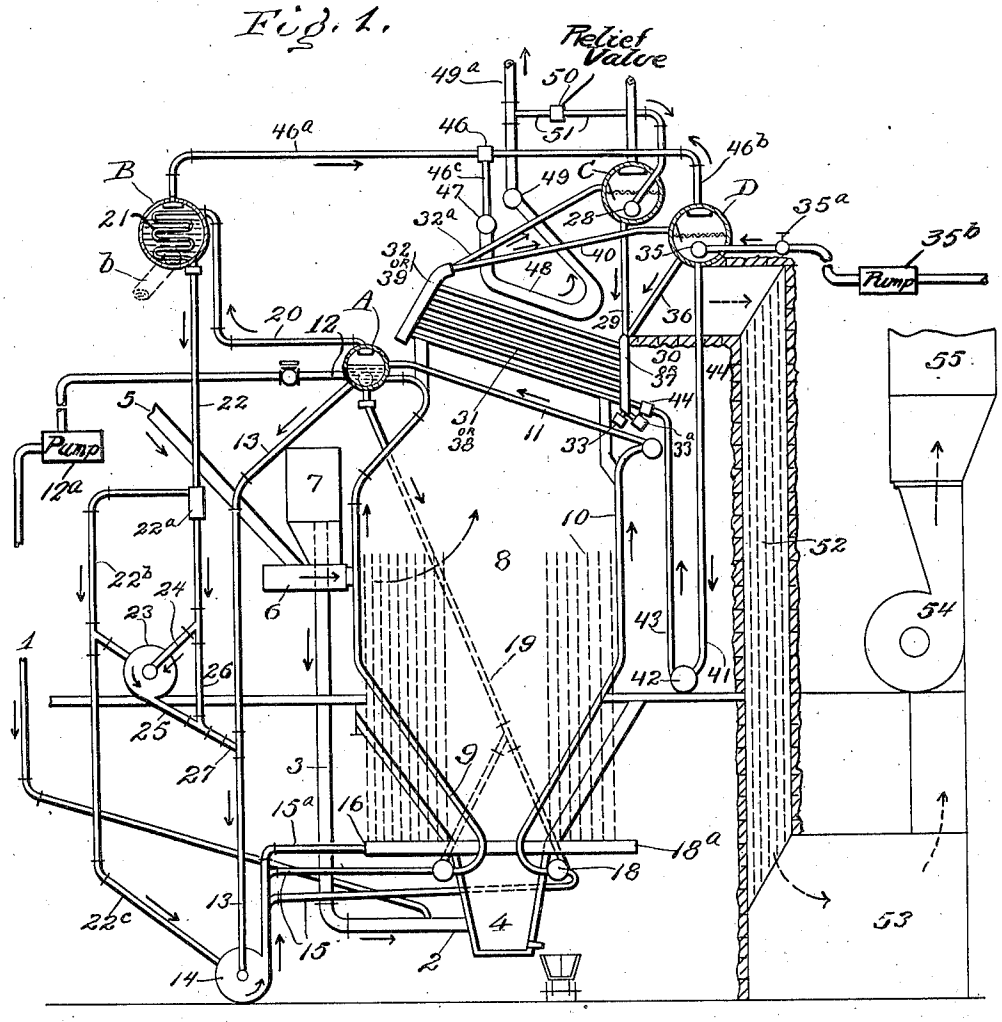
Dec. 26, 1933. J. G. COUTANT 1,940,663

STEAM GENERATING SYSTEM

Filed Nov. 20, 1930 4 Sheets-Sheet 1

Fig. 1.



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STEAM GENERATING SYSTEM

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Fig. 2.

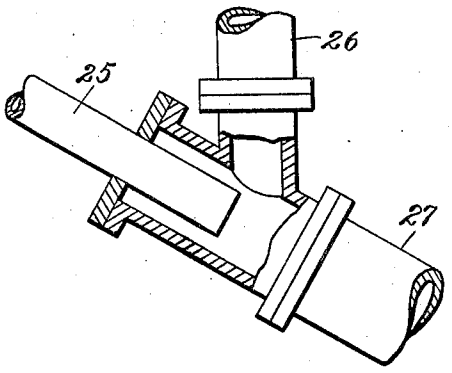


Fig. 3.

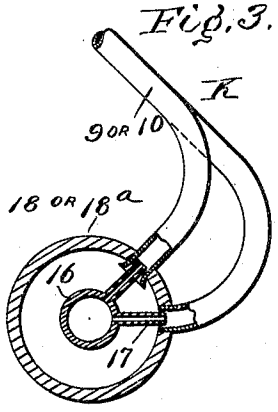


Fig. 4.

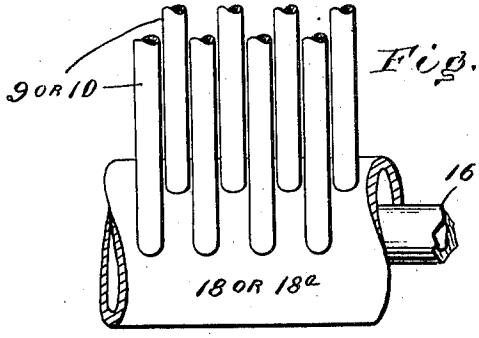


Fig. 5.

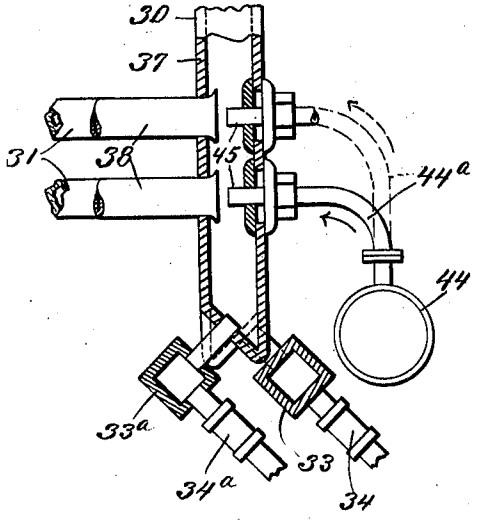
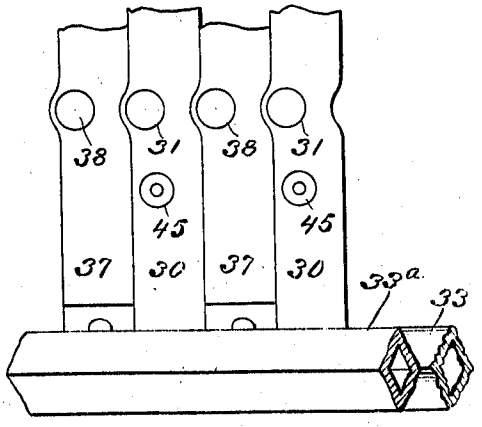


Fig. 6.



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STEAM GENERATING SYSTEM

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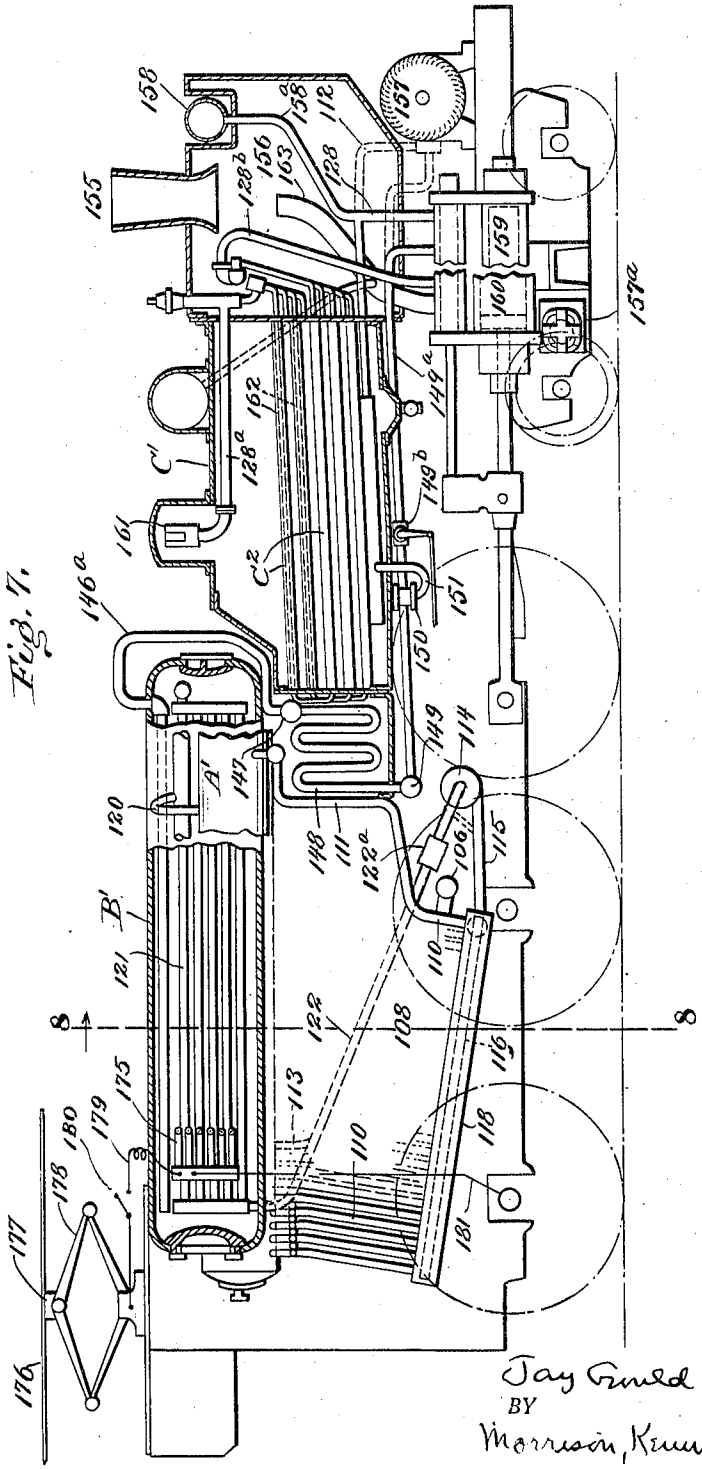


Fig. 7.

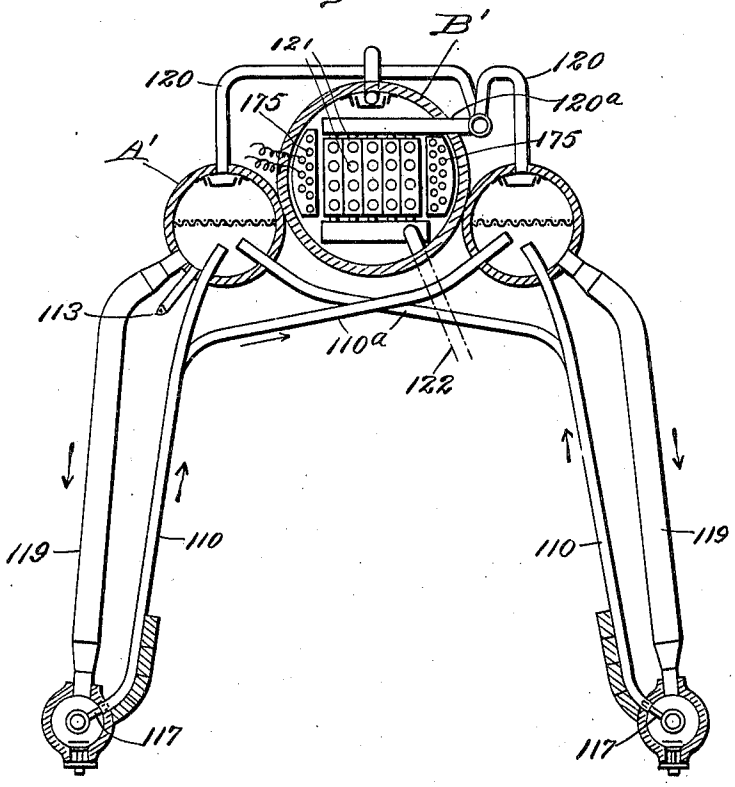
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STEAM GENERATING SYSTEM

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Fig. 8.



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UNITED STATES PATENT OFFICE

1,940,663

STEAM GENERATING SYSTEM

Jay Gould Coutant, New York, N. Y.

Application November 20, 1930, Serial No. 496,870, and in France November 22, 1929

8 Claims. (Cl. 122—33)

This invention relates to steam generating systems, such as are used in various fields, for example for power houses or other stationary uses, for locomotives, or marine uses, and for various purposes, particularly for supplying steam to drive steam turbines or other forms of engines.

One important feature of this invention is the generation of steam under a succession of different pressures, in which aspect it is herein referred to as a multiple pressure steam boiler or generator.

The main object of the invention, in this aspect, is that central power station boilers, including those existing in use, may be improved to deliver dry steam simultaneously at different and preferably constant pressures, and at substantially maximum temperatures, as may be required for example with the employment of high, intermediate and low pressure steam engines or turbines. A secondary object is to afford continuous service with ordinary feed water conditions, by avoiding the necessity of taking the boiler out of service for cleaning.

The multiple pressure steam boiler of this invention may occupy only the same space as an ordinary boiler, while yet producing as much as twice the weight of steam, and supplying the turbines with four times the energy. It may be installed as hereinbelow disclosed so as to require substantially no increase of flue area, or of induced draft capacity, or of chimney for handling the increased weight of gases, which will be at lower temperatures.

Other objects and advantages of the invention are the elimination of feed water evaporators and heaters, also the substitution of air preheaters for economizers. These objects are accomplished for example by feeding raw water to a lower pressure drum (e. g. standing a pressure of 25 kilograms per square centimeter), where it is evaporated, to be later utilized and bled from turbines or condensed; and then feeding it to a high pressure drum (100 kgs. per sq. cm.) where it is again evaporated, later utilized and bled from turbines or condensed, and then supplying a portion of it to a super high pressure drum (150 kgs. per sq. cm.) Here it is evaporated in small diameter thin wall bare tubes in which it may be caused to flow by an induced-forced system of circulation through water walls and slag screen, that afford maximum radiant heat absorption per square meter of wall surface. All of these advantages and actions are for obtaining the maximum efficiency and affording the largest return on money invested.

The results described cannot be obtained with known modern high pressure boilers for the following reasons. (*a*) It is the present practice to locate the boiler in a new building space or else the old low pressure boiler is removed to provide space for a high pressure unit. (*b*) Old boilers are usually replaced by a steam reheater made in the form of a superheater which receives exhaust steam from the high pressure turbines, and which has not any thermal storage such as a drum, and resulting in fluctuations in temperature and pressure. (*c*) The change from old boilers to reheaters involves a complete change in piping, which is a substantial expense. (*d*) Steam reheaters with the usual high pressure boiler arrangements require distilled water, and therefore involve the additional expense of economizers and evaporators. (*e*) Known high pressure boilers have large tubes, with thick metal walls, required for natural water circulation for carrying away heat. As the tube wall thickness increases, it is essential to provide more diffusion of radiant heat and reduction of heat absorption, to prevent overheating of metal. Therefore it is necessary to locate such bare tubes a great distance from flame or to cover with cast iron; such arrangements being usually highly costly and affording only an absorption of a portion, say one-half, the amount of heat. (*f*) It is customary with present high pressure boilers to evaporate water in tubes directly exposed to radiant heat of the fire, using distilled water, to avoid scale formations, while leakage of condensers sometimes causes poor boiler feed water, compelling taking the boiler out of service for cleaning. (*g*) Natural circulation in high pressure boilers and water walls often results in overheating of metal by local intense heating, where the water evaporated does not change the difference in static head or hydrostatic head sufficient to cause circulation. (*h*) High pressure steam is usually superheated below that of the low pressure steam temperature, otherwise the metal temperature would be higher, due to steam pressure under the same flow conditions. (*i*) Boilers using forced circulation consume power for the circulating at all times, and if the pump stops, due to accident, the boiler tubes become overheated. (*j*) All boilers which depend on natural circulation require cleaning at regular intervals, and the taking of the boilers out of service.

It is an object of this invention to afford a practical boiler of several pressures or stages which will overcome the many objectionable fea-

tures mentioned. The invention operates on the following principles.

First.—The size of boiler drum governs the dry steam output. The exhaust steam from the super-high pressure, and from the high pressure turbines is wet and cannot be reheated in a superheater without causing great fluctuations in temperature. Therefore, it is the plan of this invention to employ a steam drum for each pressure, for the purpose of drying the steam and maintaining uniform pressures and temperatures. The high and low pressure drums being say half filled with water receive the exhaust from the super and high pressure turbines, which exhaust enters the drums below the water level. The level of water in the several drums may be maintained as desired by any known means of boiler feed regulation.

Second.—The use of small diameter tubes with thin metal walls in which the fluid is circulated mechanically by an induced-forced circulating system that utilizes distilled feed water pumped from turbine bleeders. The small tube construction forms the furnace, including water grate at bottom, top slag screen, and water walls, allowing continuous operation as it is not necessary to take the boiler out of service for cleaning. It also permits the maximum radiant heat absorption per square meter of wall surface, and therefore permits more fuel to be burned per cubic meter without slagging of ashes on the boiler tubes, which results in a great increase or even doubling of steam production, thus increasing the energy supplied to turbine, and enables continuous operation.

Third.—The super pressure boiler may consist of a drum and thin metal small diameter tubes in which water is mechanically circulated by an induced-forced system, constructed for pressures of say 150 kgs. per sq. cm. It supplies steam to a heat exchanger consisting of a drum with a part containing heating coils; the drum being half to three quarters filled with water pumped from turbine bleeders. The super pressure steam circulating through the coils generates steam at high pressure, say 100 kg. per sq. cm.; the super pressure steam being partly condensed—or pumped back to the boiler, while a small amount of steam taken from the return after leaving the heat exchanger, is utilized for driving the induced-forced circulation pump, and it exhausts into the succeeding low pressure drum; therefore, the actual cost of circulation is nil.

Fourth.—The induced-forced mechanical system of circulation may be employed during forced operation, making it unnecessary to operate the circulating pump at all times, also, in case of accident to the pump, water will flow, due to natural circulation, and there is not any immediate danger from overheating of the tubes.

Fifth.—The invention may be practiced by use of existing boiler drums and of the piping to turbines, without any change. Some of the boiler heating surface may be removed, and that which remains placed above the top slag screen, in a position where it will not receive intense heat. Therefore, raw water can be fed to the drum and evaporated in the heating surface without forming scale; and solids deposited in the mud drum may be blown off. This arrangement eliminates evaporation and assures continuous operation of the boiler, avoiding periodical cleaning. The existing boiler drum, being say half filled with water, may receive the exhaust steam from the high pressure turbines below the water line, and it serves as a heat accumulator, taking up fluctuations and delivering dry steam to the superheater at constant pressure.

Sixth.—The amount of heating surface in existing boilers is purposely made small to allow high pressure steam to flow through a high pressure superheater at light loads, passing directly into the low pressure boiler drum below the water level, generating steam. This will not be necessary at heavy loads, and will be cut off automatically by a valve. A purpose of this invention is to allow steam to flow through a high pressure superheater at all times, to avoid overheating of the superheater tubes, but principally to obtain higher temperature high pressure steam, since by the arrangement the superheater can be located in a zone of more intense heat.

This invention includes the process of generating steam utilizing multiple boiler pressures, with circulating systems that ensure continuous operation with ordinary boiler feed water, increasing the steam production and energy output per unit volume of space occupied and at a substantially lower cost.

Other and further objects and advantages of the present invention will be explained in the following description of embodiments thereof, or will be understood to those skilled in the subject.

In the accompanying drawings Fig. 1 is a general diagrammatic elevation or vertical section of a steam boiler or generating apparatus of a type available for central power station purposes and embodying the present invention.

Fig. 2 is a vertical section of a detail, namely the device for causing mechanically induced-forced circulation at high rates of steam output but allowing natural circulation at low rates of output, applied for example for the return of condensate from the heat exchanger.

Fig. 3 is a vertical section and elevation of a circulation device, giving similar action, but being applied for the circulation of boiler water through the water grates, water bottoms, top slag screens and furnace side walls.

Fig. 4 is an elevation of the device shown in Fig. 3, looking from the right.

Fig. 5 is a vertical section and elevation of a circulation device, giving similar action, but being applied to tubes of thick walls and large diameters as used for high pressures rather than for the thin wall tubes used for low pressures, this figure showing also a suitable arrangement for high and low pressure mud drums with blow-off connections.

Fig. 6 is a side elevation of the device shown in Fig. 5, looking from the left side.

Fig. 7 shows a modified application and embodiment of the present invention, embodied in this case in a locomotive, the same being shown in diagrammatic elevation and vertical section.

Fig. 8 is a transverse vertical section taken substantially on the plane 8—8 of Fig. 7.

Referring first to the embodiment of Figs. 1 to 6, this construction is especially adaptable to power plants. One condition that prevails throughout power plant equipment is that through each element of apparatus there is a more or less continuous flow of one or more fluids, water or steam, under pressure and at elevated temperature. This invention is based on control and arrangement of flow of fluids at elevated temperatures and pressures in a manner developed from the relations observed during operations. Another factor involved is that the real purpose of circulating water in tubes exposed to

the fire is for conveying heat from a hot location to a remote and relatively cool zone. It has been determined that the amount of heat carried away by water in circulation is substantially the same for all pressures between 10 and 150 kgs. per sq. cm., because of the fact that the speed of natural circulation changes with the pressure. If the speed can be increased mechanically sufficiently, beyond natural circulation, this will avoid danger of scale formation in the tubes. Another consideration utilized herein is that radiant heat intensity delivered to and absorbed by bare circulation tubes will be less as the wall tube thickness is increased. With these factors in mind, the multiple pressure boiler of this invention may be constructed and function as follows.

Fig. 1 shows two usual drums C and D and two supplemental drums A and B, as an illustrative mode of embodying the invention. The drum A carries distilled water and steam under super high pressure, fed with hot water, for example by pipe 12 from a super pressure turbine exhaust. The drum B is a heat exchanger and carries water and steam at high pressure, and delivers to a superheater for consumption. The drum C is a low pressure drum fed by ordinary feed water and delivering for consumption. The drum D is at high pressure, and may act as a steam accumulator and being fed with distilled water, for example from the super pressure turbine.

Referring first to the combustion system, pulverized fuel may be supplied at regulated rates through a fuel pipe 1 to a pilot burner 2, which is supplied with combustion air through a pipe 3, the two being mixed at the burner 2 and projected into the combustion pilot chamber 4 where it is ignited and burns instantaneously at highest possible temperature, above the ash melting point, and maintaining the ash from the fuel in a fluid state, so that it can be allowed to flow out continuously or tapped periodically, for example, into molds to produce blocks.

The combustion in chamber 4 affords a pilot flame for the main combustion, for example of pulverized fuel, supplied through fuel pipe 5 at controlled rates to a main burner or system of burners 6, supplied with combustion air through duct 7. The air and fuel mix in the burner and the mixture is projected into the furnace 8, where it ignites and burns almost instantaneously with a clear flame, giving a clear atmosphere in the furnace, which permits the maximum transfer or diffusion of heat by radiation to the heat absorbing surfaces, namely the water grate 9, water walls 10 at all sides and top slag screen 11, all of which elements preferably constitute the heating or steam generating surface of the super-high pressure portion of the apparatus.

The super pressure portion comprises the drum A, about half-filled with distilled water received from so-called bleeders of the turbines or engines. This hot water under pressure is fed by pump 12^a into the drum by a feed pipe 12 which distributes the water in the drum. The heating surface 9, 10 and 11 is constructed of metal tubes of small diameter and thin walls, which are able to absorb heat at a faster rate than can be carried away by natural circulation which is impeded by the small internal area, and high friction. I have therefore provided mechanical circulation, and in a way to afford a system that provides some circulation at all times. What I term an induced forced circulation system is preferably embodied in this invention for the purpose. For example, some water is taken from drum A through a pipe 13 to the inlet of a pump 14, which creates a forced flow and pressure in pipes 15 and 15^a connected respectively to internal distributing pipes 16 with nozzles 17 opposite each tube of the grates 9 or of the walls 10, within headers 18 and 18^a respectively, as seen in Figs. 1, 3 and 4.

Part of the water from drum A may be conducted through pipes 19 to supply and completely fill the headers 18 with water by natural circulation. The nozzles 17, discharging pumped water at high velocity into the tubes 9 or 10 induce water flow from the header, received through pipes 19, and force it into the tubes, thus giving a very high rate of circulation, and liberation of steam in the drum A above the water level.

It is desirable to permit flow toward the boiler in case the pump becomes inoperative. The pump 14 being of the centrifugal type permits through circulation if it should cease rotation.

The pump 14 imposes a forced rapid recirculation upon the ordinary gravity recirculation which is afforded by the downtakes 19. With the present invention the forced rapid recirculation comprises a second downtake or set of downtakes 13 from the water space in the overhead drum A, these extending directly from such water space so as to be under direct hydrostatic pressure from the water in the drum, and leading to the force pump. This force pump it will be noted is at a low level, substantially adjacent to the level of the lower ends of the exposed water tubes of the boiler, meaning substantially not higher than such level, and in no case as near to the level of the overhead drum A as to the lower ends of such exposed tubes. The force pump receives the recirculated water under the direct hydrostatic pressure of the drum, plus the entire height of the downtakes 13, so that the pump is supplied with water in ample volumes at a substantially great hydrostatic pressure, which is of advantage in the operation of the pump. The force pump discharges through the several delivery pipes 15 and 15^a and through the nozzles 17, one for each exposed boiler tube, thus forcing recirculation at substantially equivalent high rates through all such exposed tubes, this forced recirculation arrangement serving supplementally to induce enhanced recirculation through the first or gravity downtakes 19.

The super pressure steam leaves drum A through a dry pan or element in a dry state, and thence passes through pipes 20 leading to heating coils 21 located in the high pressure drum B, which is preferably maintained about three-fourths filled with water. The super pressure steam, say at 150 kgs. per sq. cm., generates steam by heat exchange in the drum B, say at 100 kgs. per sq. cm. pressure. The super pressure steam partly condenses in the coils and this condensate is drained, with some steam, through pipe 22. The steam is separated and taken off at a separator 22^a and is shown used for driving certain circulating pumps. This super pressure steam is shown passing by pipe 22^b to a pump 23 and by extension 22^c to the pump 14 for operating them. Some of the water from the separator 22^a is passed by pipe 24 through the pump 23, and discharged at high velocity through a pipe 25, which induces forced flow of steam and water from pipe 26 descending from the separator, and forces all such water into a pipe 27, which delivers into the pipe 13 leading to inlet of pump 14. It will be seen that this arrangement of pump 23 is auxiliary to the pump 14 and is not absolutely neces-

sary, but may be desirable under certain conditions to ensure maximum circulation.

The heat-exchanging drum B may be fed with hot water from a turbine or engine exhaust, represented by inlet pipe *b*, and this drum is heated by the super pressure coils 21 and the water evaporated into high pressure steam adapted for consumption, preferably after traversing a superheater, as will be further on described.

Coming next to the low pressure portion of the boiler, the drum C, which may be a preexisting drum, is shown supplied with raw feed water through a longitudinal distributing pipe 28. From the drum C the water may flow down a pipe 29 to certain boiler headers 30, which are connected to heating surface boiler tubes 31, which slant upwardly and in which the water is evaporated and discharged to upper headers 32, connected by tubes 32^a to carry steam to the drum C, above the water level therein. The conventional type of tubular boiler is shown in Figs. 1, 5 and 6 as divided substantially into two boilers, in a sectional manner, the tubes 31 and headers 30 and 32 being alternated with other tubes 38 and headers 37 and 39 to be described.

The heating surface or tubes 31 is not exposed to the very intense heat and is therefore not subject to the formation of scale. Solids in suspension in the water precipitate in mud drum 33 and are blown off methodically through pipe connection and valve 34.

The existing high pressure portion of the boiler, namely drum D is herein arranged as follows. It is shown supplied with water from a suitable source, as the super pressure turbines, namely with exhaust and water drained from the bleeders of the turbines, forced by pump 35^b through a feed pipe 35 delivering into the drum. This is distilled water, free from contamination, and therefore assures continuous service. The drum D is preferably half filled with water. From the drum water flows down by pipes 36 into lower sectional headers 37, which are connected to heating surface tubes 38, discharging to upper sectional headers 39, which in turn are connected back to the drum D above the water level by pipes 40, which liberate in the drum the generated steam. The headers and tubes 37, 38 and 39 are alternated with those 30, 31 and 32 already described, giving independent circulating systems combined in one tubular boiler.

The high pressure circulation tubes are preferably made small in diameter to avoid having thick walls, so that the amount of heat absorbed per second is more than natural circulation can carry away, due to friction and small internal area of tube. With this invention some of the water is drawn from drum D, through a pipe 41, leading to the inlet of a pump 42, which discharges at high pressure through pipe 43, which is connected to a distributing header 44 with nozzles 45, opposite the tubes 38, as indicated in Figs. 5 and 6. The high velocity discharge of water from the nozzles 45 into the tubes induces and forces a greater quantity of water through the tubes, thus conveying fluid and heat at a very rapid rate away to a remote point, on the principles described.

The high pressure steam, say at 100 kgs. per sq. cm. which is generated in heat exchanger drum B, together with that generated in drum D, is conducted by pipes 46^a and 46^b respectively to a collector 46, which by pipe 46^c delivers steam to the inlet 47 of a superheater 48, its outlet 49 delivering by pipe 49^a to turbine or point of consumption. A valve 50, arranged in a pipe 51 branched from pipe 49^a operates similarly to a safety relief valve, and allows steam to flow through superheater at all times, and it may discharge into low pressure drum C. The drop in pressure between the superheater inlet and outlet, when steam is being used by a turbine, will be sufficient to cause the relief valve 50 to close, while when the turbine is not using steam the pressure in pipe 49^a will rise to the full pressure, and the relief valve being so adjusted will permit the high pressure steam to flow through the pipe 51 to the feed pipe 28 of the drum C. This may generate steam in drum C at say 25 kgs. per sq. cm., which will permit higher temperature steam to be generated in and delivered from the high pressure boiler, or drums B and D, as the superheater tubes will be protected from becoming overheated.

The waste gases, after leaving the described multiple pressure boiler, may be passed into an air preheater 52, shown conventionally, where some of the heat is recuperated and utilized for combustion. The gases then pass into a gas cleaner, 53, where the dust and moisture may be precipitated and removed and the reduced volume of cooled and contracted gas is passed through an induced draft fan 54 and delivered to a stack 55.

Figs. 7 and 8 show an application of the improvement to a vehicle or locomotive, wherein the usual drum or steam space C' is supplemented by a pair of super pressure drums A', A' and a high pressure drum B' acting as a heat exchanger, or evaporator. The drum C' may be the steam space of a fire tube boiler, with fire tubes C^2, delivering the gases to a forward flue or box 156 and stack 155.

An oil burner 106 is shown delivering into the firebox or combustion chamber 108, having closed side walls comprising circulation tubes 110, the upper parts 110^a of some of which are crossed over to form a closed water ceiling protecting the drum B', while the forward tubes are extended and shaped as at 111 to serve as a protecting screen for a high pressure superheater 148 to be described.

For certain purposes the equipment may comprise a steam turbine or turbo-generator 157, the current from which may be employed for any desired purposes, for example for operating electric motors applied to the driving of the wheel axles of the locomotive or cars of the train, a motor 157^a being indicated as representative thereof. The exhaust from the turbine 157, or fluid bled therefrom, may be conducted through pipe 112 to the super pressure drums A'. The drums A', A' may be supplied also by condensate from a condenser and feed water heater 158, from which leads a pipe 158^a for this purpose.

The locomotive however may comprise the usual reciprocating engines of high and low pressure indicated as a centrally arranged high pressure cylinder or engine 159, driving through crank, and opposite low pressure cylinders 160 operating through connecting rods directly to the driving wheels.

In the firebox 108 the injected fuel is intended to burn instantaneously with a clear flame, thus giving a clear furnace atmosphere, the products traversing the combustion space and then passing through the slag screen 111 and superheater 148 to the fire tubes C^2 of the low pressure boiler or drum C', thence by way of the flue or box 156 to the stack 155. By providing quick, complete

combustion, with super temperatures, maximum diffusion or transmission of heat by radiation is afforded, such heat being taken up by the side wall tubes 110, slag screen 111 and ceiling tubes 110[a], which elements constitute the heating or heat absorbing surface of the super pressure boiler or portion of the apparatus, and are shown delivering into the super pressure drums A', A'.

The circulation may be on the same principles as explained in connection with Figs. 1–6, and preferably the induced-forced circulation system is employed at the corresponding points. Thus a certain amount of water is drawn from the lower sides of the drums A' through pipe 113 and conducted to the inlet of a pump 114, which creates a forced flow and pressure within pipes 115 connected to interior distributing pipes 116 having nozzles 117 directed into the respective side wall tubes 110, the pipes 116 being enclosed centrally within larger pipes or headers 118. As before stated the fluid circulating upwardly through the tubes 110 delivers back into the drums A', thus completing the circulation. There may be a direct supply or descent of water from the drums A' through pipes 119 which are capable of completely and quickly filling the headers 118.

The high pressure drum B' is in the nature of a heat exchanger operated by the super pressure steam from the drums A'. This steam is taken out of drums A' by pipes 120, one at each side, these leading to a distributing pipe 120[a] which enters the upper part of the drum B' and delivers the super pressure steam to a system of heat exchanging coils 121, in which the steam will condense or partly condense, giving up its heat through the walls of the tubes and thereby evaporating the water contained in drum B'. The super pressure in drums A' may for example be 150 kg. per sq. cm., which may develop in drum B' a pressure of 100 kg. per sq. cm., referred to as high pressure.

The fluid passing out from the coils 121 is conducted by pipes 122 to a steam separator 122[a], the steam being taken off at this point thus keeping up the steam flow through the heat exchanger coils 121, and then utilized to induce a forced flow toward the boiler by driving the pump 114, as with Figs. 1 to 6.

The steam at high pressure generated in the drum B' may be drawn off by a dry pipe near the top and conducted by pipe 146[a] to the inlet 147 of a superheater 148 placed in the path of the flames leaving the firebox. The outlet 149 of the superheater connects with pipe 149[a] in which is placed a relief valve 150, in the nature of a safety valve, which, when the pressure is maximum opens to deliver steam by way of pipe 151 directly into the low pressure drum C'. By this means the superheater is continuously maintained in operation. In the pipe 149[a] is shown also a throttle 149[b] which may be controlled from the cab. The pipe 149[a] conducts the high pressure steam to the point of consumption, namely to the high pressure engine 159, or to the turbo-generator 157, or both.

The high pressure engine and turbine therefore are operated by high pressure steam, namely 100 kg. per sq. cm. while the low pressure engine 160 is operated by the low pressure steam from the drum C' at about 25 kg. per sq. cm. The exhaust of the high pressure engine is shown as conducted by pipe 128 into the low pressure drum C', which constitutes a low pressure boiler of the fire tube type. The steam outlet from the drum C' may be through pipe 128[a] in which is included a throttle valve 161. Interposed in this pipe is indicated a low pressure superheater 162 consisting of tubes extended reversely through some of the fire tubes C[2], the outlet of the superheater being connected by pipe 128[b] directly with the valve box of the low pressure engine 160. The low pressure engine is shown as exhausting through a pipe 163 located in the flue box 156 and directed into the stack 155.

As a special feature there is herein shown a locomotive which is adapted to be operated for short runs without the use of fuel, for example where electric current is provided by overhead conductor or third rail, at the same time without shutting off on the operation of the steam plant of the locomotive, or allowing it to cool down. This is of particular value in the bringing of passenger trains into and out of terminals, giving the very great advantage of avoiding the necessity of changing engines at a designated distance from the terminal. This part of the invention operates on the principle of utilizing the electric current as a means of generating heat to maintain the boiler system in operation, so that the locomotive can run on its own steam. Preferably electric heating units 175 are embodied within the high pressure boiler B', in close proximity to, or alternating with the heating tubes 121 therein. This is preferable to placing the electric heating means within the super pressure drums A', and operates to generate directly the steam required for the high pressure engine or turbine. It is only necessary to cut off the flow of fuel or oil to the firebox 108, giving instantaneous relief from smoke, after having turned the line current into the heating units 175, which should be predetermined to develop heat sufficient to generate steam in the drum B at approximately the normal pressure of say 100 kg. per sq. cm., although a lesser heat and pressure would be serviceable and sufficiently practical for the purpose, considering the great delay which is avoided by not having to change engines.

Fig. 7 indicates an overhead conductor 176 along which runs a contact or shoe 177 pressed upwardly by a lever system 178 mounted on top of the locomotive. The current received by the contact is conveyed through a wire 179 extended to the heating units 175. A switch 180 is diagrammatically indicated, as a means of throwing the current into the heating units, or cutting it off, and regulation of action may be secured by periodically opening or closing the circuit, or by rheostat. The circuit is completed by wire 181 from the other terminals of the heating units to a ground point, indicated as the axle of a wheel.

In one aspect the present invention may be described as a steam generating system including certain combinations or subcombinations of cooperating elements. First, the super pressure drum A and the heating surfaces delivering to it constitute a super pressure boiler, the surfaces of which are heated by the hottest exposure to the fire. Second, the drum B constitutes a high pressure boiler having surfaces heated by the outgoing steam from the super pressure boiler and has a steam outlet delivering to a point of consumption such as a high pressure turbine or other engine. Third, this combination of first and second elements is believed to be new when combined with means for forcing rapid circulation through the super pressure boiler and its heating surfaces, these preferably constituting a substantially closed circuit and using distilled water. Fourth, the described combination is of greater utility

when comprising also a low pressure boiler, consisting for example of the drum C and the heating surfaces delivering to it, heated by the less intense or more remote exposure to the fire, this boiler having a steam outlet to a point of consumption separate from that of the high pressure boiler. A combination feature of substantial importance is that while the exposed heating surfaces or tubes of the low pressure boiler may be ordinary boiler tubes, relatively thick, those of the super pressure boiler are preferably thin walled and relatively small in diameter, so as to absorb and convey to the circulating fluid the maximum quantity of heat without danger of breakage.

Fifth, a subordinate feature of improvement is the described mode of securing forced-induced circulation in the super pressure boiler, which is preferably a substantially closed circuit, namely the described combination of forcing pump and induction nozzle, such as to give high circulation rates under high pressures, but to permit natural circulation under other conditions; and this feature is considered to be novel irrespective of whether the steam output from the boiler is used for operating a heat exchanger such as drum B or is conveyed directly to a turbine or other point of consumption. The use of the described means of forced circulation not only allows for natural circulation at light loads, but also insures the continuation of flow in case of stoppage of the pump, thus protecting the boiler from overheating.

Sixth, another combination feature is the use of a high pressure superheater for the steam outgoing from drum B, in combination with a relief valve beyond the superheater adjusted to remain open when substantially the full boiler pressure is delivered from the superheater, in other words when consumption is subnormal, the opening of this valve permitting the superheater to be maintained under circulation, together with the entire high pressure boiler system; and the steam discharged from the relief valve may be advantageously used, for example by delivery into the drum of the low pressure boiler.

Seventh, the complete combination illustrated in Fig. 1 embodies a second high pressure boiler with heating surfaces feeding to drum D, this boiler delivering to the same superheater, and outgoing steam pipe as the high pressure drum B. This boiler may be a forced circulation boiler, and as it supplements the output of drum B, both the drums B and D may be made of smaller diameter than otherwise, with proportionately high strength.

In the complete combination the small amount of distilled water exhausting from the circulating pumps of super pressure boiler may be supplied to any of the drums B, C or D. The exhaust from the pump associated with drum D may be fed to the low pressure drum C. Preferably mainly raw water is fed to drum C, whereas drums B and D may use either raw or distilled water obtained from the turbines or otherwise, and the super boiler employs distilled water in a substantially closed circuit, the supply maintained from a turbine to insure the indicated water level in the drum A. Substantially similar considerations apply to the locomotive embodiment of Figs. 7 and 8 wherein however there is no boiler or drum indicated corresponding to D of Figs. 1–6.

The complete apparatus delivers simultaneously high pressure steam and low pressure steam, for example to high and low pressure turbines, and by the operation of this invention the maximum temperature and pressure for each boiler may be constantly maintained, to the great advantage of the operation of the power station. The use of the relief valve 50 makes possible the same high temperatures for both steam deliveries, while the valve avoids overheating of the drum B and superheater by maintaining a flow of steam therethrough to cool them.

The formation of scale is prevented throughout. In the low pressure boiler the evaporation is at a temperature below that at which scale is formed. In the high pressure boiler D the forced circulation system gives velocities at which scale will not form. In the super pressure boiler the use of distilled water, in a closed circuit, assures continuous service without formation of scale. Therefore it is unnecessary to take the boiler out of service for cleaning of scale, and feed water evaporators and economizers may be dispensed with.

The super pressure boiler is enabled to take away the maximum amount of heat per unit time, by the use of exposed tubes of small diameter and thin walls, permitting maximum absorption by radiation, coupled with high speed circulation continuously conveying away the absorbed heat to a remote part of the system.

The need of auxiliary power to operate the usual feed pumps is practically eliminated by the described circulation system involving pumps operated by a small fraction of the super pressure steam to drive distilled water into high pressure portions of the boiler.

The combination including the drum D and connected boiler is of advantage in that said boiler acts as an accumulator of steam or heat. The presence of the steam supply in the drum D, at high pressure and temperature, gives a steadying action supplementing the delivery of steam from the drum B, so that substantially constant pressure delivery can be relied on.

In various boiler drums are indicated wire meshes or gratings at about the designated water levels to minimize water turbulence and splashing or spraying into the outgoing steam.

Having thus described particular embodiments as illustrative of the principles of the present invention it is to be understood that the invention is not intended to be limited to the detail features as disclosed in said embodiments except to the extent set forth in the appended claims.

What is claimed is:

1. In a steam generating system a super pressure boiler having surfaces heated by the radiant exposure to the fire, a high pressure boiler having surfaces heated by the outgoing steam from the super pressure boiler, means for forcing rapid circulation through the super pressure boiler and its heating surfaces and a steam outlet from the high pressure boiler to the point of consumption; the super pressure boiler comprising a drum, and the high pressure boiler comprising a second drum containing a heat exchanging coil, a steam connection from the first drum to said coil, a steam separator a water connection from the coil to said steam separator, and a water connection from said separator to the super pressure boiler infeed, a direct connection from the first drum to said infeed, pump means for forcing the water through the infeed into the super pressure boiler, and a steam connection from the separator for operating such pump means.

2. In a steam generating system a super pressure boiler having surfaces heated by the radiant exposure to the fire, and having gravity recirculation through the boiler, a high pressure boiler having surfaces heated by the outgoing steam from the super pressure boiler, means for forcing rapid recirculation through the super pressure boiler and its heating surfaces supplemental to its gravity recirculation, and a steam outlet from the high pressure boiler to the point of consumption; the super pressure boiler comprising a drum, and the high pressure boiler comprising a second drum containing a heat exchanging coil, a steam connection from the first drum to said coil, a water connection from the coil to the super pressure boiler infeed, a direct connection from the first drum to said infeed, pump means for forcing the water through the infeed into the super pressure boiler, and a steam connection for operating such pump means.

3. A system as in claim 2 and wherein is a forced-induced-flow nozzle between the pump means and the boiler, and a gravity connection from the first drum to the header space adjacent said nozzle for induced feed during forced feed and for gravity feed otherwise.

4. In a steam generating system a super pressure boiler having surfaces heated by the hottest exposure to the fire, a low pressure boiler having surfaces heated by less intense exposure to the fire, a high pressure boiler having surfaces heated by the outgoing steam from the super pressure boiler, means for forcing rapid circulation through the super pressure boiler and its heating surfaces and steam outlets from the high pressure and low pressure boilers respectively to separate points of consumption; together with a second high pressure boiler or accumulator, having heating surfaces exposed to the less intense heat of the fire, means for forced circulation therethrough, and a steam outlet delivering supplementally to that from the first high pressure boiler.

5. In a steam generating system a super pressure boiler having surfaces heated by the radiant exposure to the fire, a high pressure boiler having surfaces heated by the outgoing steam from the super pressure boiler, means for forcing rapid circulation through the super pressure boiler and its heating surfaces and a steam outlet from the high pressure boiler to the point of consumption; together with a second high pressure boiler or accumulator, having heating surfaces exposed to the less intense heat of the fire, means for forced circulation therethrough, and a steam outlet delivering supplementally to that from the first high pressure boiler.

6. In a steam generating system a super pressure boiler having surfaces heated by the radiant exposure to the fire, and having gravity recirculation through the boiler, a high pressure boiler having passages with surfaces heated by the outgoing steam from the super pressure boiler, means for forcing rapid recirculation through the super pressure boiler and its heating surfaces supplemental to its gravity recirculation, and a steam outlet from the high pressure boiler to the point of consumption; and wherein the super pressure boiler comprises passages constituting a substantially closed circuit with an elevated drum to which the heated surfaces deliver, with a pipe from such drum to said passages in the high pressure boiler and a forced circulation return pipe with pump from said passages back to the lower part of the super pressure boiler.

7. In a steam generating system a tubular boiler with overhead steam-and-water drum from which the steam output is delivered to the point of consumption and said boiler having ascending water tubes exposed to the radiant heat of the fire and delivering to said drum, first downtakes from said drum for gravity recirculation through the boiler, and means for forcing rapid recirculation though the boiler and its heating surfaces supplemental to said gravity recirculation, comprising second gravity downtakes from the water space in said drum, such second downtakes extending directly downwardly from such water space so as to be under direct hydrostatic pressure from the water in said drum, a force-pump to which said second downtakes directly lead, said pump being substantially adjacent to the level of the lower ends of said exposed tubes, and receiving water through such downtakes under such direct hydrostatic pressure of said drum, and a system of forced-induced-flow nozzles connected by piping with the force pump and through which nozzles the force pump discharges into said exposed tubes, one such nozzle for each such exposed tube, and through which tubes, during forced recirculation periods, recirculation is thereby forced from said second gravity downtakes and is supplementally induced from said first gravity downtakes, into the exposed tubes, whereby recirculation is produced at substantially equivalent high rates through all said exposed boiler tubes; said nozzles being so restricted that the recirculated water pressure between the pump and nozzles is substantially greater than the boiler pressure.

8. In a vapor generating system a tubular boiler with overhead vapor-and-liquid drum from which the vapor output is delivered to the point of consumption and said boiler having ascending liquid tubes exposed to the radiant heat of the fire and delivering to said drum, first downtakes from said drum for primary recirculation through the boiler, and means for forcing rapid recirculation through the boiler and its heating surfaces supplemental to said primary recirculation, comprising secondary gravity downtakes from the liquid space in said drum, such secondary downtakes extending directly downwardly from such liquid space so as to be under direct hydrostatic pressure from the liquid in said drum, a force-pump to which said secondary downtakes directly lead, said pump being substantially adjacent to the level of the lower ends of said exposed tubes, and receiving liquid through such downtakes under such direct hydrostatic pressure of said drum, and a system of forced-induced-flow nozzles connected by piping with the force pump and through which nozzles the force pump discharges into said exposed tubes, one such nozzle for each such exposed tube, and through which tubes, during forced recirculation periods, recirculation is thereby forced from said secondary gravity downtakes and is supplementally induced from said primary downtakes, into the exposed tubes, whereby recirculation is produced at substantially equivalent high rates through all said exposed boiler tubes; said nozzles being so restricted that the recirculated liquid pressure between the pump and nozzles is substantially greater than the boiler pressure.

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