof into the bottom of the intake compartment 58 where it terminates in a check valve 160. The check valve is normally closed by the elevated head of water in the heating compartment but is free to be opened by the lack of head of water in the heating compartment, or the pump suction pipe 150, thereby to permit the pump to draw water directly from the cold water space of the tender. Cold water will be drawn by the pump, however, only when the water level in the heating compartment drops below the top of the pump suction pipe.

We claim:

1. Locomotive boiler feed water heating apparatus comprising a tender having a cold water space, a vertical heating compartment having a normal water level materially higher than the maximum cold water level in said space, means for heating the water in said compartment operative to draw water from the bottom part of said compartment and to deliver heated water to the top part thereof, means for introducing cold water from said cold water space into the bottom part of said compartment, and pumping means drawing hot water from the top part of said compartment.

2. Boiler feed water heating apparatus comprising a cold water space, a water heating compartment that has a normal water level above the top of said cold water space, means for introducing water from said cold water space into the lower part of said heating compartment, a suction pipe opening into said heating compartment under the normal water level and in the upper part of said compartment, a feed water pump drawing hot water through said suction pipe, and heating means for the water in said heating compartment drawing water from the lower part of and delivering hot water into the upper part of said compartment.

3. Boiler feed water heating apparatus comprising a cold water space, a water heating compartment that has a normal water level above the top of said cold water space, a suction pipe opening into said heating compartment under the normal water level and above the top of said cold water space, a feed water pump drawing hot water through said suction pipe, heating means for the water in said compartment, a pipe communicating between said suction pipe and the bottom part of said cold water space, and a check valve in said latter pipe so disposed

that it normally is maintained closed by the higher head of water in said suction pipe.

4. Locomotive boiler feed water heating apparatus comprising a tender having a source of cold water, a tall, narrow heating compartment on the tender, a pump drawing hot water from the top of said compartment, means operated by said pump for introducing cold water from said source into the bottom part of said compartment, water heating means for the water of said compartment, and steam supply means for said heating means, said heating means being characterized by maintaining stratified bodies of hot and cold water in the upper and lower parts of said compartment when water is flowing therethrough and irrespective of the relative rates of flow of hot water out of said compartment and steam into said heating means.

5. Locomotive boiler feed water heating apparatus comprising a tender having a source of cold water, a tall, narrow heating compartment on the tender, a pump drawing hot water from the upper part of said compartment above the maximum water level of said source of cold water, means introducing cold water into the bottom part of said compartment, and heating means located near the top of said compartment for heating the cold water in said compartment and delivering the hot water to the upper part of said compartment in a stratum that is isolated from the cold water.

6. Locomotive boiler feed water heating apparatus comprising a tender having a source of cold water, a tall, narrow heating compartment on the tender, a pump drawing hot water from the upper part of said compartment above the maximum water level of said source of cold water, means introducing cold water from said source into the lower part of said compartment, and a heater for the water in said compartment having means by which the heated water is delivered substantially uniformly throughout the cross-sectional area of said compartment in the upper portion thereof segregated from the cold water in the compartment.

7. Locomotive boiler feed water heating apparatus comprising a tender having a cold water source, a tall vertical heating compartment on the tender having relatively small horizontal dimensions, a pump drawing hot water from the upper portion of said compartment, means introducing cold water from said source into the lower portion of said compartment, and heating apparatus comprising a steam ejector drawing water from the cold water part of said compartment and having means for delivering hot water in a substantially continuous annular sheet horizontally in the intermediate part of said compartment.

8. Locomotive boiler feed water heating apparatus comprising a tender having a cold water source, a tall vertical heating compartment on the tender having relatively small horizontal dimensions, and a hot water outlet at the top and a cold water inlet at the bottom, and heating means for the water in said compartment comprising a steam injector located between said outlet and inlet having an annular generally horizontal discharge nozzle located generally in the vertical axis of said compartment and having an inlet in the lower part of said compartment for drawing water from the cold water portion of said compartment and delivering a substantially continuous annular sheet of hot water horizontally in the upper part of said compartment.

9. Locomotive boiler feed water heating apparatus comprising a tender having a source of cold water, a vertical heating compartment on the tender having relatively small horizontal dimensions, a pump for drawing hot water from the upper portion of said compartment, means for introducing cold water into the bottom portion of said compartment so that the flow of water through said compartment is in a vertical direction when said pump and said means is operating, and means for heating the flowing water in said compartment at the time hot water is drawn therefrom in such manner as to maintain a body of hot water above and segregated from the body of cold water.

10. Locomotive boiler feed water heating apparatus comprising a tender having a source of cold water, a heating compartment on the tender, a heater for the water in said compartment, a pump for introducing cold water from said source into said heating compartment, and overflow means for excess water in said heating compartment conducting cold water from the lower part of said compartment to the inlet of said pump.

11. Locomotive boiler feed water heating apparatus comprising a tender having a source of cold water, a heating compartment on the tender, a pump drawing hot water from said compartment, an injector operated by the pressure hot water of said pump for delivering cold water from said source into said heating compartment, a heater in said compartment delivering hot water to the upper portion of said compartment above the cold water in the bottom portion thereof, and overflow means for said compartment conducting cold water therefrom into the inlet of said injector.

12. Locomotive boiler feed water heating apparatus comprising a tender having a source of cold water, a heating compartment on the tender, a pump drawing hot water from said compartment, an injector operated by the pressure of the hot water of said pump for delivering cold water from said source into said heating compartment, a heater in said compartment delivering hot water to the upper portion of said compartment above the cold water in the bottom portion thereof, and overflow means for said compartment conducting cold water therefrom into the inlet of said injector, said injector having another inlet receiving cold water directly from said source.

13. Locomotive boiler feed water heating apparatus comprising a tender having a cold water space and a heating compartment, heating means in said compartment taking cold water from the lower portion and delivering hot water into the upper portion of said compartment, a pump drawing hot water from the upper portion of said compartment, means introducing cold water from said cold water space into the lower portion of said compartment, and overflow means for said compartment having an inlet in the lower portion of said compartment for conducting cold water only from said compartment.

14. Locomotive boiler feed water heating apparatus comprising a tender having a heating compartment, means drawing hot water from one portion of said compartment, means introducing cold water into another portion of said compartment, heating means taking cold water from the cold water portion of said compartment and delivering hot water into the hot water portion of said compartment, and overflow means conducting cold water only from said compartment, said overflow means comprising a siphon pipe having one

leg open to the cold water zone of said compartment and the other leg open outside of and below the water level in said compartment and its bend at the normal water level and vented to the atmosphere.

15. Boiler feed water heating apparatus comprising a cold water compartment, a heating compartment higher than said cold water compartment, means for limiting a high water level in said heating compartment that is higher than the water level in said cold water compartment comprising a siphon pipe having its bend vented to the atmosphere located at a point above the water level in said cold water compartment and having one leg open to the bottom portion of said heating compartment and its other leg open to said cold water compartment, a heater for the water in said heating compartment, a pump for drawing hot water from the upper portion of said compartment, and means for introducing water from said cold water compartment into the bottom portion of said heating compartment.

16. Boiler feed water heating apparatus comprising a cold water compartment, a heating compartment that is higher than said cold water compartment, a siphon for returning excess cold water from said heating to said cold water compartment and for limiting the high water level in said heating compartment at a point that is higher than the top of said cold water compartment, a pump for drawing hot water from the upper portion of said heating compartment, means for introducing cold water from said cold water compartment into the bottom portion of said heating compartment, and means for heating cold water from the bottom portion of said heating compartment and delivering the heated water in the upper portion of said heating compartment segregated from the cold water therein.

17. Locomotive boiler feed water heating apparatus comprising a tall and narrow heating compartment, a pump for drawing hot water from the upper portion of said compartment, means for introducing cold water at low velocity into the bottom portion of said compartment, and heating means for drawing cold water from the bottom portion of said compartment and heating it and delivering the heated water in an annular stream at low velocity substantially horizontally in the upper portion of said heating compartment, the velocity of the cold water and the heated water being sufficiently low so that the bodies of hot and cold water above and below the heating means are substantially stratified.

18. Boiler feed water heating apparatus comprising a cold water compartment, a heating compartment having a water level higher than the water level in said cold water compartment, and means for introducing cold water from said cold water compartment into said heating compartment, comprising a pump having an inlet open to said cold water compartment below the water level thereof, and a siphon into one leg of which said pump discharges, said siphon having its other leg open to the bottom portion of said heating compartment and having its bend located at least at the water level of said heating compartment and vented to the atmosphere.

19. Boiler feed water heating apparatus comprising a cold water compartment, a heating compartment having a water level higher than the water level in said cold water compartment, and means for introducing cold water from said cold water compartment into said heating compartment, comprising a pump having an inlet open to said cold water compartment below the water level thereof, a siphon into one leg of which said pump discharges, said siphon having its other leg open to the bottom portion of said heating compartment and having its bend located at least at the water level of said heating compartment and vented to the atmosphere, and an overflow siphon for said heating compartment having one leg open at the bottom portion of said heating compartment and its other leg open to said cold water compartment and its bend located at the water level of said heating compartment and vented to the atmosphere.

20. Boiler feed water heating apparatus comprising a cold water compartment, a vertical heating compartment higher than the top of said cold water compartment and having relatively small horizontal dimensions, a siphon in said heating compartment for determining the water level therein having one leg open to the bottom portion of said heating compartment and its other leg open to said cold water compartment, and its bend located above the top of said cold water compartment and vented to the atmosphere, an injector for forcing water from said cold water compartment into said heating compartment having an inlet opening into said cold water compartment, a siphon into which said injector delivers water, said siphon having one leg connected to the outlet of said injector and its other end opening into the bottom portion of said heating compartment and its bend located at least not below the water level in said heating compartment and vented to the atmosphere, a suction pipe in said heating compartment having its open upper end disposed under the water level in said heating compartment and above the top of said cold water compartment, a pump drawing hot water through said suction pipe, and a heater in said heating compartment drawing cold water from the lower portion thereof and delivering the heated water in an annular stream crosswise of said heating compartment.

21. Locomotive boiler feed water heating apparatus comprising the combination with the locomotive boiler, its cylinders and draft nozzle of a heating compartment having a water capacity approximately equaling that of the boiler capacity between high and low water levels, an exhaust steam water heater for the water of said heating compartment having a steam orifice discharging steam into the water, means for supplying said heater and draft nozzle with exhaust steam from said locomotive cylinders whenever exhaust steam is available, the areas of said draft nozzle and said heater orifice being so proportioned that the amount of steam discharged through said heater orifice is such that the amount of water in said compartment is heated to the desired temperature at about just the time when the amount of the water in the boiler between high and low level marks has been consumed, said heater being constructed to circulate the water in said compartment in proportion to the amount of steam supplied to it and to discharge water at the high feed water temperature, a boiler feed water pump drawing water from said compartment, and means for maintaining a constant water level in said compartment at all times when said pump is drawing water therefrom including means operative positively with each operation of said pump for introducing cold water into said compartment.

22. Locomotive boiler feed water heating apparatus comprising in combination with a lo-

comotive boiler its cylinder and draft nozzle, of a water heating compartment having approximately the water capacity of the boiler between high and low level water marks, a pump drawing hot water from the top part of said compartment and delivering the hot water to said boiler, means for introducing cold water into the bottom part of said compartment, a steam heater for the water in said compartment having an orifice discharging steam into intimate contact with the water, said heater having means for maintaining a stratification of the hot water above and the cold water below it, and means for supplying said heater and draft nozzle with exhaust steam from said cylinders whenever exhaust steam is available, said steam orifice and said draft nozzle being so proportioned that the amount of steam supplied to said heater is sufficient to heat to the desired temperature a weight of water equivalent to the weight of exhaust steam, said heater having means to circulate the water in said compartment in proportion to the amount of steam supplied to it and to discharge hot water at the high feed water temperature above the heater.

23. Locomotive boiler feed water heating apparatus comprising, in combination with the locomotive boiler and its cylinders, of a water heating compartment having a hot water zone and a cold water zone, exhaust steam heating means therein, a boiler feed water pump having an inlet in said hot water zone, means for maintaining a constant level of water in said compartment at all times including means operating positively with each operation of said pump for introducing cold water into said cold water zone, and means for automatically supplying exhaust steam to said heater in proportion to the water consumption of said boiler, said heating means having means to circulate the water in said compartment in proportion to the amount of steam supplied to it and to discharge hot water at the high feed water temperature into said hot water zone.

24. Locomotive boiler feed water heating apparatus comprising a tender having a cold water space and a heating compartment, a hot water withdrawal conduit opening into the upper part of said compartment, means for introducing cold water from said cold water space into the bottom part of said heating compartment, heating means for the cold water in said compartment operative to supply the water space of the compartment above said heating means and at the opening of said conduit with hot water.

25. Locomotive boiler feed water heating apparatus comprising a tender having a cold water space and a heating compartment, a hot water withdrawal conduit opening into the upper part of said compartment, means for introducing cold water from said cold water space into the bottom part of said heating compartment, heating means for the water in said compartment operative to supply the water space of the compartment above said heating means and at the opening of said conduit with hot water, and an overflow conduit establishing communication between the cold water zone in the bottom part of said compartment and said cold water space.

26. Locomotive boiler feed water heating apparatus comprising a tender having a cold water space and a heating compartment, a withdrawal conduit opening into the upper part of said compartment, a boiler feed water pump located below the opening of said conduit and operative to draw hot water therethrough, a steam heater operative to supply the water space of the compartment above said heating means and at the opening of said conduit with hot water, and means for maintaining a substantially constant head of water above said conduit opening when said pump is operating including means operatively responsive to the operation of said pump to introduce cold water from said cold water space into the bottom part of said compartment under said heater, and an overflow conduit opening at one end in the cold water zone in the bottom part of said compartment and at the other end into said cold water space.

27. Locomotive boiler feed water heating apparatus comprising a cold water supply having a variable water level, a heating compartment, a boiler feed water pump located below the level of water in and drawing water from said compartment, means to maintain a materially higher substantially constant normal water level in said compartment than the maximum cold water level at all times when said pump is drawing hot water including means automatically and positively operative in response to each operation of said pump for transferring water from the cold water supply to said heating compartment, and exhaust steam means for heating the water in said heating compartment when exhaust steam is available and both when and when not cold water is entering said compartment.

28. Locomotive boiler feed water heating apparatus comprising a tender having a cold water space, a vertical heating compartment that is higher than the top of the cold water space and has a normal water level above the top of said space, exhaust steam means for heating the water in said compartment irrespective of introduction of water therein, a pump drawing hot water from said compartment and located below the bottom of said cold water space, and means operating positively in response to each operation of said pump for transferring water from said cold water space into said compartment and for maintaining said normal water level therein constant at all times.

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