Feb. 28, 1939. P. R. CASSIDY 2,149,007

HEAT EXCHANGER

Filed June 4, 1936 3 Sheets-Sheet 1

Fig. 1

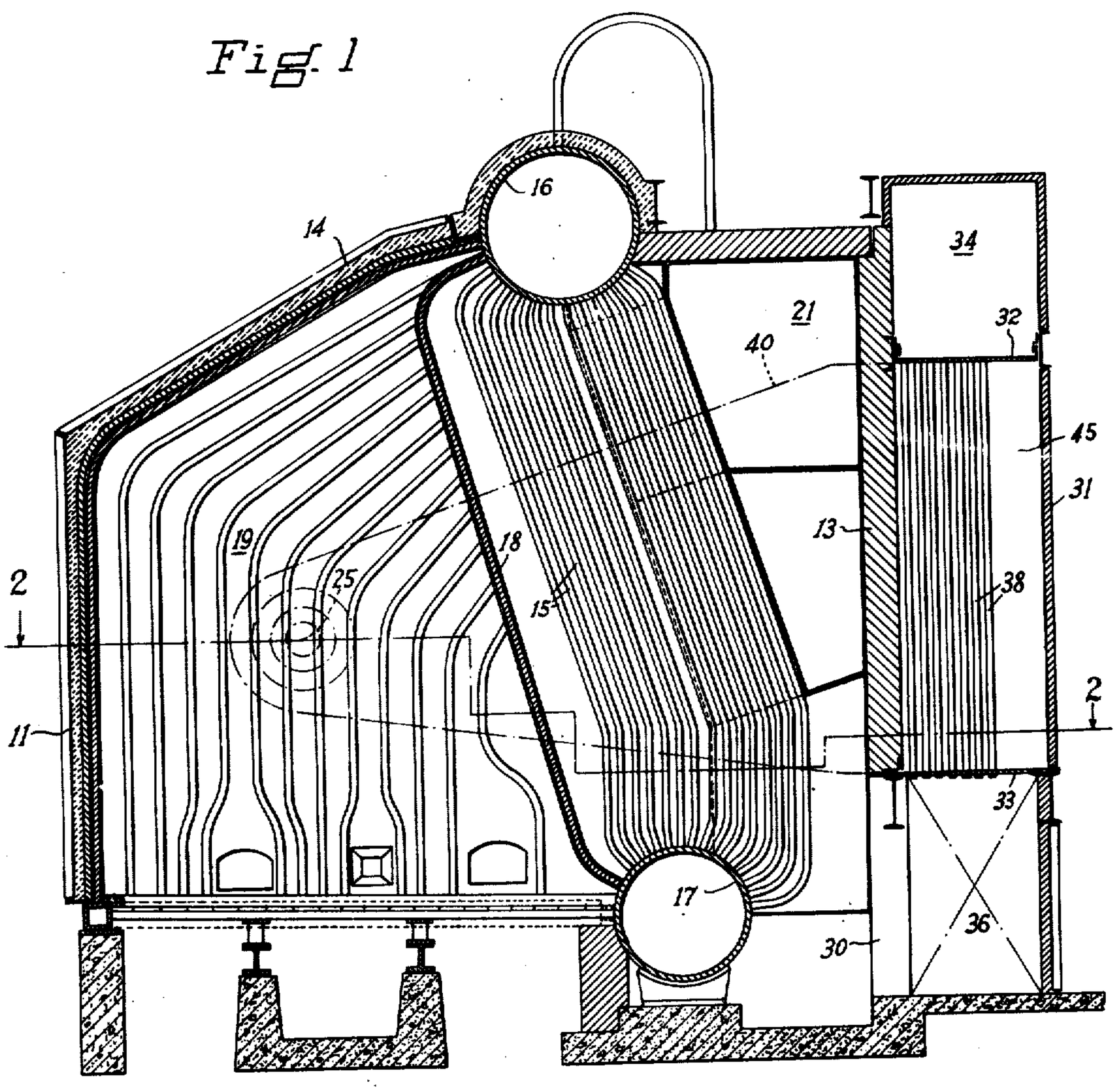

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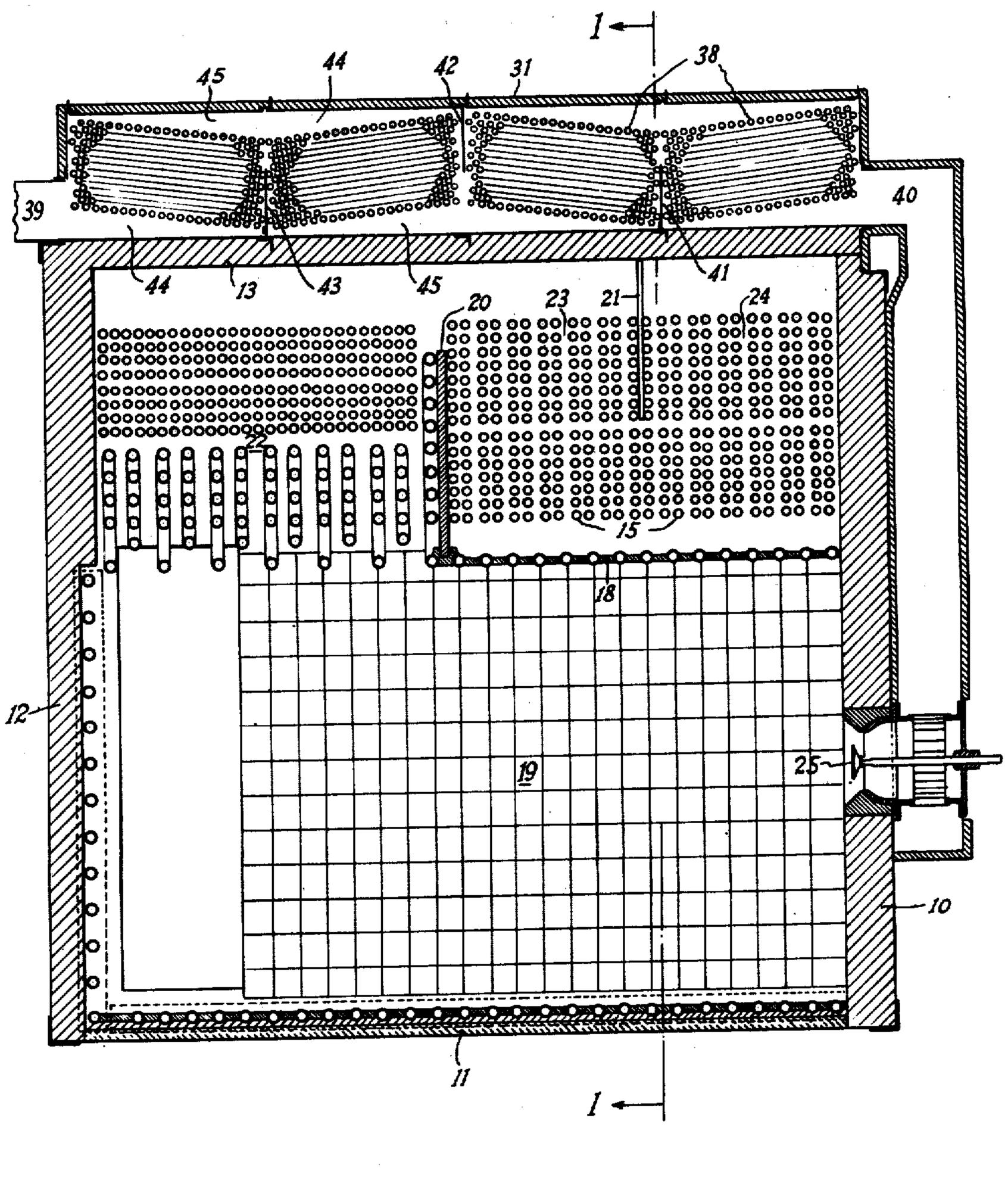
Fig. 2



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Filed June 4, 1936 3 Sheets-Sheet 3

Fig. 4

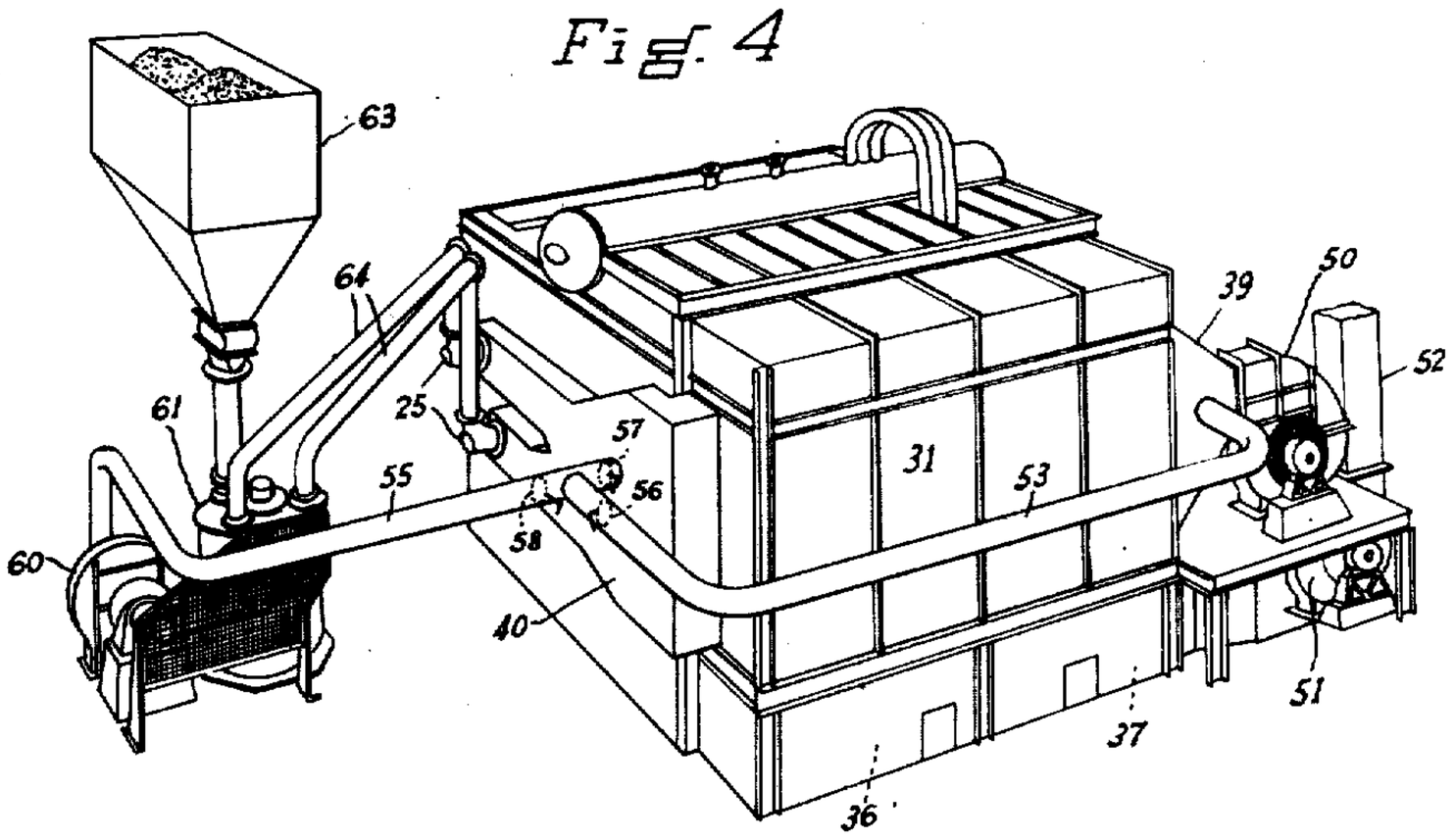
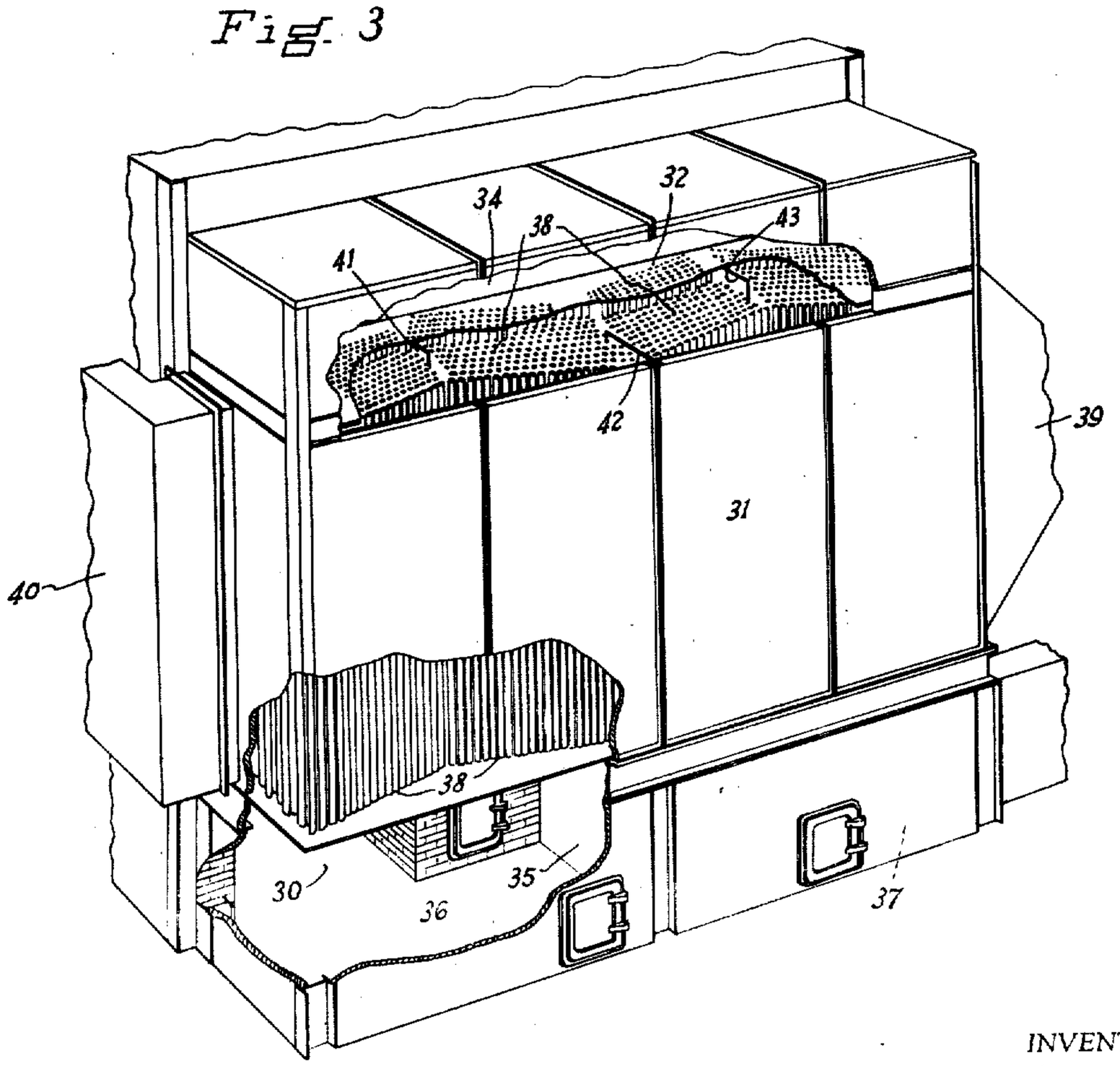


Fig. 3



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Patented Feb. 28, 1939 2,149,007

UNITED STATES PATENT OFFICE

2,149,007

HEAT EXCHANGER

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Application June 4, 1936, Serial No. 83,443

14 Claims. (Cl. 122—336)

The present invention relates to the construction of tubular heat exchangers, and more particularly to the construction and arrangement of an air heater especially designed and adapted for use as an integral part of a steam generator unit utilizing preheated air in operation.

The main object of my invention is the provision of a tubular heat exchanger having an improved construction and arrangement of the heat transfer surface and flow paths for the heating and heated fluids providing highly effective heat transfer conditions and low floor space and head-room requirements. A further and more specific object is the provision of an air heater construction especially useful in conjunction with a compact low head-room steam boiler utilizing preheated air in operation. Another object is the provision of an air heater design permitting substantial changes in the amount of heat transfer surface without substantially changing the draft loss conditions therein or the efficiency as indicated by the temperature of the exit gases, and without changing the arrangement of the air and heating gas flow paths, or materially varying the floor space requirements per unit of capacity.

The various features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described a preferred embodiment of my invention.

Of the drawings:

Fig. 1 is a sectional elevation of a steam boiler and an associated air heater embodying the invention, taken on the line 1—1 of Fig. 2;

Fig. 2 is a horizontal section taken on the line 2—2 of Fig. 1;

Fig. 3 is a partly diagrammatic perspective view of the air heater with parts broken away; and

Fig. 4 is a perspective view of a steam generator unit constructed in accordance with my invention.

In the drawings I have illustrated a water tube steam boiler of the compact low head-room type illustrated and claimed in U. S. Patent No. 1,999,984, granted April 30, 1935, with which my improved air heater is especially adapted for use. The steam boiler shown comprises a substantially rectangular setting formed by vertically disposed walls 10, 11, 12 and 13, and a partly inclined roof 14. At one side of the setting is arranged a steam generating tube bank 15 connected to upper and lower parallel drums 16 and 17 respectively. Along the inner side of the tube bank extends a vertical partition 18 separating the tube bank for a portion of its length from a laterally adjacent fluid cooled furnace chamber 19. Transverse vertical baffles 20 and 21 cooperate with the partition 18 and setting to form three connecting gas passes 22, 23, and 24 for a serial flow of heating gases horizontally and transversely of the tube bank beyond the furnace. The first gas pass 22 adjacent the rear wall 12 opens at one side to the furnace chamber, while the third or front pass 23 communicates with the heating gas outlet from the setting. One or more fuel burners 25 are mounted in the front wall 10 for introducing and burning a fluid fuel such as pulverized coal or oil in suspension, or gas in the furnace chamber and for generating heating gases which flow horizontally longitudinally of the furnace chamber and serially through the three gas passes to the gas outlet of the boiler proper, which is the gas inlet of the air heater.

The steam boiler construction described is especially characterized by its low head-room and floor space requirements and its advantageous use of all of the space within its dimensional limits as to capacity and efficiency. The over-all efficiency of the unit can be advantageously increased by the addition of an air heater in position to absorb heat from the outgoing heating gases while maintaining the advantageous use of all space occupied. In accordance with my invention the gas outlet from the front or last gas pass of the boiler proper is provided by a rectangular opening 30 formed in the lower part of the portion of the side wall 13. The air heater comprises a gas-tight casing 31 of rectangular vertical and horizontal cross-section which extends along and unites with the boiler side wall 13 to enclose the heat transfer surface of the air heater. The casing 31 extends substantially the full length of the boiler with its top slightly below the top of the drum 16. Vertically spaced horizontally arranged top and bottom tube sheets 32 and 33 respectively extend the full length of the air heater casing at levels spaced from the top and bottom of the casing respectively. The space 34 between the top tube sheet 32 and the top of the casing is unobstructed from end to end and serves as a gas turning space, while the space between the bottom tube sheet 33 and the bottom of the casing is divided transversely by a vertical partition 35 into a gas inlet chamber 36

into which the gas outlet 30 from the boiler proper opens and a gas outlet chamber 37 communicating with a stack.

The tubular heat transfer surface of the air heater is located in the space between the tube sheets 32 and 33 and consists of a bank of straight vertically arranged tubes 38 having their upper and lower ends fitted to holes in the tube sheets 32 and 33 respectively. As shown in Figs. 2 and 3, the space between the tube sheets and outside of the tubes is connected at its rear end to a fresh air inlet conduit 39 and at its front end to a hot air outlet conduit 40 extending along the boiler front wall 10 to the fuel burner 25 for supplying preheated combustion air to the furnace chamber along with the fuel introduced. The conduits 39 and 40 open to the space between the tube sheets and outside of the tubes throughout its height, but extend only partly across the width of the end walls of the air heater casing.

The bank of tubes 38 are advantageously divided into four sections or groups arranged in a zig-zag formation extending the full length of the air heater, each group being of rhomboidal cross-section with its opposite sides inclined to the casing walls. Vertical transversely extending baffles 41, 42 and 43 are alternately connected to and extend from the side wall 13 and the opposite side of the casing 31 between the tube banks and partially separating them. The first and last tube sections are set to extend into the corners formed by the end walls and the outer side wall of the casing 31 and into the diagonally opposite corners formed by the transverse baffles 41 and 43 respectively and the boiler wall 13. The baffle 42 extends inwardly from the middle of the outer casing wall and the two intermediate tube bank sections extend from the two corners formed by the baffle 42 and the outer side walls into the diagonally opposite corners formed by the wall 13 and the baffles 41 and 43. With this arrangement of the four sections of air heater tubes, there will be triangular open spaces 44 and 45 between each section and the adjacent side walls 13 and 31.

With the described arrangement the air will enter at the larger end of the open space 44 in front of each tube bank section and due to the tapering form of the space and the opposite arrangement of the corresponding tapering open space 45, the air will be substantially uniformly distributed over the full length of each tube bank section due to the uniform velocity in the open space and the uniform pressure drop across all portions of its length. The heated air leaving the first of the four tube bank sections of the air heater flows around the baffle 43, partly in the free flow space formed by the communicating tapering open spaces 44 and 45 and partly through the intertube spaces beyond the end of the baffle 43. The air heater is so constructed that the total flow area between the end of the baffle 43 and the casing wall is substantially the same as the air flow area transversely of the tubes in each section. The apices formed by adjoining tube groups extend close to but not in contact with the adjacent wall to facilitate contact of the gases with the air heater tubes located in that area.

With the air heater construction described, the cold air will enter the rear end of the casing 31 and flow in a horizontal sinuous path successively around the baffles 43, 42 and 41 past the four tube bank sections in series and through the front end of the casing 31 to the hot air conduit 40, from which the preheated air is delivered to the fuel burner 25, either wholly or in part, as hereinafter described. The heating gases leaving the boiler proper through the outlet 30 turn upwardly in the gas inlet chamber 36 of the air heater and enter the tubes 38 of the first two tube groups, horizontally in the gas turning space 34 and then downwardly through the tubes constituting the other two tube groups in parallel to the gas outlet chamber 37. The heating fluid therefore flows past the heat transfer surface in two vertical passes each including two tube groups in parallel, while the fluid to be heated flows in a horizontal sinuous path past the heating surface in the four serially connected passes, the relative flow of the two fluids being generally counter-current.

With the steam boiler design described a series of boiler sizes with similar tube spacings may be obtained while maintaining substantially the same efficiency and draft loss and without changing the furnace transverse cross-sectional area and shape, by merely changing the total number of transverse rows of tubes and correspondingly changing the number of transverse rows of tubes in each gas pass. The transverse flow of heating gases relative to the boiler inherently provides substantially similar constant performance characteristics for various sizes of such boilers indicated by the uniform gas outlet temperatures obtained therein under similar operating conditions. The air heater design described is likewise applicable to such a line of sizes of boilers having substantially the same draft loss and the final gas outlet temperatures by merely changing the total number of transverse rows of tubes in the air heater, and correspondingly changing the number of transverse rows of tubes in each group.

In Fig. 4 is illustrated a steam generator unit comprising a steam boiler and air heater of the character shown in Figs. 1 to 3, in which the cold air is introduced into the conduit 39 by a forced draft fan 50, and the gas outlet chamber 37 is connected to an induced draft fan 51 having a flue 52 leading to the stack. A by-pass pipe 53 is arranged around the air heater for conducting cold air from the conduit 39 to an air pipe 55 connected to the conduit 40, and/or to the conduit 40 depending upon the positions of control dampers 56, 57 and 58 located in the pipes 53 and 55. The pipe 55 is arranged to conduct air at the desired temperature to a forced draft fan 60, which delivers the air to a pulverizer 61 for pulverizing fuel supplied from a bin 63 and carrying the same through a pair of supply pipes 64 to corresponding fuel burners 25.

As will be observed from Fig. 4, the resulting steam generating unit will be unusually compact and occupy a relatively small amount of floor space and head room, while incorporating features of construction and arrangement which permit highly efficient operation at a wide range of boiler loads.

While in accordance with the provisions of the statutes I have illustrated and described herein the best form of my invention now known to me, those skilled in the art will understand that changes may be made in the form of the apparatus disclosed without departing from the spirit of the invention covered by my claims, and that certain features of my invention may sometimes be used to advantage without a corresponding use of other features.

I claim:

1. A steam generating unit comprising a setting including a pair of longitudinally extending upper and lower drums, a bank of water tubes connecting said drums, means forming a furnace

chamber laterally adjoining the space containing said tube bank and communicating therewith at one end, baffle means arranged to divide said tube space into a plurality of serially connected gas passes extending transversely of said tube bank, means for burning fuel in said furnace chamber and effecting a flow of heating gases through said gas passes, and an air heater comprising a casing extending along one side of said setting, a bank of vertical tubes in said casing for the passage of heating gases from said setting, and baffle means arranged to divide said casing into a plurality of serially connected gas passes extending transversely of said second named tube bank.

2. A steam generating unit comprising a setting including a pair of longitudinally extending upper and lower drums, a bank of water tubes connecting said drums, means forming a furnace chamber laterally adjoining the space containing said tube bank and communicating therewith at one end, baffle means arranged to divide said tube space into a plurality of serially connected gas passes extending transversely of said tube bank, means for burning fuel in said furnace chamber and effecting a flow of heating gases through said gas passes, an air heater comprising a casing extending along one side of said setting, a bank of vertical tubes in said casing for the passage of heating gases from said setting, baffle means arranged to divide said casing into a plurality of serially connected gas passes extending transversely of said second named tube bank, a forced draft fan for effecting a horizontal sinuous flow of air through said casing gas passes and transversely of said second named tube bank, and a hot air conduit connecting said casing to said fuel burning means.

3. A steam generating unit comprising a setting including a pair of longitudinally extending upper and lower drums, a bank of water tubes connecting said drums, means forming a furnace chamber laterally adjoining the space containing said tube bank and communicating therewith at its rear end, baffle means arranged to divide said tube space into a plurality of serially connected gas passes extending transversely of said tube bank, means at the front end of said furnace chamber for burning fuel therein and effecting a flow of heating gases through said gas passes, an air heater comprising a casing extending along one side of said setting, a bank of vertical tubes in said casing for the passage of heating gases from said setting, baffle means arranged to divide said casing into a plurality of serially connected gas passes extending transversely of said second named tube bank, a forced draft fan at the rear end of said casing for effecting a horizontal sinuous flow of air through said casing gas passes and transversely of said second named tube bank, and a hot air conduit connecting the front end of said casing to said fuel burning means.

4. A steam generating unit comprising a setting including a pair of longitudinally extending upper and lower drums, a bank of water tubes connecting said drums, means forming a furnace chamber laterally adjoining the space containing said tube bank and communicating therewith at its rear end, baffle means arranged to divide said tube space into a plurality of serially connected gas passes extending transversely of said tube bank, means at the front end of said furnace chamber for burning fuel in suspension therein and effecting a flow of heating gases through said gas passes, an air heater comprising a casing extending along one side of said setting, a bank of vertical tubes in said casing for the passage of heating gases from said setting, baffle means arranged to divide said casing into a plurality of serially connected gas passes extending transversely of said second named tube bank, a forced draft fan at the rear end of said casing for effecting a horizontal sinuous flow of air through said casing gas passes and transversely of said second named tube bank, a hot air conduit connecting the front end of said casing to said fuel burning means, an air swept pulverizer connected to said fuel burning means, and a hot air pipe connecting said hot air conduit to said pulverizer.

5. A steam generating unit comprising a setting including a pair of longitudinally extending upper and lower drums, a bank of water tubes connecting said drums, means forming a furnace chamber laterally adjoining the space containing said tube bank and communicating therewith at its rear end, baffle means arranged to divide said tube space into a plurality of serially connected gas passes extending transversely of said tube bank, a fuel burner at the front end of said furnace chamber for burning fuel in suspension therein and effecting a flow of heating gases through said gas passes, an air heater comprising a casing extending along one side of said setting, a bank of vertical tubes in said casing for the passage of heating gases from said setting, baffle means arranged to divide said casing into a plurality of serially connected gas passes extending transversely of said second named tube bank, a forced draft fan at the rear end of said casing for effecting a horizontal sinuous flow of air through said casing gas passes and transversely of said second named tube bank, a hot air conduit connecting the front end of said casing to said fuel burner, and an induced draft fan at the rear end of said casing below said forced draft fan for withdrawing heating gases from said casing.

6. A steam generating unit comprising a setting including a pair of longitudinally extending upper and lower drums, a bank of water tubes connecting said drums, means forming a furnace chamber laterally adjoining the space containing said tube bank and communicating therewith at its rear end, a fuel burner at the front end of said furnace chamber for burning fuel in suspension therein and effecting a flow of heating gases through said tube space, an air heater comprising a casing extending along one side of said setting, a bank of vertical tubes in said casing for the passage of heating gases from said setting, a forced draft fan at the rear end of said casing for effecting a horizontal flow of air through said casing and in contact with said second named tube bank, a hot air conduit connecting the front end of said casing to said fuel burner, an air swept pulverizer connected to said fuel burner, a hot air pipe connecting said hot air conduit to said pulverizer, and a by-pass pipe arranged to deliver cold air from said forced draft fan around said air heater to said hot air pipe.

7. A steam generating unit comprising a setting including a pair of longitudinally extending upper and lower drums, a bank of water tubes connecting said drums, means forming a furnace chamber laterally adjoining the space containing said tube bank and communicating therewith at its rear end, a fuel burner at the front end of said furnace chamber for burning fuel in suspension therein and effecting a flow of heating gases through said tube space, an air heater comprising a casing extending along one side of said

setting, a bank of vertical tubes in said casing for the passage of heating gases from said setting, a forced draft fan at the rear end of said casing for effecting a horizontal flow of air through said casing and in contact with said second named tube bank, a hot air conduit connecting the front end of said casing to said fuel burner, an air swept pulverizer connected to said fuel burner, a fan delivering air to said pulverizer, a hot air pipe connecting said hot air conduit to said last named fan, a by-pass pipe arranged to deliver cold air from said forced draft fan around said air heater to said hot air pipe, and dampers arranged to control the amount of by-passed air delivery to said hot air conduit and hot air pipe respectively.

8. A steam generating unit comprising a setting including a pair of longitudinally extending upper and lower drums, a bank of water tubes connecting said drums, means forming a furnace chamber laterally adjoining the space containing said tube bank and communicating therewith at its rear end, baffle means arranged to divide said tube space into a plurality of serially connected gas passes extending transversely of said tube bank, a fuel burner at the front end of said furnace chamber for burning fuel in suspension therein and effecting a flow of heating gases through said gas passes, an air heater comprising a casing extending along one side of said setting, a bank of vertical tubes in said casing for the passage of heating gases from said setting, baffle means arranged to divide said casing into a plurality of serially connected gas passes extending transversely of said second named tube bank, a forced draft fan at the rear end of said casing for effecting a horizontal sinuous flow of air through said casing gas passes and transversely of said second named tube bank, a hot air conduit connecting the front end of said casing to said fuel burner, an air swept pulverizer connected to said fuel burner, a fan delivering air to said pulverizer, a hot air pipe connecting said hot air conduit to said last named fan, a by-pass pipe arranged to deliver cold air from said forced draft fan around said air heater to said hot air pipe, and dampers arranged to control the amount of by-passed air delivered to said hot air conduit and hot air pipe respectively.

9. A tubular heat exchanger comprising a casing including a pair of parallel vertical side walls, a bank of vertical tubes consisting of a plurality of tube groups arranged in a zig-zag end-to-end formation longitudinally of said casing relative to said side walls to form oppositely arranged fluid flow spaces of tapering cross-section at opposite sides of each tube group, vertical baffle means extending transversely of said casing between said tube groups at the narrow ends of adjacent fluid flow spaces and arranged relative to said side walls to divide the tube bank space into a plurality of serially connected fluid flow passes, and fluid inlet and outlet openings at opposite ends of said tube bank space.

10. A tubular heat exchanger comprising a casing including a pair of parallel vertical side walls, a bank of vertical tubes consisting of a plurality of tube groups of rhomboidal horizontal cross-section arranged in a zig-zag end-to-end formation longitudinally of said casing relative to said side walls to form oppositely arranged fluid flow spaces of tapering cross-section at opposite sides of each tube group, vertical baffle means extending transversely of said casing between said tube groups and arranged relative to said side walls to divide the tube bank space into a plurality of serially connected fluid flow passes, and fluid inlet and outlet openings at opposite ends of said tube bank space.

11. A tubular heat exchanger comprising a horizontally elongated casing including a pair of parallel vertical side walls, a bank of vertical tubes consisting of a plurality of tube groups arranged in a zig-zag end-to-end formation longitudinally of said casing relative to said side walls to form oppositely arranged fluid flow spaces of tapering cross-section at opposite sides of each tube group, vertical baffle means extending transversely of said casing between said tube groups at the narrow ends of adjacent fluid flow spaces and arranged relative to said side walls to divide the tube bank space into a plurality of serially connected fluid flow passes, and fluid inlet and outlet openings at opposite ends of said tube bank space at the wide end of the adjacent fluid flow spaces.

12. A tubular heat exchanger comprising a horizontally elongated casing including a pair of parallel vertical side walls, a pair of vertically spaced horizontal tube sheets extending longitudinally of and vertically spaced from the top and bottom of said casing, a partition dividing the space between the bottom tube sheet and the bottom of said casing into fluid inlet and outlet chambers, a bank of vertical tubes extending between and opening through said tube sheets, said tube bank consisting of a plurality of tube groups arranged in a zig-zag end-to-end formation longitudinally of said casing relative to said casing side walls to form oppositely arranged fluid flow spaces of triangular cross-section at opposite sides of each tube group, vertical baffle means extending transversely of said casing between said tube groups at the narrow ends of adjacent fluid flow spaces and arranged relative to said side walls to divide the intertube-sheet space into a plurality of serially connected fluid flow passes, and fluid inlet and outlet openings at opposite ends of said intertube-sheet space at the wide end of the adjacent fluid flow spaces.

13. A tubular air heater comprising a horizontally elongated casing including a pair of vertical side walls, a pair of vertically spaced horizontal tube sheets extending longitudinally of and vertically spaced from the top and bottom of said casing, a bank of vertical tubes extending between and opening through said tube sheets, said tube bank consisting of a plurality of tube groups arranged in a zig-zag end-to-end formation longitudinally of said casing relative to said casing side walls to form oppositely arranged air spaces of tapering cross-section at opposite sides of each tube group, vertical baffle means extending transversely of said casing between said tube groups at the narrow ends of adjacent air spaces and arranged relative to said side walls to divide the intertube-sheet space into a plurality of serially connected air passes, and air inlet and outlet openings at opposite ends of said intertube-sheet space at the wide end of the adjacent air spaces.

14. A tubular air heater comprising a horizontally elongated casing including a pair of parallel vertical side walls, a pair of vertically spaced horizontal tube sheets extending longitudinally of and vertically spaced from the top and bottom of said casing, a partition dividing the space between the bottom tube sheet and the bottom of said casing into heating gas inlet and outlet chambers, a bank of vertical tubes extending be-

tween and opening through said tube sheets, said tube bank consisting of a plurality of tube groups of rhomboidal horizontal cross-section arranged in a zig-zag end-to-end formation longitudinally of said casing relative to said casing side walls to form oppositely arranged air spaces of triangular cross-section at opposite sides of each tube group, vertical baffle means extending transversely of said casing between said tube groups at the narrow ends of adjacent air spaces and arranged relative to said side walls to divide the intertube-sheet space into a plurality of serially connected air passes, and air inlet and outlet openings at opposite ends of said intertube-sheet space at the wide end of the adjacent air spaces.

PERRY R. CASSIDY.

CERTIFICATE OF CORRECTION.

Patent No. 2,149,007. February 28, 1939.

PERRY R. CASSIDY.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 4, first column, line 75, claim 10, after the word "groups" insert at the narrow ends of adjacent fluid flow spaces; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 18th day of April, A. D. 1939.

Henry Van Arsdale

(Seal) Acting Commissioner of Patents.

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