

July 22, 1930.

G. D. MANTLE

1,770,936

RECUPERATOR

Filed July 2, 1925

3 Sheets-Sheet 1

FIG. 1.

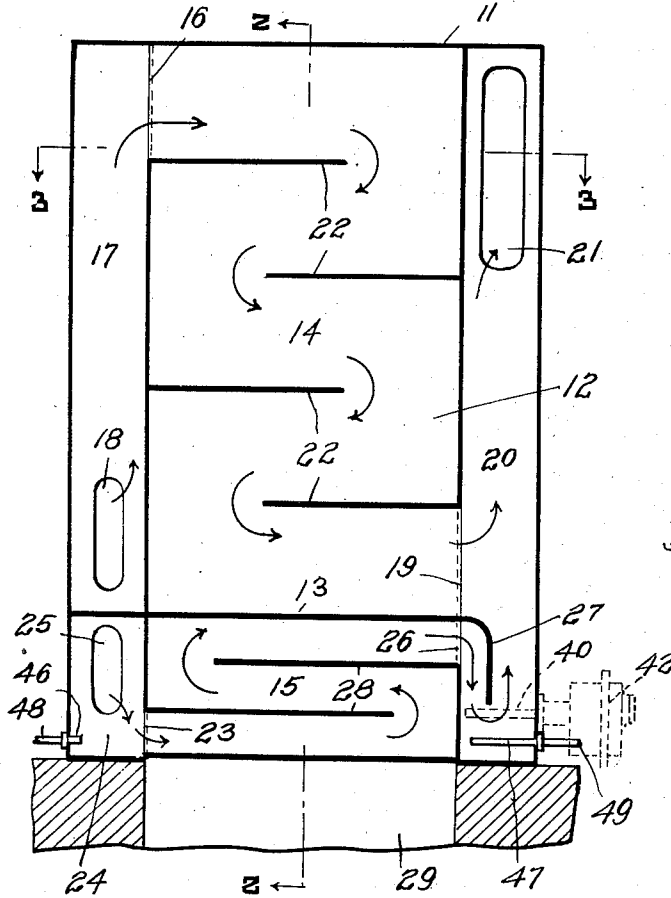


FIG. 2.

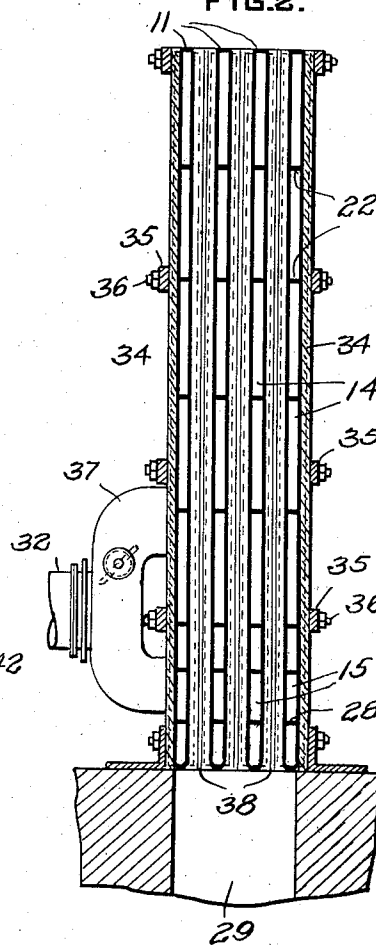
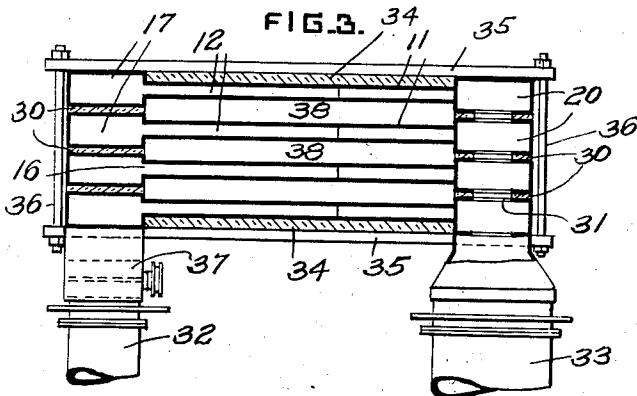


FIG. 3.



INVENTOR

WITNESS

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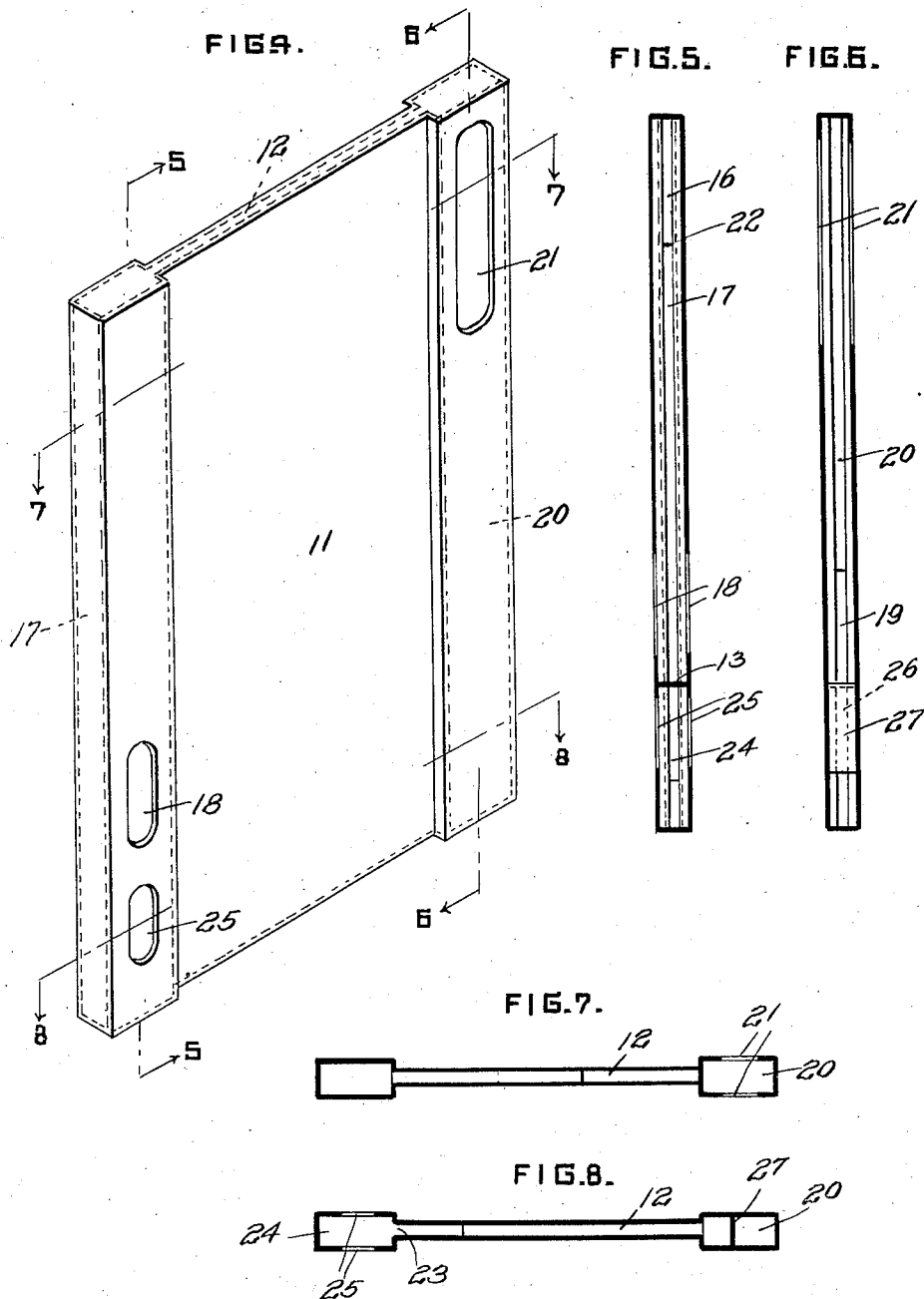
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FIG. 9.

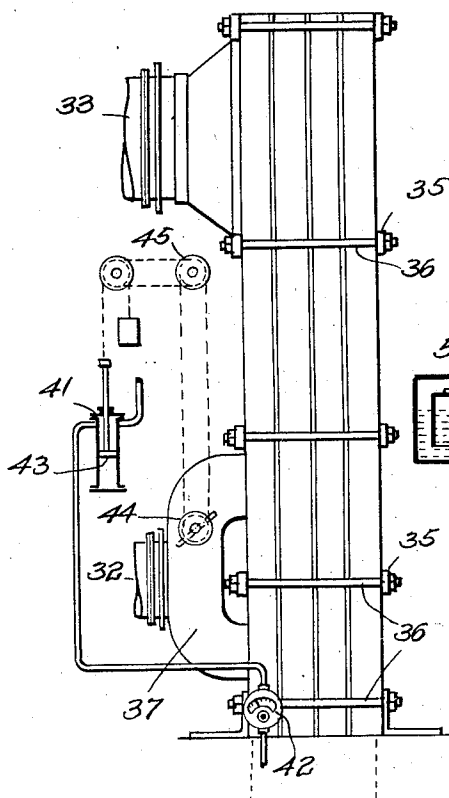
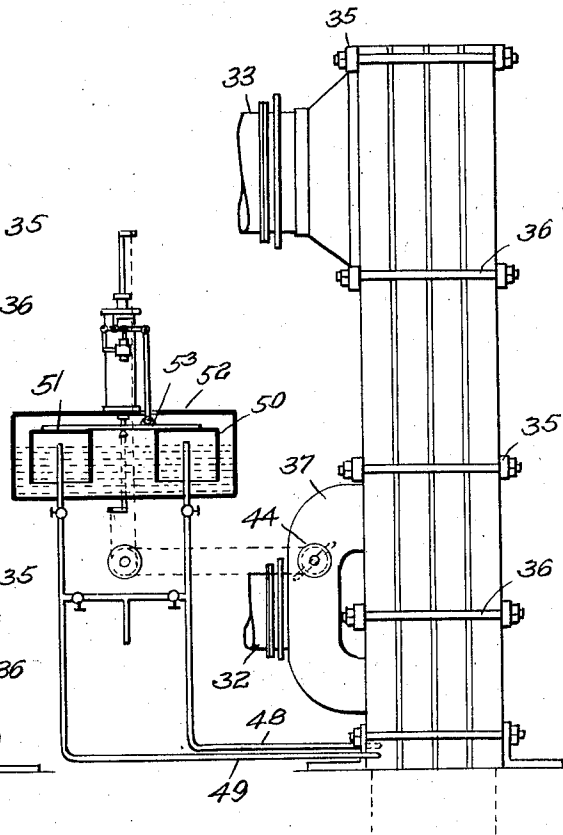


FIG. 10.



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UNITED STATES PATENT OFFICE

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RECUPERATOR

Application filed July 2, 1925. Serial No. 41,135.

This invention relates to heat exchange apparatus and more particularly to recuperators of the type adapted to be installed in or on a flue chamber for the purpose of utilizing the heat of the flue gases to raise the temperature of air or other fluid passed through the recuperator.

Theoretically the most efficient form of heat exchange apparatus is the straight counter flow type in which the direction of flow of the air through the device is opposite to the direction of flow of the flue gases, but this type has certain practical disadvantages, among others the fact that that part of the device conveying the hottest gases is also the part conveying the hottest air with the result that the temperature of the metal from which the device is constructed is so high as to materially reduce the effective life of the structure.

The rate of heat exchange between two bodies is directly proportional to their difference in temperature, and for this reason a heat exchange apparatus embodying the counter flow principle takes the greatest advantage of the convected heat as this type insures the greatest difference in mean temperature between the fluid to be heated and the flue or other heating gases. On the other hand, this form fails to utilize the radiant heat of the adjacent flue chamber to the best advantage for the reason that such heat is most intense at the point where the flue gases enter the device, or where the air is hottest so that the heat exchange at this point is relatively low.

An object of this invention is to provide a recuperator for the purpose set forth which is of such construction as to utilize to the greatest advantage both the radiant heat of the flue chamber and the convected heat of the flue gases.

A further object is to provide a recuperator in which the amount of air subjected to the radiant heat of the flue chamber can be so controlled as to insure the temperature of the material from which the recuperator is made being within safe limits.

A still further object is to provide a heat exchange apparatus of such construction and

arrangement that the flow of fluid to be heated through that portion of the device subject to the highest temperature can be so controlled that the material forming that portion will be kept within its safe temperature limits, irrespective of variations in the total flow through the apparatus.

A still further object is to provide a device of the type set forth which is composed of a plurality of separable sections adapted to be combined so as to form a recuperator of any desired size or capacity.

A still further object is to provide a heat exchange apparatus of such construction as to form a plurality of completely enclosed channels for the passage of flue gases so that all necessity for a brick setting or the like is eliminated, and so that the flue gases will be substantially surrounded by air containing chambers.

These and other objects which will appear obvious to those skilled in this particular art are attained by means of this invention, one embodiment of which is illustrated in the accompanying drawings, in which Figure 1 is a sectional view of the interior of a single section of a heat exchange apparatus illustrating one form of this invention. Fig. 2 is a vertical transverse sectional view on the line 2—2 of Fig. 1 through a device formed of four sections showing the same in position on a flue chamber. Fig. 3 is a horizontal transverse section of the structure shown in Fig. 2 taken on the line 3—3 of Fig. 1. Fig. 4 is a perspective view of the section shown in Fig. 1. Fig. 5 is a vertical section thereof taken on the line 5—5 of Fig. 4 and Fig. 6 is a similar view on the line 6—6 of Fig. 4. Figs. 7 and 8 are horizontal transverse sections on the lines 7—7 and 8—8, respectively, of Fig. 4. Fig. 9 is a view in elevation of a built up apparatus illustrating its use in connection with one form of mechanism for maintaining a relatively constant velocity of fluid through that portion of the apparatus subjected to the highest temperature, and Fig. 10 is a similar view showing a different control mechanism.

The particular embodiment of this inven-

tion which has been chosen for the purposes of illustration is built up of a plurality of separable sections, each of which is similar in construction. Each section consists of an elongated relatively narrow body portion having chambers therein through which separate streams of air or other fluid to be heated are passed. At one side of the central body portion are relatively wide air ducts for the entrance of air streams to the heating chambers and on the other side is a similarly formed, widened duct leading to the outlet of the section. When placed side by side the walls of the inlet and outlet ducts of the different sections are in contact with each other so that channels are formed between the relatively thin body portions of the sections through which channels the flue gases or other heating fluid pass so that the latter are substantially surrounded by air passages. A partition separates the interior of each section so as to form separate chambers or passageways through which separate streams of air are led from separate inlets to the common outlet duct. One of the air streams is led upwardly to the top of the section and thence downwardly through the narrow body portion in a direction counter to the flow of the heating gases so that this stream takes the utmost advantage of the convected heat of such gases. The air stream from the second inlet is drawn back and forth across the lower end of the narrow heating chamber in a generally ascending direction so that this stream utilizes to the greatest advantage the radiant heat of the adjacent flue chamber, which heat is greatest at that part of the apparatus. The two streams are then combined in the outlet duct which is in series with both of the separated heating chambers and the combined streams are led to the single air outlet.

As illustrated, each recuperator section 11 is formed with a relatively thin, central heating section 12 which is divided by a partition 13 into an upper chamber 14 and a lower heating chamber 15. The upper chamber is closed except for the opening 16 at its top through which air passes into the upper chamber from a relatively wide, vertically extending air duct 17 having an air inlet opening 18 near its lower end. The upper heating chamber 14 is provided with an opening 19 through which the heated air passes to a relatively wide outlet duct 20, leading to an air outlet 21. The upper chamber is provided with a plurality of baffles 22 for causing the air passing through the chamber to follow a circuitous passage from the opening 16 to the opening 19 in a generally counter direction to the passage of flue gases. The lower heating chamber is provided with an opening 23 through which air enters from an air duct 24 having an air inlet 25. The air duct 24 is similar to the duct 17 leading

to the upper section but is separated therefrom by an extension of the partition 13.

The lower heating chamber has an opening 26 leading to the air outlet duct 20, and opposite the opening 26 a downwardly extending baffle 27 is formed for directing the air stream emerging through the opening 26 downwardly to the lower end of the duct 20 after which the air stream rises and joins the air issuing from the opening 19 of the upper heating chamber. The lower heating chamber is provided with a number of air directing baffles 28 for causing the air stream to follow a circuitous passage therethrough in a direction generally parallel to the flow of the flue gases which pass upwardly through the built-up recuperator from the flue chamber 29 in connection with which the device is adapted to be used.

In building up the complete recuperator, such, for example, as that illustrated in Figs. 2, 3, 9 and 10, the desired number of sections are placed side by side as shown in Figs. 2 and 3 and the relatively wide air ducts along the side of each section are separated by gaskets 30 of asbestos, or any other desired material, having holes 31 cut therein to correspond with the inlet and outlet openings of the sections. In this connection it will, of course, be realized that in the illustrated embodiment each of the sections is provided with inlet openings 18 and 25 and outlet openings 21 in each face of the respective inlet and outlet air ducts as shown in Figs. 3, and 5 to 8 so that a single air line 32 will suffice for supplying air to all the sections and a single line 33 will similarly suffice for removing the air from all sections. The end section, shown at the top of Fig. 3, of course, has inlet openings and outlet openings at one side only of the respective inlet and outlet ducts 17 and 20.

As illustrated in Fig. 3, each end section is covered with insulating material 34 and the various parts are clamped in assembled relation between end bars 35 by any suitable means such as the bolts 36.

A suitable fitting 37 is provided for supplying air from the line 32 to both the inlets 18 and 25 of the sections. When assembled, channels 38, see Figs. 2 and 3, are provided between the narrow heating sections 12 for the passage of flue gases through the recuperator.

In operation, air or other fluid to be heated from the supply line 32 is fed through the fitting 37 to both the series of inlet openings 18 for the upper heating chambers and the series of inlet openings 25 for the lower heating chambers. In the upper chambers the air rises in the duct 17 and enters the chamber 14 through the opening 16 following the direction of the arrows shown on Fig. 1. This air stream follows a circuitous passage around the baffles 22 in a generally down-

ward direction counter to the flow of flue gases through the channels 38 so that this air stream takes the utmost advantage of the convected heat of the flue gases. This stream enters the outlet duct 20 through opening 19.

The air entering the lower inlet openings 25 flows into the lower chamber through the opening 23 and follows a circuitous pathway around the baffles 28 as indicated by the arrows in Fig. 1. This part of the recuperator is subjected to the intense radiant heat of the combustion chamber 29 and the stream of air flowing through the lower heating chamber 15 takes the utmost advantage of the heat radiated from the flue chamber. This air stream passes out through the opening 26 and downwardly around the baffle 27 into the outlet duct 20, where in rising, it joins the air stream from the upper heating chamber 14 and combines therewith in flowing through the outlet 21.

In order to insure a temperature in the lower heating chamber which is within the safe working limit of the material from which the recuperator is constructed, it is desirable that the volume of air passing through this lower chamber (which is subjected to the highest temperature gases) should be sufficient to maintain the temperature of the material within the desired limit.

One way of assuring the passage of a sufficient quantity of fluid to be heated through the lower section, to hold the temperature of the material within the desired limits, is to so design the device that the resistance to passage of fluid to be heated through the lower section or passage is less than the resistance to the flow through the upper section or passage. This may be accomplished by properly proportioning the areas of the respective passages or by the introduction or removal of suitable resistances such, for example, as baffles, dampers or the like.

Another way of maintaining the desired temperature of the material in the lower chamber 15 within the desired limits is by providing a mechanism for maintaining a substantially constant velocity through such chamber irrespective of variations in the total flow through the apparatus. This can be accomplished by utilizing the temperature of the air stream emerging from the opening 26 leading from the lower heating chamber into the outlet duct 20. Such a device is illustrated in Fig. 9 and consists of a thermostat 40 which is adapted to operate a hydraulic cylinder 41 by means of a relay 42. Movement of the piston 43 in the cylinder operates a butterfly valve 44 positioned in the inlet line leading to the inlet opening 18 of the upper heating chambers. The butterfly valve can be operated from the piston by any suitable mechanism such as the well-known pulley mechanism 45. By means of

such a device the relative proportions of air in the two air streams and hence the velocity of the fluid to be heated passing through the lower section is controlled directly by the temperature of fluid leaving the lower chamber and irrespective of the total flow through the device so long as the total flow is above a certain minimum. For example, assume that the safe limit of temperature for leaving the lower section is set at 1000° F., and that at all temperatures below 800° F. the thermostat would be inoperative and the butterfly valve open. When the temperature of the lower air stream reaches 800° the thermostat will operate the relay admitting water from any desired source, not shown, to the hydraulic cylinder and partially close the butterfly valve O until the proportion of air diverted from the upper heating chambers to the lower chambers is sufficient to reduce the temperature of the lower air stream to the desired limit and thus maintain the material forming the lower chamber below the desired maximum. Although a relay may be necessary on large recuperators it will, of course, be understood that a direct acting thermostat would be practical on smaller installations. Also it is obvious that the operating thermostat can be placed in any one of the individual sections or in a line from all sections if one were provided.

Still another way of varying the relative proportion of the two air streams so as to maintain substantially constant the flow of fluid through the lower chamber for the purpose of keeping the temperature thereof at the desired point is by utilizing the drop in pressure of the air across either of the chambers as an actuating medium in place of the thermostat. For example, a positive pressure tap 46, see Fig. 1 could be placed in the inlet duct 24 leading to the lower heating chamber and a negative pressure tap 47 could be similarly positioned in the lower end of the outlet duct 20 adjacent the outlet opening 26, leading from the heating chamber. Pipes 48 and 49 lead from the positive and negative taps, respectively, to the under side of the well known bells 50 and 51, respectively, of the regulator 52 which operates the butterfly valve 44 through the usual mechanism. Obviously if the volume of air passing through the lower heating chamber is not sufficient to cause a pressure drop for which the regulator 52 is set the regulator beam 53 will be unbalanced and the regulator operated so as to close the butterfly valve and divert more air to the lower heating chamber so as to maintain a sufficient flow of air through the lower section to hold the temperature thereof within the safe limits.

The effectiveness of an apparatus constructed in accordance with this invention is due to the fact that separate air streams are provided for utilizing in the most advan-

tageous way the different sources of heat which are effective upon the recuperator in heating the air passing therethrough. One stream of air takes full advantage of the radiant heat of the flue chamber. Another stream of air takes full advantage of the convected heat of the flue gases and the relative proportions of these streams can be varied so as to maintain the recuperator at its highest efficiency and at the same time insure the maintenance of a temperature in the device which is within the safe limits of the material of which it is constructed.

The sectional construction provides standard units which can be employed to form an apparatus of any desired size. They are constructed in such a manner and combined in such a way that the heating fluid is substantially surrounded on four sides by sections transmitting fluid to be heated. No brick setting is required. The flue channels are present in the assembled structure as a result of the peculiar shape of the individual sections and these flue channels are substantially surrounded on four sides by fluid traveling in directions most conducive to the highest heat exchange efficiency.

In the foregoing description and accompanying drawings the device has been shown and described as in a vertical position for the purposes of convenience and clearness of illustration. It will, however, be apparent that the device may be used in any desired position without affecting the principles employed.

Although I have described in detail one embodiment of this invention, I do not wish to be limited to the specific structure disclosed, but various additions, omissions, substitutions and modifications can be made therein without departing from the spirit of this invention or the scope of the appended claims.

What I claim as new and desire to secure by Letters Patent is:

1. A recuperator provided with heating passages for simultaneously subjecting separate streams of air to the heating effect of an associated flue or the like and means actuated by a condition of such air for varying the relative proportions of air in said streams without materially affecting the total amount of air traversing said recuperator.

2. A recuperator provided with heating passages for simultaneously subjecting separate streams of air to the heating effect of an associated flue or the like, means for delivering air to be heated to both of said passages and means actuated by a condition of such air for reducing the amount of air delivered to one of said passages and for increasing the amount of air delivered to the other of said passages so as to vary the relative proportion of air in said streams without

affecting the total amount of air traversing said recuperator.

3. A recuperator provided with heating passages for simultaneously subjecting separate streams of air to the heating effect of an associated flue or the like, a supply line for furnishing air to both of said passages and a valve actuated by a condition of such air associated with said supply line for varying the relative proportions of air in said streams without materially affecting the total amount of air traversing said recuperator.

4. A recuperator provided with fluid heating passages for separate streams of air, a supply line for furnishing air to both of said passages, a valve associated with said supply line for diverting a portion of the air from one of said passages to the other of said passages and means responsive to a characteristic of the air flow through one of said passages for operating said valve.

5. The combination with a flue chamber of a recuperator provided with a heating chamber for subjecting a stream of air to the convected heat of flue gases, a second heating chamber for subjecting a separate stream of air to the radiant heat of the flue chamber and a common outlet for the heated air.

6. The combination with a flue chamber of a recuperator provided with a heating chamber for subjecting a stream of air to the convected heat of the flue gases, a second heating chamber for subjecting a separate stream of air to the radiant heat of the flue chamber, a separate supply duct in said recuperator for each of said heating chambers and a single outlet duct for said chambers.

7. The combination with a flue chamber of a recuperator provided with a heating chamber for subjecting a stream of air to the convected heat of the flue gases, an air duct for admitting air to the top of said chamber, an outlet adjacent the bottom of said chamber, baffles in said chamber for causing said air stream to follow a circuitous path therethrough, a second heating chamber in said recuperator for subjecting a separate stream of air to the radiant heat of the flue chamber, an air duct for admitting air to the bottom of said second chamber, an air outlet adjacent the top of said second chamber, baffles in said second chamber for causing said second stream of air to follow a circuitous path through said chamber and an air duct communicating with both of said outlet openings.

8. A recuperator including a plurality of sections, each section having in combination, separate heating chambers, an air inlet for each chamber and a common outlet for said chambers.

9. A recuperator including a plurality of sections, each section having in combination two separate air heating chambers for heat-

ing separate streams of air and an outlet duct in series with both of said chambers.

10. A recuperator including a plurality of sections adapted to be combined to form a device of predetermined capacity, each section provided with chambers for heating separate streams of air and an outlet duct in series with both of said chambers, said chambers being in parallel with each other.

11. A recuperator having in combination a plurality of sectional members each of which is provided with relatively narrow heating chambers through which air to be heated is passed, air ducts along each side of each of said chambers communicating therewith and formed so that when said sections are assembled a plurality of channels for the passage of heating gases between said chambers are provided.

12. A recuperator having in combination a plurality of sectional members each of which is provided with relatively narrow heating chambers through which air to be heated is passed, relatively wide air ducts along each side of each of said chambers communicating therewith and formed so that when said sections are assembled a plurality of channels for the passage of heating gases between said chambers are provided.

13. A recuperator section having a relatively narrow central heating chamber, a relatively wide air duct along one side of said heating chamber for admitting air thereto, a relatively wide air duct along the opposite side of said chamber for conveying air therefrom, said ducts being so formed that a plurality of assembled sections provide channels for the passage of flue gases therebetween, said channels being surrounded by said chamber and ducts.

14. The combination in a heat exchange apparatus of two fluid heating passages communicating with a common source of supply and means responsive to a variation in conditions within one of said passages for varying the flow through the other of said passages to thereby reestablish said conditions.

15. The combination in a heat exchange apparatus of two fluid heating passages communicating with a common source of supply and means for maintaining a substantially constant flow through one of said passages under varying flow conditions by varying the flow through the other of said passages.

16. The combination in a heat exchange apparatus of two fluid heating passages communicating with a common source of fluid supply and delivering into the same region and means for maintaining a substantially constant flow through one of said passages under varying flow conditions by varying the flow through the other of said passages.

17. The combination in a heat exchange apparatus of two passages for fluid flow communicating with a common source of fluid

supply and means whereby variations in the total flow occasion variations in flow through one of said passages while the flow through the other of said passages is maintained substantially constant.

18. The combination in a heat exchange apparatus of two fluid heating passages communicating with a common source and means for maintaining the flow through one of said passages substantially constant irrespective of variations in the total flow.

19. The combination in a heat exchange apparatus of a passage adapted to direct a stream of fluid to be heated therethrough, a second passage for directing a separate stream through that part of the apparatus subjected to the highest temperature, a valve adapted to vary the flow through said first passage and means operated by a characteristic of flow through said second passage for operating said valve so as to maintain the flow through said second passage substantially constant.

20. The combination in a heat exchange apparatus of a passage for directing a stream of fluid therethrough, a second passage for directing a separate stream of fluid through that part of the apparatus subjected to the highest temperature, said second passage being positioned so as to protect said first passage from said high temperature and means for maintaining the flow through said second passage substantially constant irrespective of variations in total flow through the apparatus.

21. The combination with a flue chamber of a recuperator provided with a heating chamber for subjecting a stream of air to the convected heat of flue gases, an air duct for admitting air to the top of said chamber, an outlet duct adjacent the bottom of said chamber, a second heating chamber for subjecting a separate stream of air to the radiant heat of the flue chamber, an air duct for admitting air to the bottom of said second chamber, an air outlet adjacent the top of said second chamber and an air duct communicating with both of said outlet openings.

In testimony whereof, I have hereunto subscribed my name this 22nd day of June, 1925.

GREGORY D. MANTLE.