

Aug. 9, 1955

P. R. WALTER

2,715,019

MEANS FOR TEMPERATURE EQUALIZATION IN HEAT EXCHANGER

Filed June 25, 1951

4 Sheets-Sheet 1

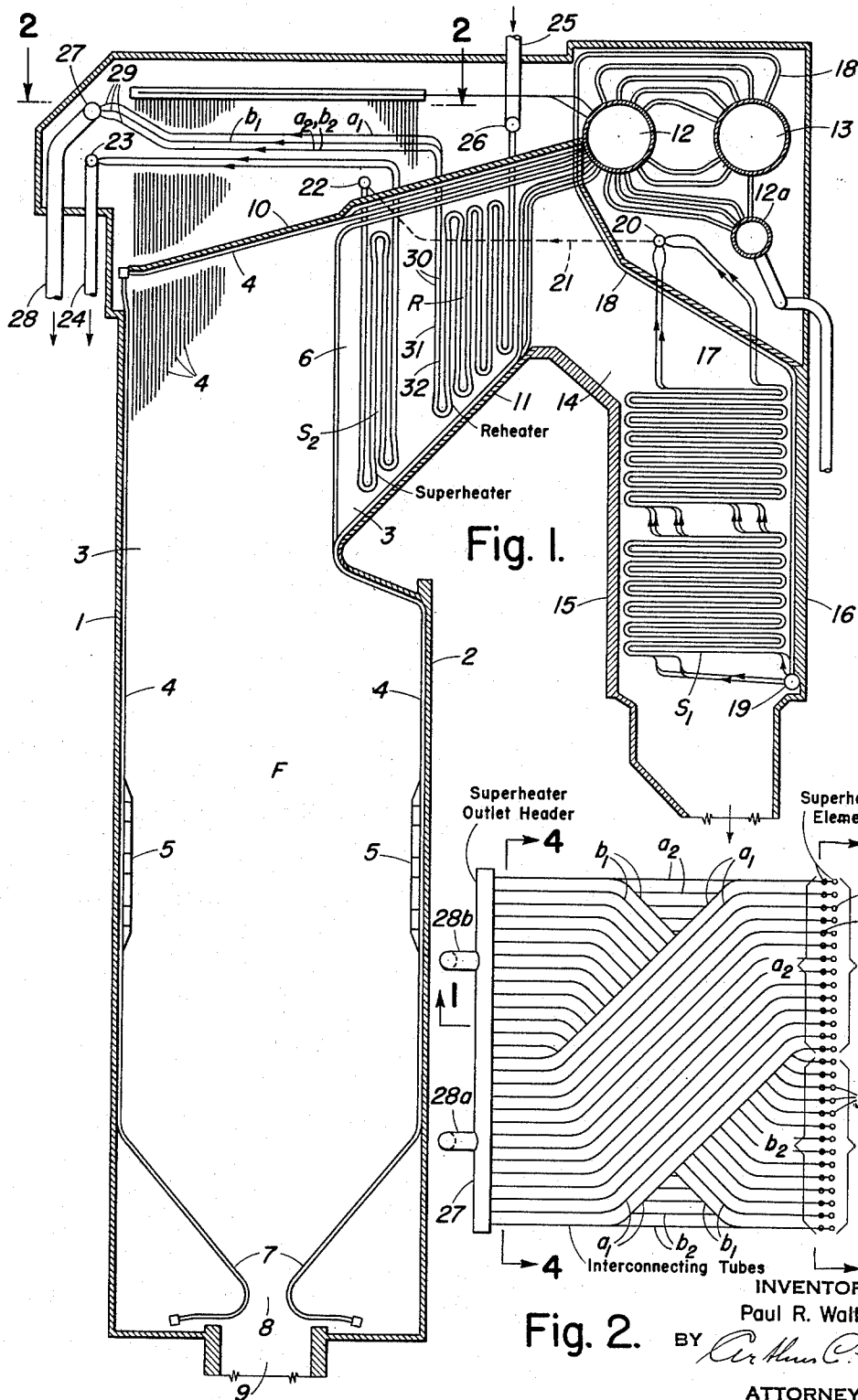


Fig. 2.

INVENTOR  
Paul R. Walter  
BY *Arthur C. Gird*  
ATTORNEY

Aug. 9, 1955

P. R. WALTER

2,715,019

MEANS FOR TEMPERATURE EQUALIZATION IN HEAT EXCHANGER

Filed June 25, 1951

4 Sheets-Sheet 2

Fig. 3.

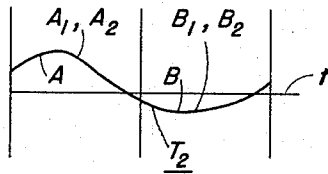


Fig. 4.

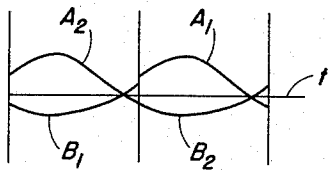


Fig. 6.

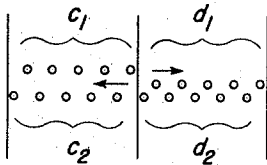


Fig. 7.

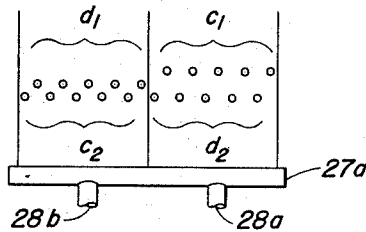


Fig. 5.

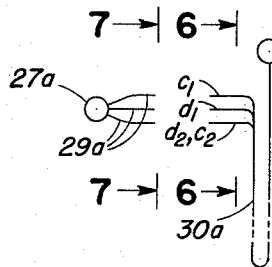


Fig. 8.

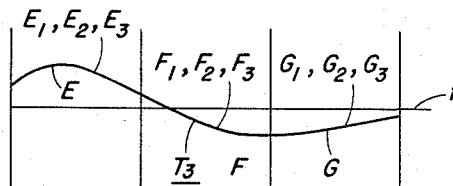
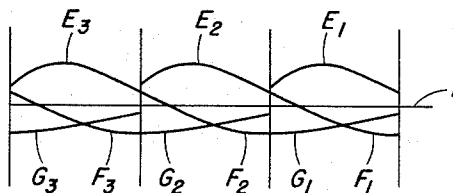


Fig. 9.



INVENTOR  
Paul R. Walter  
BY *Arthur C. Ford*  
ATTORNEY

Aug. 9, 1955

P. R. WALTER

2,715,019

MEANS FOR TEMPERATURE EQUALIZATION IN HEAT EXCHANGER

Filed June 25, 1951

4 Sheets-Sheet 3

Fig. 11.

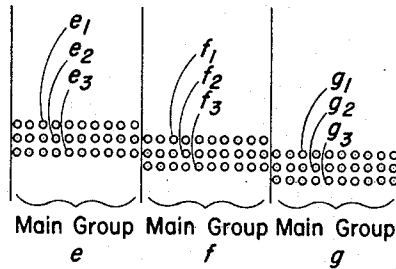


Fig. 12.

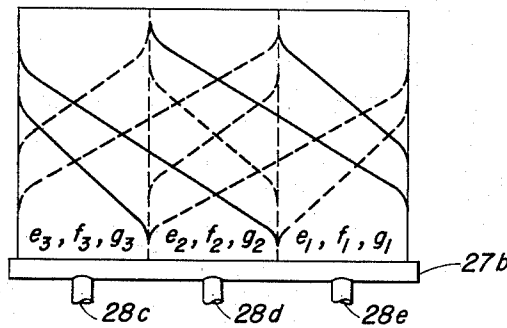


Fig. 13.

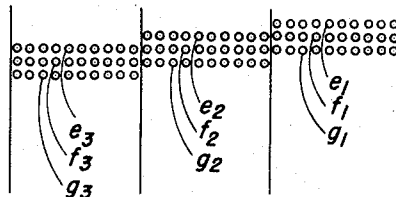


Fig. 12e.

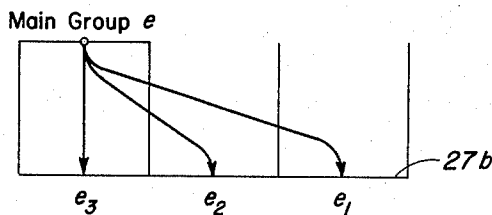


Fig. 12f.

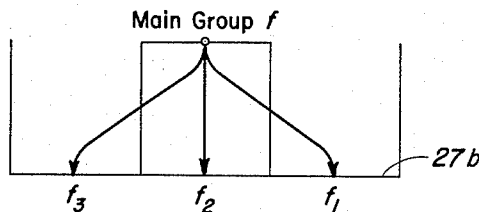


Fig. 12g.

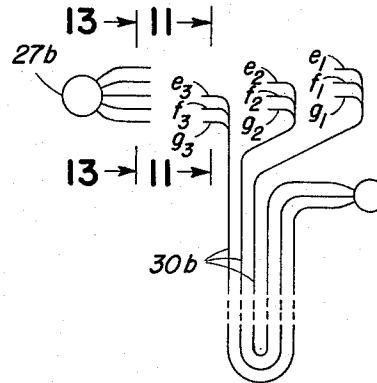
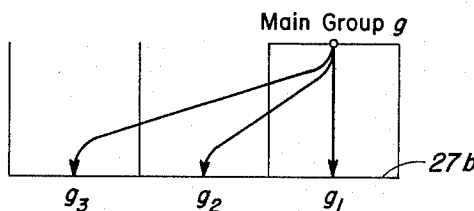


Fig. 10.

INVENTOR  
Paul R. Walter  
BY *Arthur C. Gird*  
ATTORNEY

Aug. 9, 1955

P. R. WALTER

2,715,019

MEANS FOR TEMPERATURE EQUALIZATION IN HEAT EXCHANGER

Filed June 25, 1951

4 Sheets-Sheet 4

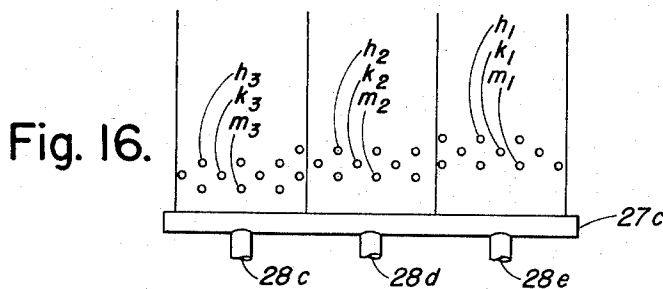
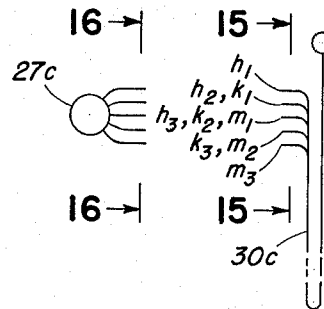
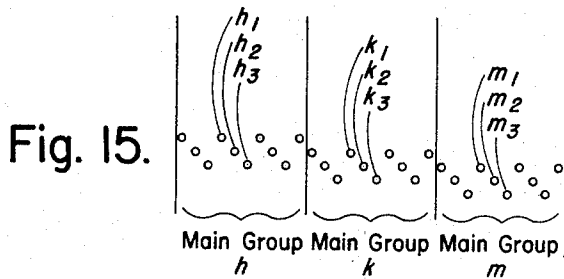


Fig. 14.

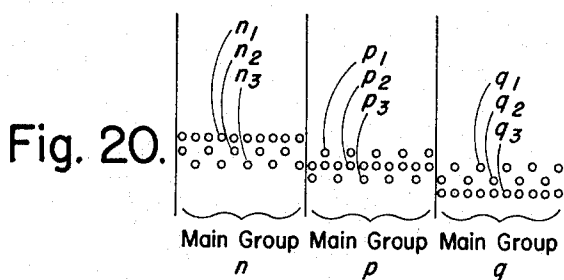
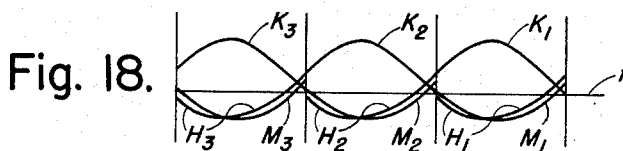
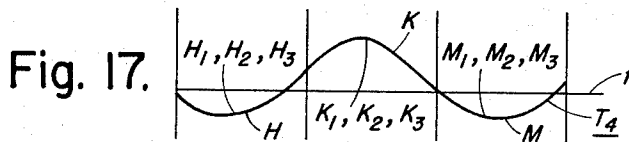
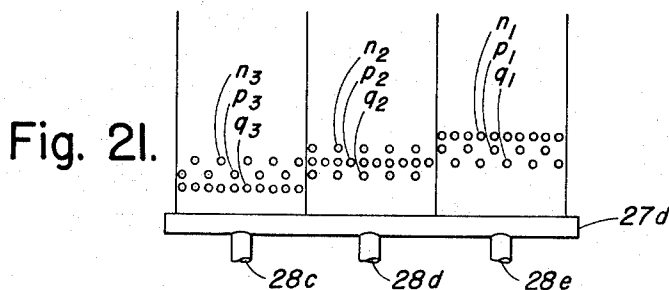
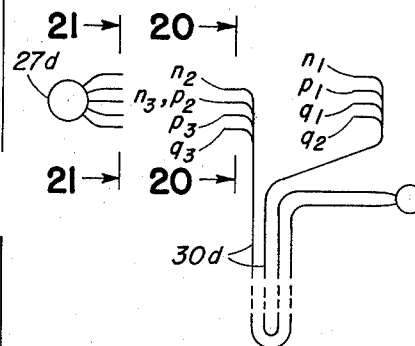


Fig. 19.



INVENTOR  
Paul R. Walter  
BY *Paul R. Walter*  
ATTORNEY

1

2

2,715,019

## MEANS FOR TEMPERATURE EQUALIZATION IN HEAT EXCHANGER

Paul R. Walter, East Orange, N. J., assignor to Combustion Engineering, Inc., New York, N. Y., a corporation of Delaware

Application June 25, 1951, Serial No. 233,331

10 Claims. (Cl. 257—241)

This invention relates to an apparatus for exchanging heat between fluids and particularly to steam superheaters associated with steam generators. Such a superheater may be a primary superheater or a reheat superheater and generally comprises a multiplicity of tubular elements each of which is made up of flat return bend tube coils or loops through which the steam flows from an inlet header or drum into an outlet header. The elements are usually arranged in parallel alignment transversely of the direction of flow of the gases that leave the furnace with which the steam generator is associated. When heating steam at the high temperatures now required in modern steam generation practise the superheater is located closely adjacent the furnace gas offtake so as to be swept by the gases being discharged from the furnace at elevated temperatures.

### The problem which the invention solves

The temperature of the gases leaving a large furnace may be of unequal value and the gases may flow at different rates over different portions of the cross section of the offtake. This may be caused by nonuniform burning of the fuel within different portions of the furnace and by an uneven absorption of heat from the products of combustion by the furnace walls which are generally lined with steam generating tubes. Consequently, various groups of superheater elements will absorb different amounts of heat from the furnace gases and deliver steam of varying superheat into the outlet header of the superheater. If the steam is conveyed from the outlet header by a large single offtake pipe, the hotter and cooler portions of steam thus delivered to the header by the elements having absorbed more or less heat, will mix and issue at a mean mixture temperature. But if several smaller steam offtake pipes are connected to and are spaced longitudinally of the outlet header, each of such pipes may receive steam of a different temperature. If, for example, the outlet header is that of a reheat superheater, each of said several steam removal pipes may be connected to one or more of several inlets to an intermediate stage of a steam turbine and different inlets would then receive steam at different temperatures which would impair the thermal efficiency of the turbine. A marked saving in the cost of pipework can be realized by the use of a plurality of smaller sized off-take steam pipes between said superheater offtake header and the steam turbine, instead of a combination of a large pipe with smaller pipes connecting to the superheater.

The primary object of this invention resides in providing an improved heat exchange apparatus of the type herein considered wherein the heated fluid may be withdrawn from the heat exchanger through a plurality of outlet pipes and at substantially the same fluid temperature.

Another object of this invention is to provide in a more economical manner than heretofore thought possible, equalization of the fluid temperature at the outlets of a heat exchanger of the type herein considered.

### General description of the drawings

Other objects and advantages of the invention will become apparent from the following description of an illustrative embodiment thereof when taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a cross section through a steam generator showing the associated primary superheater and the reheat superheater embodying one form of the invention.

Fig. 2 is a plan view of a section taken on line 2—2 of Fig. 1, illustrating one form of the herein disclosed inventive arrangement of the tube connections between the two-tube loop elements of the reheat superheater and its outlet header.

Fig. 3 is a diagrammatic representation of a typical variation of the temperature of the steam when leaving a row of superheater elements and as plotted across the width of the superheater when facing in the direction indicated by line 3—3 of Fig. 2.

Fig. 4 is a diagrammatic representation of the temperature variation of the steam leaving each row of the terminals of a two-loop element reheat superheater as plotted across the width of the superheater when facing in the direction indicated by line 4—4 of Fig. 2. The Fig. 4 diagram shows the relative steam temperature obtained if one row of terminals is divided into four groups, the points of straight line entry of the terminals of two groups into the outlet header having been interchanged in accordance with the herein disclosed invention.

Fig. 5 shows in diagrammatic form the elevation of a single-tube loop superheater element.

Fig. 6 represents a cross section taken at line 6—6, adjacent the elements, of Fig. 5, and shows the arrangement of groups of tubes upon leaving the single-tube loop elements of Fig. 5 while connecting said elements to the outlet header of the reheat superheater.

Fig. 7 represents a cross section taken on line 7—7, adjacent the outlet header of Fig. 5, and shows the arrangement of the groups of tubes of Fig. 6 upon entering said outlet header.

Fig. 8 is a diagrammatic illustration similar to Fig. 3 but distinguished therefrom by showing a curve indicating typical assumed temperature variations in the steam leaving the row of elements as plotted across the width of the superheater, said curve being divided into three groups instead of two.

Fig. 9 shows a diagram similar to Fig. 4, but indicating the steam temperature curves that result from dividing the tubes connecting the elements to the outlet header of the superheater into three groups instead of two and interchanging the three groups before entering the outlet header, according to the invention.

Fig. 10 shows a diagrammatic elevation of a three-tube loop superheater element, the terminals of which being organized in a manner corresponding to the arrangement of the groups of tubes in Fig. 11.

Fig. 11 shows a cross section taken at line 11—11 of Fig. 10 illustrating an arrangement of three groups of connecting tubes adjacent the elements, said tubes connecting the superheater elements with the superheater outlet header.

Fig. 12 is a diagrammatic plan view similar to Fig. 2, showing how the tubes as arranged in Figs. 10 and 11 are connected to the outlet header, according to the invention.

Figs. 12e, 12f, 12g are diagrams indicating the manner in which each main group of the connecting tubes of Fig. 11 is subdivided into three subgroups while communicating with the outlet header.

Fig. 13 shows a cross section taken at line 13—13 of Fig. 10, and illustrates the positions into which the groups of tubes shown in Figs. 11 have been shifted

before entering the outlet header, according to the teachings of my invention.

Fig. 14 shows a diagrammatic elevation of a single-tube loop superheater element, the terminals of which being organized in a manner corresponding to the arrangement of the groups of tubes in Fig. 15.

Fig. 15 shows a cross section taken at line 15—15, of Fig. 14, illustrating an arrangement of three groups of tubes connecting the elements of the superheater with the outlet header at a location adjacent the elements.

Fig. 16 represents a cross section taken at line 16—16 of Fig. 14, and illustrates the positions into which the groups of tubes shown in Fig. 15 have been shifted before entering the outlet header, in accordance with the invention.

Fig. 17 is a diagrammatic illustration, similar to Fig. 8, showing another typical assumed temperature variation curve of the temperature in the steam leaving the row of elements across the width of the superheater.

Fig. 18 shows a diagram similar to that shown in Fig. 9, but based on the temperature variation curve of Fig. 8, and indicating the steam temperatures that result from dividing the tubes connecting the elements to the outlet header of the superheater into three groups before entering the outlet header, according to the invention.

Fig. 19 shows a diagrammatic elevation of a two-tube loop superheater element, the terminals of which being organized in a manner corresponding to the arrangement of the groups of tubes in Fig. 20.

Fig. 20 shows a cross section taken at line 20—20 of Fig. 19, illustrating an arrangement adjacent the elements of three groups of the tubes connecting the two-tube loop elements of the superheater with the outlet header.

Fig. 21 shows a cross section taken at line 21—21 of Fig. 19, and illustrates the positions into which the groups of tubes shown in Fig. 20 have been shifted before entering the outlet header, according to the invention.

#### *Description of the preferred embodiment*

In Fig. 1 is illustrated a steam generator which comprises a furnace F bounded by front wall 1, rear wall 2 and the side walls 3. All walls are lined inside with steam generating tubes 4. Fuel and air for combustion is delivered into the furnace F through burners 5, the products of combustion rising and leaving the furnace through offtake 6. Residual ash falls downwardly into the hopper shaped bottom 7, through hopper outlet 8 into an ash pit 9 from which it is removed by well known conventional means, not shown. Bounding the furnace offtake 6, which offtake slopes upwardly and rearwardly from the furnace, are the roof 10, the inclined bottom wall 11 and the side walls 3.

All of the furnace tubes 4 facing the walls and roof of furnace F and of the offtake 6 absorb heat from the combustion gases for the generation of steam and are connected for steam discharge and water supply to the steam drum 12 and water drum 12a to form a water circulating system in any well known manner (only partly shown). Rearwardly of the offtake 6 and connected thereto for the flow of the products of combustion through is a conduit 14 bounded by conduit walls 15, 16 and 17.

Within offtake 6 are suspended the second stage section S2 of a primary superheater and a reheat superheater R. Within conduit 14 is suspended the first stage section S1 of the primary superheater. Steam discharged by furnace lining tubes 4 into steam drum 12 and thence into dry drum 13 flows via tubes 18 into the intake header 19 at the bottom of superheater section S1, thence through the superheater S1 into the outlet header 20, thence via pipes 21 to the inlet header 22 of superheater section S2, through superheater S2 to outlet header 23, whence it leaves through pipe 24 to flow to the high pressure stage of a steam turbine, not shown. The steam at lower pressure and temperature is then taken from an intermediate stage of the steam turbine and flows via

pipe 25 and inlet header 26 into the reheat superheater R wherein the temperature of the steam is again increased by the absorption of heat from the combustion gases. The superheated steam leaves reheater R through terminal or connecting tubes  $a_1$ ,  $a_2$ ,  $b_1$ ,  $b_2$ , see also Fig. 2, which connect the reheater tubes individually with the outlet header 27 and thence flows via pipe 28 back to the turbine (not shown) for further extraction of energy.

The reheat superheater R, being equipped with the herein disclosed inventive improvement comprises a plurality of vertical return bend tubular elements 30 suspended in the furnace offtake 6 and arranged in spaced parallel relationship transversely to the direction of the gas flow through said furnace offtake. In the preferred embodiment illustrated in Fig. 1, each superheater element 30 comprises two series of separate nesting loops 31 and 32 made up of tubes which are bent back and forth, in a plane normal to the direction of flow of the products of combustion, between the top and bottom walls 10 and 11 of the offtake 6. As will appear later, the reheat superheater R may be constructed of single-tube loop elements as diagrammatically shown in Figs. 5 and 14, or may have two-tube loop elements as indicated in Figs. 1 and 19, or may have three-tube loop elements as shown in Fig. 10, or may also have more than three tubes per element loop (not illustrated).

Referring again to Fig. 1 and also to Fig. 2, showing the preferred embodiment of my invention, the outlet header 27 of superheater R is provided with two offtake pipes 28a and 28b instead of one pipe 28. There are three layers of groups of terminal tubes 29 which connect the outlets of superheater elements 30 to the outlet header 27. These are a top layer  $a_1$ , an intermediate layer  $b_1$  and a bottom layer  $a_2b_2$ . Looking toward the rear of the steam generator 1, that is in the direction indicated by section line 3—3 of Fig. 2, the top group  $a_1$  of the tubes 29 connects the left half of tubes 32 of the elements 30 with the right half of header 27, thereby serving outlet 28a; the middle group  $b_1$  of the terminal tubes 29 connects the right half of tubes 32 to the left half of header 27, thereby serving outlet 28b; and the bottom group  $a_2b_2$  of terminal tubes 29 being a complete row extends across the full width of the furnace and connects all of the tubes 31 of elements 30 directly across with header 27. The above described manner of connecting the four groups of tubes ( $a_1$ ,  $b_1$ ,  $a_2$  and  $b_2$ ) to the superheater R and header 27 provide novel means for assuring substantially the same temperature of steam in each of the offtake pipes 28a and 28b regardless of variations in heat absorption in the elements 30. This may be fully understood by reference to Fig. 3 in which the curve  $T_2$  shows an assumed temperature variation of the steam leaving each of the two rows of tubes 31 and 32 on top of the superheater elements 30. Each curve, identical for each row 31 and 32 is shown superimposed in Fig. 3 and is divided into two portions. The curve representing the temperature of the steam leaving tubes 32 is divided into curve sections  $A_1$  and  $B_1$ , and the curve representing the temperatures of the steam leaving tubes 31 is divided into curve sections  $A_2$  and  $B_2$ . The mean temperature is represented by line  $t$ . As mentioned above, the left half group  $a_1$  of connecting tubes Fig. 2, connects to the right half of header 27, while the right hand group  $b_1$  connects to the left half of header 27. Analogously one portion  $A_1$  of temperature curve  $T_2$  (Fig. 3) moves to the right as shown in Fig. 4 and one portion  $B_1$  of temperature curve  $T_2$  moves to the left hand side as also shown in Fig. 4. On the other hand the groups  $a_2$  and  $b_2$ , connecting tubes 31 with header 27, do not shift. Consequently the temperature curve  $A_2$  and  $B_2$  representing the temperature of steam leaving tubes 31 remains, in Fig. 4, in the same position as that shown in Fig. 3. It can be observed by visual inspection of Fig. 4 that the two halves of header 27 now each contain steam at the mean temperature  $t$

which is the average of the temperatures of the groups  $a_1$  and  $b_2$  serving header outlet  $28a$  and also of the groups  $b_1$  and  $a_2$  serving the header outlet  $28b$ . (See Fig. 2.) If convenient the groups of tubes may occupy different levels; e. g., the group  $a_1$ , of the connecting tubes  $29$  may be placed at the bottom level and the groups  $a_2$ ,  $b_2$  at the middle level.

*Invention applied to a single-tube loop superheater element*

In the preferred illustrative embodiment of Figs. 1 and 2 is shown a superheater element  $30$  having two tubes per loop namely  $31$  and  $32$ . In another alternate embodiment of the invention as shown in Figs. 5, 6 and 7 the superheater element now called  $30a$  comprises but one tube per loop and there are therefore required but half the number of tube connections  $29a$ , than in the two-tube loop element arrangement of Figs. 1 and 2, between the outlets of the elements  $30a$  and the outlet header now designated  $27a$ . The arrangement of the tube connections for the single-tube loop element is shown in Fig. 6, wherein the outlet ends of the single row of tubes  $30a$  are again divided into four groups,  $c_1$ ,  $d_1$ ,  $c_2$  and  $d_2$  of alternately spaced tube terminals forming three rows of tube connections  $c_1$ ,  $d_1$  and  $c_2d_2$  (see Fig. 5). As the groups of connecting tubes extend from the element outlets toward the outlet header  $27a$ , the tubes of group  $c_1$  are bent to the right to enter the right hand portion of header  $27a$  serving outlet  $28a$  as shown in Fig. 7, and the tubes of group  $d_1$  are bent to the left to enter the left hand portion of header  $27a$ , serving outlet  $28b$  while the groups  $c_2d_2$  are not bent but extend straight forward to connect into header  $27a$  thereby contributing steam to both outlets  $28a$  and  $28b$ . Their position therefore remains the same in Fig. 7 as that shown in Fig. 6. Again it can be seen that the steam entering the header  $27a$  is distributed in such a manner that the temperature differences balance out, as is shown in Fig. 4. Each of the offtake pipes  $28a$  and  $28b$  (Fig. 5) accordingly receive steam at substantially the same mean temperature.

*Invention applied to a superheater having three offtake pipes*

The hereinabove described novel arrangement of the connecting tubes between the superheater elements and the outlet header may also be applied to a header  $27b$  having three offtake pipes  $28c$ ,  $28d$  and  $28e$ . (See Fig. 12.) Fig. 8 accordingly, shows a steam temperature curve  $T_3$  similar to the curve  $T_2$  indicated in Fig. 3, but divided into three sections E, F and G, Fig. 8 (instead of two), in conformity with the three header offtake pipes  $28c$ ,  $28d$  and  $28e$  in header  $27b$  (Fig. 12). These curve sections correspond to three main groups  $e$ ,  $f$  and  $g$ , of the connecting tubes, see Fig. 11, each main group comprising about one-third of the total number of element outlet ends. There will be three subgroups to main group  $e$ , marked  $e_1$ ,  $e_2$  and  $e_3$ ; three subgroups to main group  $f$ , marked  $f_1$ ,  $f_2$  and  $f_3$ ; and three subgroups to main group  $g$ , marked  $g_1$ ,  $g_2$  and  $g_3$ , as shown in Figs. 10 and 11; each sub-group containing about the same number of tubes or serving substantially the same superheater heating surface. As shown in Fig. 12e the three sub-groups  $e_1$ ,  $e_2$ ,  $e_3$  will be arranged to have one sub-group  $e_1$  delivering steam into one-third portion of outlet header  $27b$ , a second sub-group  $e_2$  to a second third portion, and the third sub-group  $e_3$  to the remaining third portion. The three sub-groups  $f_1$ ,  $f_2$ ,  $f_3$  of Fig. 12f and the three sub-groups  $g_1$ ,  $g_2$ ,  $g_3$  of Fig. 12g are similarly arranged in connecting to header  $27b$ . Fig. 12 shows a composite diagrammatic plan view similar to Fig. 2 and illustrates how the subgroups of all three main groups  $e$ ,  $f$  and  $g$  are connected to the header  $27b$  in accordance with the teachings of the invention.

As mentioned hereinabove Fig. 8 shows an assumed temperature variation (curve  $T_3$ ) across the superheater width of the steam leaving tubular elements  $30b$  (Fig. 10), said curve  $T_3$  being divided into three sections E, F and G corresponding to the three aforementioned main groups of tubes  $e$ ,  $f$  and  $g$ . Each of the sub-groups  $e_1$ ,  $e_2$  and  $e_3$  of main group  $e$  has a temperature curve corresponding to section E (Fig. 8). Each of the three subgroups  $f_1$ ,  $f_2$  and  $f_3$  of the main group  $f$  has a temperature curve corresponding to section F, and each of the subgroups  $g_1$ ,  $g_2$  and  $g_3$  has a temperature curve corresponding to section G. By connecting the various groups in the manner hereinabove set forth, when entering outlet header  $27b$  and as individually illustrated in Figs. 12e, 12f and 12g and as compositely shown in Fig. 12, the corresponding steam temperature will also be shifted accordingly in the manner shown in Fig. 9, and as explained in greater detail in connection with Figs. 3 and 4. Visual inspections show that the average temperature in each of the three header sections will be the same, resulting in a temperature of the steam leaving the three header outlets  $28c$ ,  $28d$  and  $28e$  of substantially the same value.

Referring again to Figs. 10, 11, 12 and 13 there are five levels of connecting tube groups which carry steam to the outlet header  $27b$  and to the three offtake tubes  $28c$ ,  $28d$  and  $28e$  connected thereto. As hereinabove set forth each third portion of the header  $27b$  receives substantially the same amount of steam from the superheater elements  $30b$  and at substantially the same mean temperature  $t$ , as shown in Fig. 9. In general it can be shown that the number of levels connecting tube groups will equal twice the number of offtake pipes less one. Thus for two offtake pipes  $28a$  and  $28b$ , the number of tube levels is three, Figs. 5, 6 and 7, while for three offtake pipes  $28c$ ,  $28d$  and  $28e$ , the number of tube levels is five, Figs. 10, 11 and 13.

As described hereinabove Fig. 10 shows three-tube loop superheater elements  $30b$ , the tube ends of which are marked with the same letters as are those of the tube subgroups in Figs. 11 and 13 to which they are connected. The embodiment of the invention illustrated here is but an example of a variety of arrangements that can be employed. When the number of tube loops per element  $30b$  equals the number of offtake pipes, such as is the case in the illustrative example of Figs. 10, 11, 12 and 13 the spacing of the tubes in the rows of Figs. 11 and 12 equals the spacing of the superheater elements  $30b$ .

On the other hand, if the tube groups  $e$ ,  $f$  and  $g$  are supplied from a superheater having a single-tube loop element  $30c$ , as shown in Fig. 14, the number of tubes shown in Fig. 11 will be reduced to one third in order to accommodate the reduced number of element connections. This is shown in Figs. 15 and 16, which are similar to Figs. 11 and 13. Again there are five levels over which the connecting tubes are distributed and three main groups  $h$ ,  $k$ , and  $m$  corresponding to the three header offtake pipes  $28c$ ,  $28d$  and  $28e$  (Fig. 12). The subgroups of  $h_1$ ,  $h_2$  and  $h_3$  of main group  $h$ , the subgroups  $k_1$ ,  $k_2$  and  $k_3$  of main group  $k$  and the subgroups  $m_1$ ,  $m_2$  and  $m_3$  of main group  $m$  are connected in the same manner as described above with respect to main groups  $e$ ,  $f$  and  $g$  and as shown in Figs. 12e, 12f, 12g and 12. Again each third portion of the header  $27c$  receives substantially the same amount of steam from the superheater and at substantially the same mean temperature  $t$  as shown in Fig. 9.

If a superheater having two-tube loop elements (Fig. 19) instead of three (Fig. 10) is to be connected to an outlet header  $27c$  having three outlets such as  $28c$ ,  $28d$  and  $28f$  (Fig. 12), it will be necessary to reduce the number of tubes shown in Fig. 11 to two thirds in order to accommodate the reduced number of element tube connections. In the two-tube loop superheater illustrated in Fig. 19 the tube ends of elements  $30d$  are also arranged in five tube row levels to afford equal distribution over

three header outlets 28c, 28d and 28e (Fig. 12), in accordance with the herein disclosed invention.

*Invention applicable to wide temperature variations*

In order to show the versatility of the invention and its wide field of application, a temperature variation curve  $T_4$  of an entirely different character than that shown in Figs. 3 and 8 has been assumed and is illustrated in Fig. 17. Curve  $T_4$  accordingly represents the temperature variation across the superheater width in each of the two tube terminal rows of a two-tube loop element 30d (Fig. 19), and is divided into three curve sections H, K and M which correspond to the three header off-take pipes 28c, 28d and 28e (Fig. 21). Proceeding in the same manner as hereinabove described for Fig. 8, each curve section shifts in conformity with its corresponding group of connecting tubes. For example, referring to Figs. 20 and 21, the subgroup  $n_1$  of main group  $n$  (Fig. 20) connects to the right hand one third portion of header 27d (Fig. 21), the subgroup  $n_2$  connects to the middle third portion of header 27d and the subgroup  $n_3$  connects straight forward to the left hand one third portion of header 27d. In a similar fashion, the three subgroups  $p_1$ ,  $p_2$  and  $p_3$  of main group  $p$  and subgroups  $q_1$ ,  $q_2$  and  $q_3$  of main group  $q$  connect to the respective one third portions of header 27d as indicated in Fig. 21 and analogous to the arrangement shown in Fig. 12. The respective temperature curve sections (Fig. 17),  $H_1$ ,  $H_2$  and  $H_3$  corresponding to subgroups  $n_1$ ,  $n_2$  and  $n_3$  (Fig. 20);  $K_1$ ,  $K_2$  and  $K_3$  corresponding to subgroups  $p_1$ ,  $p_2$  and  $p_3$ ; and  $M_1$ ,  $M_2$  and  $M_3$  corresponding to subgroups  $q_1$ ,  $q_2$  and  $q_3$  shift accordingly in the manner indicated in Fig. 18. Again each third portion of the header 27d receives substantially the same amount of steam from the superheater and at substantially the same mean temperature  $t$ .

*Invention applicable to a superheater having more than three offtake pipes*

In a similar manner as in the examples shown above, the invention may be applied to an organization having four or more superheater header offtake pipes 28. Accordingly four or more groups of tubes may be arranged between the superheater elements and the outlet header 27, crossconnected in the inventive manner hereinabove set forth so as to achieve substantially equal steam temperature in each header offtake pipe.

As a general rule, according to my invention, the number of offtake pipe connections or header discharge openings determine the number of main groups into which the connecting tubes 29 must be divided and also determines the number of subgroups into which each main group must be divided.

Thus, if  $X$  offtake pipes (28) are used then the connecting tubes (29) will be divided into  $X$  main groups and each main group in turn will be divided into  $X$  subgroups; each subgroup of each main group going organized to communicate with a different one of the  $X$  discharge openings or header outlets, as herein above disclosed.

If the various superheater elements are connected in this novel manner it will be found that the average steam temperature or mixture temperature in each header discharge opening or offtake pipe 28 will be substantially the same.

*Advantages accruing from the invention*

My invention is particularly applicable to conveying steam from a reheat superheater to an intermediate stage of a steam turbine where low flow resistance losses are desired.

In operation the return pipes 28 from the superheater R to an intermediate stage of the steam turbine may convey steam at about 1000 deg. F., and are consequently made of a costly heat resisting steel, such as a chrome molybdenum alloy. Because the pressure drop from the turbine through pipe or pipes 26 to the superheater R, through the superheater and through the return pipes

28 back to the turbine must be kept low to maintain turbine efficiency, the cross sectional area of the conveying pipes must be relatively large. Heretofore a single return pipe was used alone or in combination with smaller superheater pipe connections in order to equalize the temperature of the steam flowing from the various parts of the superheater, so that the various nozzles used to direct the steam into the intermediate stage of the turbine would receive steam at equal temperatures from said pipe. However said single pipe became very large and its cost was high because of the special manufacturing process required for its fabrication in the tube mill and also because of the large wall thickness required for pressure piping.

According to the invention it is now possible to use a plurality of smaller return pipes 28 of standard size with a relatively thin wall therefore of much lower cost, and still obtain substantially equal steam temperature in each pipe. These pipes may be connected into different portions of the superheater outlet header 27 and carry the steam directly to said various nozzles in the intermediate stage of the steam turbine (not shown). For example, one twenty inch pipe, which is prohibitive in the cost due to special manufacturing process, may be replaced by two fourteen inch standard pipes of relatively low cost with the steam temperature in each pipe substantially the same.

While the preferred embodiment of my invention has been here shown and described, it will be understood that changes in construction, combination, and arrangement of parts may be made without departing from the spirit and scope of the invention as claimed.

*I claim:*

1. In a fluid heat exchange apparatus, means forming a pass for furnace gas flow of non-uniform and non-symmetrical heat exchange values over the cross section of said pass, a plurality of flat tubular heating coils arranged in said gas pass with their axes in planes substantially parallel to the walls of the gas pass for heat exchange fluid flow through those coils, an outlet header to receive the heated fluid from said coils, said header having means forming two outlets and tubular connections each establishing direct communication between said heating coils and header outlets said tubular connections being located substantially outside of said furnace gas flow path and being divided into two groups each having a substantially equal number of tubes, one half of the number of said tubular connections in each of said two groups communicating with one header outlet the other half communicating with the other header outlet each connection forming with its heating coil and the header outlet with which it communicates a flow path, each group of said tubular connections comprising flow paths having heating coils arranged in gas flow zones of different heat exchange values some of said flow paths' discharging fluid having a temperature different from that of the fluid discharged by others, whereby the fluid temperature in the one header outlet nevertheless substantially equals the fluid temperature in the other header outlet.

2. In a fluid heat exchange apparatus, means forming a pass for flow of furnace gas having non-uniform heat exchange values over the cross section of said pass, a plurality of flat tube coils arranged in said gas pass with their axes in planes substantially parallel to the walls of the gas pass for heat exchange fluid flow through those coils, an outlet header to receive the heated fluid from said coils, said header having means forming discharge openings, and tubular connections each establishing communication between said tube coils and said discharge openings, said tubular connections being divided into three groups each group having a substantially equal number of tubes, one third of the number of said tubular connections in each of said three groups communicating with one of the three discharge openings, another third of the number of said tubular connections in each

group communicating with one of the other two discharge openings and the remaining third of the number of said tubular connections communicating with the remaining and third discharge opening, each of said connecting tubes forming with its coil and the corresponding discharge opening with which it communicates a flow path, each group comprising flow paths having coils arranged in gas flow zones of different heat exchange values, and the high heat exchange value of some of the flow paths in one group compensating for the low heat exchange value of some of the flow paths in any other group, whereby the fluid temperature in the one discharge opening substantially equals the fluid temperature in any one of the other discharge openings.

3. In a fluid heat exchange apparatus, means forming a pass for furnace gas flow of non-uniform heat exchange values over the cross section of said pass, a plurality of flat tube coils arranged in said gas pass with their axes in planes substantially parallel to the walls of the gas pass for heat exchange fluid flow through those coils, an outlet header to receive the heated fluid from said header having means forming discharge openings, and tubular connections each establishing communication between said tube coils and said discharge openings, said tubular connections being divided into three groups each group having a substantially equal number of tubes, one fourth of the number of said tubular connections in each of said three groups communicating with one of the three discharge openings, another fourth of the number of said tubular connections in each group communicating with one of the other two discharge openings and the remaining half of the number of said tubular connections communicating with the remaining and third discharge opening, each of said connecting tubes forming with its coil and the corresponding discharge opening with which it communicates a flow path, each group comprising flow paths having coils arranged in gas flow zones of different heat exchange values, and the high heat exchange value of some of the flow paths in one group compensating for the low heat exchange value of some of the flow paths in any other group, whereby the fluid temperature in the one discharge opening substantially equals the fluid temperature in any one of the other discharge openings.

4. In a fluid heat exchange apparatus, means forming a pass for furnace gas flow of nonuniform heat exchange values over the cross section of said pass, a plurality of flat tubular heating coils arranged in said gas pass with their axes in planes substantially parallel to the walls of the gas pass for heat exchange fluid flow through those coils, at least one outlet header to receive the heated fluid from said coils, said header or headers having means forming a total of at least two discharge openings, and tubular connections each establishing direct communication between said heating coils and discharge openings, said tubular connections being located substantially outside said gas pass and being divided into as many main groups as the number of said discharge openings, said tubular connections in each of said main groups again being divided into as many sub-groups as the number of said discharge openings, each of said sub-groups of each main group communicating with a discharge opening different from that with which other sub-groups of the same main group are communicating, each tubular connection forming with its coil and said one discharge opening with which it communicates a flow path, each group comprising flow paths having heating coils arranged in zones of different heat exchange values, some of said flow paths' discharging fluid having a temperature different from that of the fluid discharged by others, whereby the fluid temperature in the one discharge opening substantially equals the fluid temperature in any one of the other discharge openings.

5. In a fluid heat exchange apparatus, means forming a pass for furnace gas flow of non-uniform heat exchange values over the cross section of said pass, a plurality of flat tubular heating coils arranged in said gas pass with

their axes in planes substantially parallel to the walls of the gas pass for heat exchange fluid flow through those coils, at least one outlet header to receive the heated fluid from said coils, said header or headers having means forming a total of at least two discharge openings, and tubular connections each establishing direct communication between said heating coils and discharge opening means, said tubular connections being located substantially outside of said gas pass and being divided into as many groups as the number of said discharge opening means, said connections in each of said groups communicating with one discharge opening means each connection forming with its coil and said one discharge opening means with which it communicates a flow path, each group comprising flow paths having heating coils arranged in gas flow zones of different heat exchange values, some of said flow paths' discharging fluid having a temperature different from that of the fluid discharged by others whereby the fluid temperature in the one discharge opening substantially equals the fluid temperature in any one of the other discharge openings.

6. In a duct through which flows a stream of combustion gases having heating values of non-uniform and non-symmetrical intensities across said duct, a superheater disposed within said duct and having a multiplicity of elements for steam flow therethrough each element forming a heating surface which is exposed to different heating intensities of said combustion gas some elements absorbing individually a total of more or less heat than other elements, all of said superheater elements being divided into main groups of substantially equal numbers of elements, said main groups being arranged with respect to each other for parallel flow of the steam and the elements in each of said groups being divided into sub-groups containing a substantially equal number of heater elements; a steam collecting header for receiving the heated steam said collecting header being divided into portions equal in number to the aforesaid main groups and having a steam offtake pipe connected to each of said portions; and connecting tubes communicating directly with the outlet of one of each of the sub-groups of superheater elements and with one of each of said portions of said collecting header means; whereby a compensation is achieved for the unequal heating intensities of the combustion gases to which said heater elements are exposed, so that the temperature of the heated steam flowing through each of said steam offtake pipes will be of substantially equal value.

7. In a duct through which flows a stream of a heating medium having heating values of non-uniform intensities across said duct, a fluid heater disposed within said duct and having a multiplicity of elements for fluid flow therethrough each element forming a heating surface which is exposed to different heating intensities of said heating medium some elements therefore absorbing individually a total of more or less heat than other elements, all of said heater elements being divided into main groups of substantially equal number of elements and being arranged with respect to each other for parallel flow of the heated fluid, the elements in each of said groups being divided into sub-groups containing a substantially equal number of heater elements; fluid collecting means for receiving the heated fluid said collecting means being divided into portions equal in number to the aforesaid main groups and having a fluid offtake pipe connected to each of said portions; and connecting conduit means communicating directly with the outlet of one of each of the sub-groups of heater conduits and with one of each of said portions of said collecting means; whereby a compensation is achieved for the unequal heating intensities of the heating medium to which each of said heater elements is exposed, so that the temperature of the heated fluid flowing through each of said fluid offtake pipes will be of substantially equal value.

8. In a duct through which flows a stream of a heating medium having heating values of non-uniform intensities

11

across said duct; a fluid heater disposed within said duct and having a multiplicity of elements for fluid flow therethrough, said elements being spacedly distributed in a uniform pattern transversely of the duct, each element forming a heating surface and being exposed to different heating intensities of said heating medium whereby the fluid in some elements absorbs individually a total of more or less heat than that in other elements; all of said heater elements being divided transversely of said duct into main groups having parallel fluid flow therethrough and of substantially equal numbers of elements, the fluid flowing through the elements in each of said main groups being divided into equal portions, fluid collecting means for receiving said equal portions of the heated fluid, said collecting means being divided into sections equal in number to the aforesaid main groups and having a fluid offtake pipe connected to each of said sections; and connecting conduit means communicating directly with the outlets of said main groups and said collecting means for conducting one of each of said fluid portions from each main group into one of each of said sections of said collecting means; whereby a fluid flow path is formed between each collecting section and one fluid portion of each main group to achieve compensation for the unequal heating intensities of the heating medium to which said heater elements are exposed, so that the temperature of the heated fluid flowing through each of said fluid offtake pipes will be of substantially equal value.

9. In a duct defined by a front, rear and two sides and through which flows a stream of a heating medium having heating values of non-uniform intensities across said duct; a fluid heater disposed within said duct and having a multiplicity of elements for fluid flow therethrough, said elements being spacedly distributed in a uniform pattern transversely of the duct, each element forming a heating surface and being exposed to different heating intensities of said heating medium whereby the temperature of the fluid leaving some of said elements may be higher or lower than the temperature leaving other elements; all of said heater elements being divided transversely of said duct from side to side into main groups having parallel fluid flow therethrough and of substantially equal numbers of elements, the elements in each of said main groups being divided from front to rear into as many portions as there are main groups, fluid collecting means for receiving the heated fluid flowing through said equal portions, said collecting means being divided into sections equal in number to the aforesaid main groups and having a fluid offtake pipe connected to each of said sections, and connecting

12

conduit means communicating with said main groups and said collecting means for conducting the heated fluid from one of each of said element portions from each main group into one of each of said sections of said collecting means; whereby a fluid flow path is formed between each collecting section and one of said element portions of each main group to achieve compensation for the unequal heating intensities of the heating medium to which said heater elements are exposed, so that the temperatures of the heated fluid flowing through each of said fluid offtake pipes will be of substantially equal value.

10. In a duct defined by a front, rear and two sides and through which flows a stream of hot combustion gases having heating values of non-uniform intensities across said duct; a steam heater disposed within said duct and having a multiplicity of tubular elements for steam flow therethrough, said elements extending longitudinally of the duct, each element forming a heating surface and being exposed to different heating intensities of said hot gases whereby the temperature of the steam leaving some of said elements may be higher or lower than the temperature leaving other elements; all of said heater elements being divided transversely of said duct from side to side into main groups having parallel steam flow therethrough and of substantially equal numbers of elements, the elements in each of said main groups being divided from front to rear into as many portions as there are main groups, steam header means for receiving the heated steam flowing through said equal element portions, said steam header means being divided into sections equal in number to the aforesaid main groups and having a steam offtake pipe connected to each of said sections, and connecting conduit means communicating with said main groups and said steam header means for conducting the steam from one of each of said element portions from each main group into one of each of said sections of said steam header means; whereby a steam flow path is formed between each header section and one of said element portions of each main group to achieve compensation for the unequal heating intensities of the hot gases to which said steam heater elements are exposed, so that the temperatures of the heated steam flowing through each of said steam offtake pipes will be of substantially equal value.

#### References Cited in the file of this patent

#### UNITED STATES PATENTS

|           |           |              |
|-----------|-----------|--------------|
| 2,281,580 | Hobbs     | May 5, 1942  |
| 2,587,720 | Fritzberg | Mar. 4, 1952 |