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C. H. WOOLLEY

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STEAM GENERATOR

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3 Sheets-Sheet 1

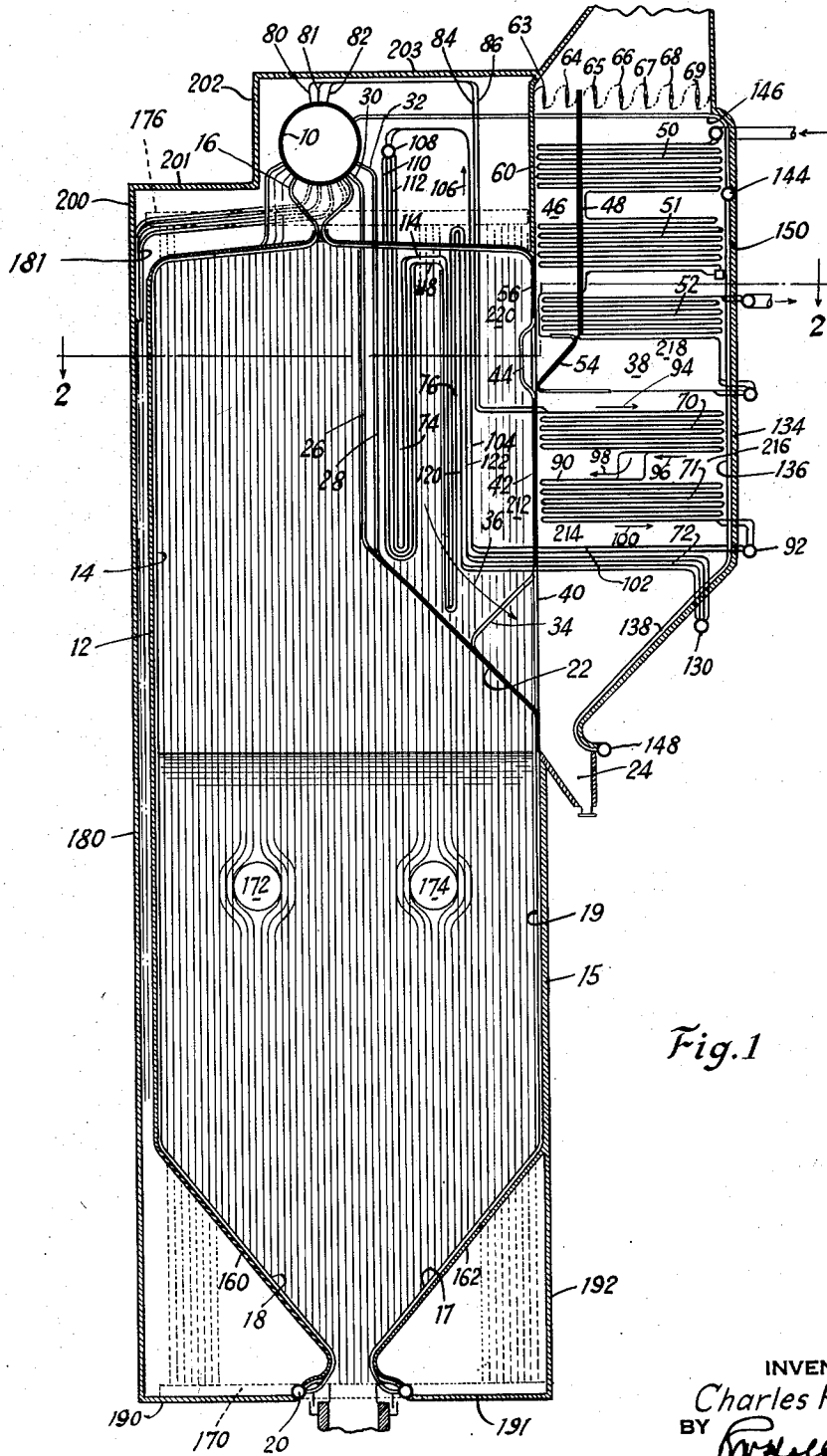


Fig. 1

INVENTOR
Charles H. Woolley
BY *R. W. Holbrook*
ATTORNEY

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3 Sheets-Sheet 2

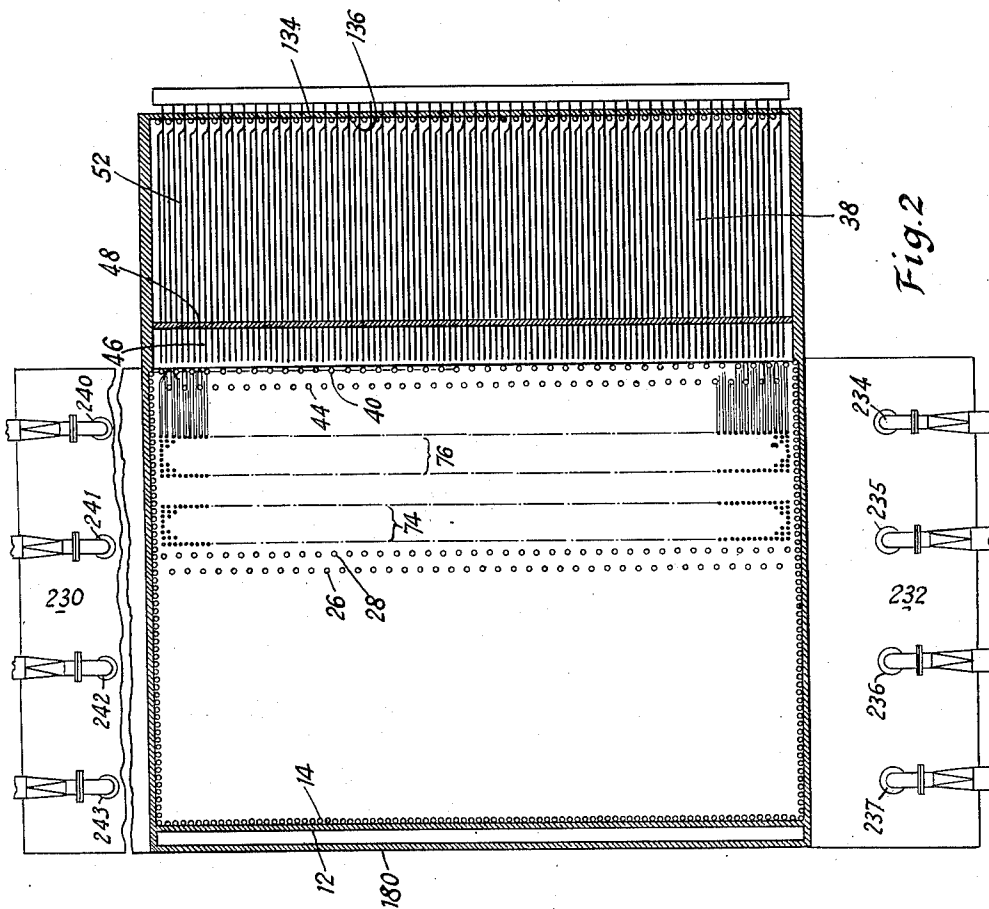


Fig. 2

INVENTOR
Charles H. Woolley
BY *M. Holbrook*
ATTORNEY

UNITED STATES PATENT OFFICE

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STEAM GENERATOR

Charles H. Woolley, Cranford, N. J., assignor to
The Babcock & Wilcox Company, Rockleigh,
N. J., a corporation of New Jersey

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6 Claims. (Cl. 122-477)

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This invention relates to improvements in fluid heat exchange apparatus, and it is more particularly concerned with the control of superheat in the operation of a high pressure and superheat water tube steam boiler.

The invention is particularly concerned with the maintenance of superheat within close limits under conditions which involve widely varying boiler loads, and the steam boiler with which the invention is concerned involves upright steam generating tubes most of which are furnace wall tubes. A superheater including spaced tubes, receives steam generated in said tubes and subjects it to the heat from furnace gases. It is one object of the invention to provide such improvements in apparatus of this type that the requirements of modern high pressure and high temperature steam power plants may be effectively met. Such installations, in the interest of high efficiencies of associated prime movers, operate at high superheats, and, as the associated steam turbines are apt to be damaged by uncontrolled and excessively wide variations in steam temperatures, it is important that such variations be controlled and limited. A more specific object of the invention is to provide a particular means for regulating and limiting such variations in superheat in this type of boiler.

For high superheats, and especially for steam generators in which there is a high ratio of heat of superheat to heat of steam generation, a relatively large superheater tube surface is necessary, but excessive superheater costs are avoided, and the desired high superheats are obtained by locating the superheater in gas zones in which the temperatures are as high as practical consistent with safe metal temperatures and with the desired conditions of non-adherence of the particles of slag or ash suspended in the furnace gases.

The invention also provides means for bypassing furnace gases about superheater surface in order to reduce heat input and control final steam temperature.

This temperature control results in a flat superheat curve over the upper rating range of the installation within the limits of temperature permissible by the piping, and turbine receiving the superheated steam.

It is an object of the invention to provide a superheater of the cross-tube gas flow type, the elements of which are conveniently arranged for accessibility.

It is also an object of the invention to provide a gas bypass about a portion of the cross-tube

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superheater surface which will direct the bypassed gases over all of the economizer water circuits which are correspondingly subjected to heating by gases which flow over the entire superheater.

A further object of the invention is to arrange the cross flow superheater elements in vertically and horizontally extending groups so disposed with respect to dust separating zones that the separated dust may be conveniently collected in and removed from a single transversely extending hopper.

Other objects of the invention will appear from the following description referring to the accompanying drawings showing a preferred embodiment of the invention.

In the drawings:

Fig. 1 is a vertical section through the illustrative steam generator and superheater installation;

Fig. 2 is a transverse horizontal section on the line 2-2 of Fig. 1; and

Fig. 3 is a vertical section of a modification of the installation shown in Fig. 1.

The furnace of the steam generator indicated in Fig. 1 is generally rectangular in cross section, and it is vertically elongated, with its walls defined by steam generating tubes having their upper ends connected to the steam and water drum 10. One of these walls 12 is defined by the wall tubes 14 having their upper end portions 16 connected to the drum 10 as shown, and their lower hopper portions 18 connected to the header 20 which may be appropriately joined by appropriate downcomer connections to the water space of the drum.

Along the opposite wall 15 of the furnace, there are vertically extending wall tubes 19. Some of the tubes 19 have their upper portions inclined inwardly toward the wall 12 to delineate the furnace baffle 22 which inclines rearwardly and downwardly toward the hopper 24 from which solids depositing from the furnace gases are periodically removed. The wall tubes 19 which have portions extending the full length of the baffle 22 have more widely spaced upper parts 26 and 28, to form a screen across the gas outlet of the furnace. They are connected to the drum 10 as indicated at 30 and 32.

A small number of the tubes along the wall 15 extending only part way along the baffle 22 will then have rearwardly bent parts 34 extending across the line of gas flow (indicated by the arrow 36) to the inlet of the gas pass 38, just above the hopper 24. Others of the tubes along

the wall 15 have parts 40 continuing vertically beyond the lower end of the baffle 22, first crossing the inlet to the gas pass 38 and then extending along the wall 42 at one side of the gas pass. Some of these tubes just above the wall section 42 have gas bypass sections such as 44 bent out of wall alignment so as to form an inlet to the gas bypass 46. This bypass is defined at its right hand side by the vertical wall 48 extending across the banks 50—52 of the economizer tubes and substantially joined to the wall section 42 by the inclined intermediate wall section 54 carried on the diagonally extending tube portions of the connectors between the down flow banks 50 and 51 and the upflow bank 52. The other side of the superheater gas bypass is formed at its lower part by the wall section 56 which is defined by the upper portions of the tubes extending along the wall section 42. Beyond this wall section 56 and in vertical alignment therewith is a gas bypass wall 60.

The flow of gas through the bypass 46 to control superheat is regulated by the operation of the dampers 63 and 64 either with or without operation of the dampers 65—69, the superheater consisting of banks 70—72 of horizontally extending tubes across the lower part of the gas pass 38 and the banks 74 and 76 of vertically extending tubes disposed immediately rearwardly of the screen tubes 26 and 28 extending across the upright furnace gas outlet.

The cross-flow type of superheater, particularly when the elements are arranged vertically, is advantageous in avoiding excessive accumulation of slag or ash, but a disadvantage is often incurred when a bypass to direct heating gases about superheating surface for the purpose of temperature control is involved. The disadvantage results from the fact that bypassed gases are of comparative high temperatures, particularly when high pressure and superheats are involved and provisions must be made in the arrangement of subsequent heat absorptive surfaces which are usually provided by economizer tubes so that the heat absorption from the higher temperature gases will not disturb the internal cooling fluid condition of the economizer.

The present invention provides an upright high gas temperature superheater section with transverse gas flow thereover, a subsequent lower gas temperature section with cross-tube gas flow from which the gases flow to a multiple circuit economizer, and a gas bypass leading from a position between the section and directing heating gases over tube portions of all of the economizer circuits, insuring that all of the circuits will be subject to corresponding heat inputs not only from the gas flow through the bypass but also from the gases flowing from the second superheater section.

Thus, with an economizer having cross-tube gas flow over the three banks 50, 51, and 52, the first two being arranged for down flow of water while the bank 52 has an upflow of water, the heat given up by the gases will be substantially equally distributed to all the parallel water circuits, irrespective of whether all of the gases pass from the high temperature vertical superheater section to and over the low temperature horizontal superheater section, or whether the gases leaving the high temperature section are divided with a portion flowing through the bypass to flow over all the economizer section, while the remainder flows over the low temperature section and then over economizer tube portions of the

same circuits as receive heat from bypass gases.

In the high rating positions of bypass dampers 63 and 64, shown in Fig. 1, the gases in the equalization space or cavity 220 will be of the order of 1700° F. for a high pressure installation, a portion of the gases as regulated by dampers 63 and 64 will flow over all of the circuits of the down flow and upflow economizer sections, while the major portion of the gases flowing from the superheater section 76 will flow downward to the inlet of the gas pass 38, and then upwardly over the horizontally extending superheater tubes.

The provision of the cavity 220 and the position of the bypass inlet at the lower end of the wall 56 contribute to a reduction in the dust carried by the gases which flow rearwardly through the inlet after having passed downwardly along the wall 56. Bypass gases thus must execute a turn of 180° in the zone of the bypass inlet and this turn will have a tendency to separate the heavier dust particles which will pass on down along the rear wall 42 to be collected in hopper 24 with those particles separated from the main gas flow.

Steam flows from the top of the drum 10 through the superheater inlet tube connections 80—82 to the upright superheater inlet tube connections 84 and 86 and thence into the first row of tubes of the superheater section 70, at the top of that bank. It then flows through the series connected tubes of this bank and into the series connected tubes 90 of the upper part of the bank 71. From the tubes of this bank, the steam flows to an intermediate superheater header 92, the steam flow through the tube banks 70 and 71 to this header being indicated by the arrows 94, 96, 98, and 100.

From the intermediate superheater 92, the steam flows through horizontally extending tubes 102 to the upright tubular sections 104 which may be considered as part of the bank of tubes 76. The steam flows through the upper parts of these tubes as indicated by the arrow 106 to the inlet header 108 for the second superheater section. From that header the steam flows downwardly through upright tubes such as 110 and 112, and then through the remainder of the tubes of the bank 74, then through the cross-over tubes 114 and 118 to the bank of tubes 76. From the last two rows of tubes 120 and 122 of the bank 76, the steam flows through the horizontally extending tubes of the bank 72 to the superheater outlet header 130 from which the steam is appropriately conducted to a point of use. Horizontally extending tubes 102 and tubes of bank 72 are at wider transverse spacing than tubes of bank 71 providing lower inter-tube gas velocities. Gas flow equalization spaces such as 210, 212, 214, 216, 218, etc. are provided rearwardly of the successive banks of superheater tubes. Gas flow conditions are also improved by the double transverse spacing of the horizontal superheater tube sections leading from the bank of tubes 76 to the banks 70—72.

The walls of the gas pass 38 other than the walls above described may be delineated by fluid cooled tubes connected into the circulation of the installation as is the case with the wall 134, the tubes such as 136 extending vertically along this wall. The lower portions 138 incline so as to form, with the oppositely inclined furnace baffle 22, gas turning and dust separating space from which solids are discharged from the furnace gases into the hopper 24. The tubes 136 are connected to an upper header 144 which is in turn

connected to the drum 10 by other tubes 146. The lower ends of the tubes 136 are connected to the header 148 adjacent the hopper 24.

It will be understood of course that all of the furnace and gas pass walls above mentioned will have appropriate heat insulating or refractory material associated with the wall tubes so as to close the spaces between the tubes and otherwise complete the wall constructions. Such material is indicated at 150 exteriorly of the tubes 136 and the gas pass 38.

The lower parts 17 of the wall tubes 19 are inclined oppositely to the tube sections 18 of the opposite wall so as to form a hopper at the bottom of the furnace. The opposite sides of this hopper are indicated at 160 and 162.

The remaining walls of the furnace are constructed similarly to the walls above indicated except that they do not have any inwardly bent hopper portions. For example, the wall facing the observer in Fig. 1 is formed by vertical wall tubes connected at their lower ends to the header 170 and extending upwardly past burners 172 and 174 to the horizontal upper header 176 which is joined by appropriate circulators to the steam and water drum 10.

At the left hand side of the furnace, there is indicated an outside casing wall, or additional wall 180 forming a space in which downcomers such as 181 are disposed. These downcomers connect the water space of the drum 10 with lower headers such as the headers 170, 20, and 21. This outside casing may extend about the lower parts of the installation as indicated at 190, 191, and 192. At the upper part of the installation similar casing sections are indicated at 200, 201, 202, and 203.

The lower part of the furnace of the illustrative installation is increased in volume and capacity by lateral extensions such as indicated at 230 and 232 in Fig. 2. The burners, such as 172 and 174 may be disposed in the water tube walls of these extensions, or, when there is downward firing, the roof of each extension may have a group of burners extending downwardly there-through. Such groups of burners are indicated at 234-237, inclusive, at the lower part of Fig. 2, and by 240-243, inclusive, at the upper part of this figure.

The above indicated arrangement of extensions of the lower part of the furnace also applies to the modification indicated in Fig. 3 of the drawings, and the construction and arrangement of the furnace, superheater, and economizer of the Fig. 3 modification is also generally similar to the installation indicated in Fig. 1, the banks of economizer tubes 250-252 of Fig. 3 corresponding to the banks of tubes 50-52 of Fig. 1, and the banks of superheater tubes 270-272, 274, and 276, of Fig. 3 corresponding to the banks of superheater tubes 70-72, 74 and 76 of the Fig. 1 installation. In the Fig. 3 modification, the steam and water drum 280 is located toward one side of the furnace and some of the saturated steam tubes 282, leading from the steam space of the drum 280, extend along in the rear wall 284 of the cavity 286, which generally corresponds to the cavity 220 of Fig. 1. These tubes 282, at the top of the gas inlet 288 for the bypass 290 have horizontally and rearwardly extending parts 292 bent out of wall formation to afford less restriction between the space 286 at the rear of the vertical superheater bank 276, and the bypass. Below the position of the tube portions 292, the saturated steam tubes continue

with the downwardly inclined portions 294 to connections with the inlet tubes of the bank of superheater tubes 270, the portions 294 providing support for refractory material which completes the inclined wall at the bottom of the bypass. The top of this wall is joined to the upright wall 296 separating the bypass 290 from the main part of the gas pass 298.

Extending across the bypass inlet 288 are upright parts 300 of steam generating tubes, leading from headers at the lower part of the installation and corresponding generally with parts of some of the tubes 19 of the Fig. 1 modification. The lower furnace wall parts of these tubes are indicated at 302 in Fig. 3. Parts of these tubes extend through the dust hopper 304, these parts being indicated at 306 and 308, with the parts 306 bent out of their wall formation in the zone of the hopper. Above this zone and extending to the bypass inlet 288, appropriate refractory material is applied to the tubes to provide the wall section 310 separating the zone of the vertical banks 274 and 276 of superheater tubes and the upright gas pass 298.

Extending over the lower part 312 of the dust hopper are spaced steam generating tubes 314 leading from the header 316 and extending along the rear upright wall 318 of the gas pass 298, to the header 320 which is connected to the steam and water drum 280 by the tubes 315.

Some of the furnace wall tubes along the right hand wall of the furnace, as indicated in Fig. 3, have vertically inclined portions extending into the upper part of the furnace to delineate the baffle or furnace wall 322. Beyond this baffle some of these tubes 324 are disposed out of wall alignment to form, with the tube portions 326, a tubular screen across the gas inlet for the superheater. These tubes lead upwardly along the furnace roof 328 to the water space of the steam and water drum 280. The continuation of the roof 328 over the vertical banks of superheater tubes is delineated by extensions of the wall tubes 302.

The wall of the furnace 330 of the Fig. 3 installation opposite the wall tubes 302 includes furnace wall tubes 332 and refractory material 334, the wall tubes being connected to the water space of the drum 280. Each of the remaining walls of the furnace includes an upper header such as indicated at 340. This header has the wall tubes connected thereto, and it also communicates with the steam and water drum 280 by appropriate circulatory connections.

Saturated steam from the steam and water drum 280 first flows through the tubes of the superheater bank 270, some of the connections between the drum 280 and the bank of tubes 270 being formed by the tubes 282. Other saturated steam connections are formed by the tubes 342 which lead from the top of the steam space of the drum 280. Parts of these tubes together with corresponding parts of the tubes 282 lead first horizontally along the roof 344 of the installation to the wall 346. Tubes 342 have parts extending downwardly through the roof 328 and then through the cavity 286 to a position where they are bent to the right to extend through the wall 310 and thereafter form parts of the bank of superheater tubes 270. Steam flows downwardly through this bank of tubes and then through the next lower bank of superheater tubes 271 to the intermediate superheater header 350. From this header steam flows through rows of tube sections 352 and 354 to other sections constituting

part of the vertical bank of superheater tubes 276. This flow continues to the upper superheater header 356. From this header the steam flows through the vertical tubes 358, the lower parts of which constitute the vertical bank of superheater tubes 274. The steam flows downwardly through four of the rows of tubes in this bank and then upwardly through connected tube sections to cross-over tubes 360 to the first two rows 362 and 364 of upright tubes at the left hand side of the bank of superheater tubes 276. The steam flow is reversed at the bottom of this bank and then reversed a second time as it continues to the lower four rows of tubes of the bank 272. From these rows of tubes the steam flows to a superheater outlet header 370, from which the steam flows to a point of use. All of the above indicated steam flow is clearly indicated by arrows in the various superheater banks of tubes of Fig. 3.

Feed water flowing through the banks of tubes 250-252 enters the header 312 at the top of the bypass 298 and continues in series flow through the tubes of the bank 250 and then downwardly through the bank of tubes 251 to the intermediate economizer header 314. From this header continued flow is through connecting tubes 376 to the economizer header 378 situated near the bottom of the bank of tubes 252. From this header the water flows upwardly through the series connected tubes of the bank 252 to the economizer outlet header 380. This header is in communication with the drum 280 through rows of circulators 382 and 382.

At the top of the gas pass 298 there are dampers 390 extending from the right hand wall to the gas bypass wall 296, and similar dampers 392 are disposed across the outlet of the bypass. These dampers may be automatically operated in response to departures of the superheat from an optimum value, to maintain a substantial constant superheat.

It will be understood that the various furnace wall tubes of the Fig. 3 installation are appropriately connected at their lower ends to suitable headers, and these headers are in turn in communication with the water space of the drum 280, to complete the circulation circuit. A large diameter downcomer such as that indicated at 400 may be a part of the connections between such lower headers and the drum 280.

To facilitate inspection, maintenance, and repair in connection with the illustrative installations, the deep gas flow equalization spaces on the downstream sides of the various banks of economizer and superheater tubes have large inspection openings associated therewith. Such openings are indicated at 410 to 416, inclusive. These openings are normally provided with suitable closures which may be manually operable.

What is claimed is:

1. In a steam generator and superheater installation, a furnace, means forming a heating gas passage extending laterally from a side of the furnace near its upper part and having diverging top and bottom walls; an upright wall at the rear of said passage, a superheater including a bank of vertically disposed serially connected tubes disposed substantially normal to gas flow in said passage and at a position spaced forwardly of said upright rear wall, means forming a gas outlet between the lower end of said rear wall and the lower end of said bottom wall, means forming an upright gas pass leading from said gas outlet, upper and lower groups of heat

absorbing tubes in said upright pass, said upper heat absorbing tubes constituting a feed water heater and the lower group of tubes constituting a part of the superheater, each of said tube groups constituting a plurality of circuits with serially connected tube portions of each circuit extending horizontally across said last mentioned pass, an upright baffle disposed rearwardly of said upright rear wall and combining therewith to form a gas by-pass through which the superheater in the upright gas pass may be bypassed, the by-pass having at its lower portion an inlet through said upright rear wall, and damper means controlling the gas flow through the by-pass.

2. In a combined steam generator and superheater installation, steam generating wall tubes defining the boundary surfaces of a furnace having a gas outlet laterally directed from the side of its upper portion, a steam and water drum disposed at the upper part of the furnace and connected to the upper ends of the steam generating wall tubes, the upper parts of some of said wall tubes along one wall of the furnace having upwardly inclined intermediate sections defining an upwardly and inwardly inclined furnace gas baffle extending from a position on said wall to form the lower boundary of said gas outlet of the furnace, said last mentioned tubes extending vertically upwardly beyond said baffle and across said outlet in a gas-passing screen formation, means forming an upright gas pass along said last mentioned furnace wall with some of the tubes of this furnace wall bent out of their wall alignment at the lower end of but above said baffle to form a gas pass inlet through this furnace wall, a superheater including a bank of horizontally extending series connected tubes disposed across the gas flow in said gas pass and at a level above that of said gas inlet, the superheater additionally having a bank of vertically disposed series connected tubes disposed between the gas pass and the furnace gas outlet and transversely of gas flow from the latter, tubular means connecting the steam space of the steam and water drum with said superheater, means connecting the vertical and horizontal banks of superheater tubes for series steam flow therethrough, some of the furnace wall tubes along the wall separating the gas pass from the vertically extending superheater tubes being bent out of their wall formation at a level above the levels of the banks of horizontally extending superheater tubes to form a superheater gas by-pass inlet, wall means forming a gas by-pass disposed above said last mentioned inlet so that gases may flow therethrough and upwardly without intermingling with other gases in the upright gas pass, and dampers disposed at the upper end of the gas pass for proportioning the flow of gas through the main part of the gas pass and through the by-pass to control superheat.

3. In a steam generator and superheater installation, means including closely disposed upright steam generating wall tubes defining a vertically elongated furnace of rectangular cross-section and generating substantially all of the steam for the installation, a furnace baffle disposed intermediate the height of the furnace and including parts of steam generating tubes extending downwardly toward one of the furnace walls, the furnace gas outlet being disposed above the upper end of the baffle, wall means including some of said steam generating tubes forming an

upright gas pass alongside said furnace wall, said gas pass being provided at its lower part with a gas inlet, means connecting the furnace gas outlet to said gas pass inlet, part of said wall means having its lower portion inclined oppositely and convergently relative to said furnace baffle to form therewith an upper hopper through which solids deposited from the gases are caused to move convergently downwardly to a hopper outlet, means forming a second hopper below said hopper outlet and exteriorly of the furnace for the periodical removal of solids collected from the gases, and auxiliary fluid heating devices disposed across the flow of gases above said furnace baffle and in said gas pass.

4. In a steam generator and superheater installation, steam generating tubes defining boundaries of a furnace, a steam and water drum to which said tubes are connected, means forming a heating gas passage extending horizontally from the upper part of the furnace and having rearwardly diverging top and bottom walls, an upright wall at the rear of said passage, the upright wall including some of said steam generating tubes and non-metallic heat resistant material, a superheater including a bank of vertically disposed serially connected tubes disposed transversely of gas flow in said passage and at a position spaced from said upright rear wall, said gas passage having a gas outlet between the lower end of said rear wall and the lower end of but above said bottom wall, means forming an upright gas pass for upward gas flow from said outlet, upper and lower groups of heat absorbing tubes in said upright gas pass, said upper groups of heat absorbing tubes constituting a feed water heater and including a plurality of circuits with serially connected tube portions extending horizontally from front to rear of said pass, an additional upright wall disposed rearwardly of the first mentioned upright wall and forming therewith a superheater gas by-pass, said first upright wall at the rear of the first mentioned gas passage having an opening therethrough constituting a gas inlet leading to the lower end of the by-pass, and damper means controlling the gas flow through the by-pass.

5. In a steam generator and superheater installation, a furnace, steam generating tubes subject to the heat of the furnace, means forming a heating gas passage leading horizontally from the upper part of the furnace and having rearwardly diverging top and bottom walls, an upright wall at the rear of said passage, the upright wall including some of said steam generating tubes, a convection superheater including a bank of vertically disposed serially connected tubes disposed transversely of gas flow in said passage and at a position spaced from said upright rear wall, said heating gas passage having a gas outlet between the lower end of said rear wall and the lower end of but above said bottom wall, means

forming an upright main gas pass for upward gas flow from said gas outlet, upper and lower groups of heat absorbing tubes in said upright main gas pass, said upper heat absorbing tubes constituting a feed water heater and including a plurality of circuits of serially connected tube portions extending horizontally across gas flow in said main gas pass, an additional upright wall disposed transversely of said upper heat absorbing tube portions and rearwardly of the first mentioned upright wall and combining with the latter to form therewith a superheater gas by-pass having an inlet disposed at a level above the level of the lower group of tubes and leading through the rear wall of said first passage to the lower end of the by-pass, and damper means controlling the gas flow through the by-pass, said by-pass having its major transverse dimension substantially equal to the major transverse dimension of the main pass.

6. In a steam generating superheater installation, a vertically elongated furnace including closely disposed steam generating wall tubes which generate substantially all of the steam of the installation, a superheater having a bank of vertically extending series connected tube sections disposed within the space defined by said wall tubes or extensions thereof, the furnace having a gas outlet in which the superheater is positioned, means including some of said wall tubes and forming an upright gas pass the lower end of which is connected to the gas outlet of the furnace, the superheater also including a bank of horizontally extending series connected tube sections disposed across upright gas flow in the gas pass and generally disposed at levels lower than the levels of the major parts of the vertically extending superheater tubes, wall means including heat resistant material and forming a part of one wall of said gas pass and including parts of some of the furnace wall tubes to form a superheater gas by-pass, the by-pass leading upwardly from the furnace gas outlet at a position rearwardly of the vertically extending superheater tube sections and upstream of the horizontally extending superheater tube sections relative to gas flow, and damper means at the upper end of the gas pass for proportioning the flow of gases between the by-pass and the main part of the gas pass to control superheat.

CHARLES H. WOOLLEY.

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