

Dec. 18, 1956

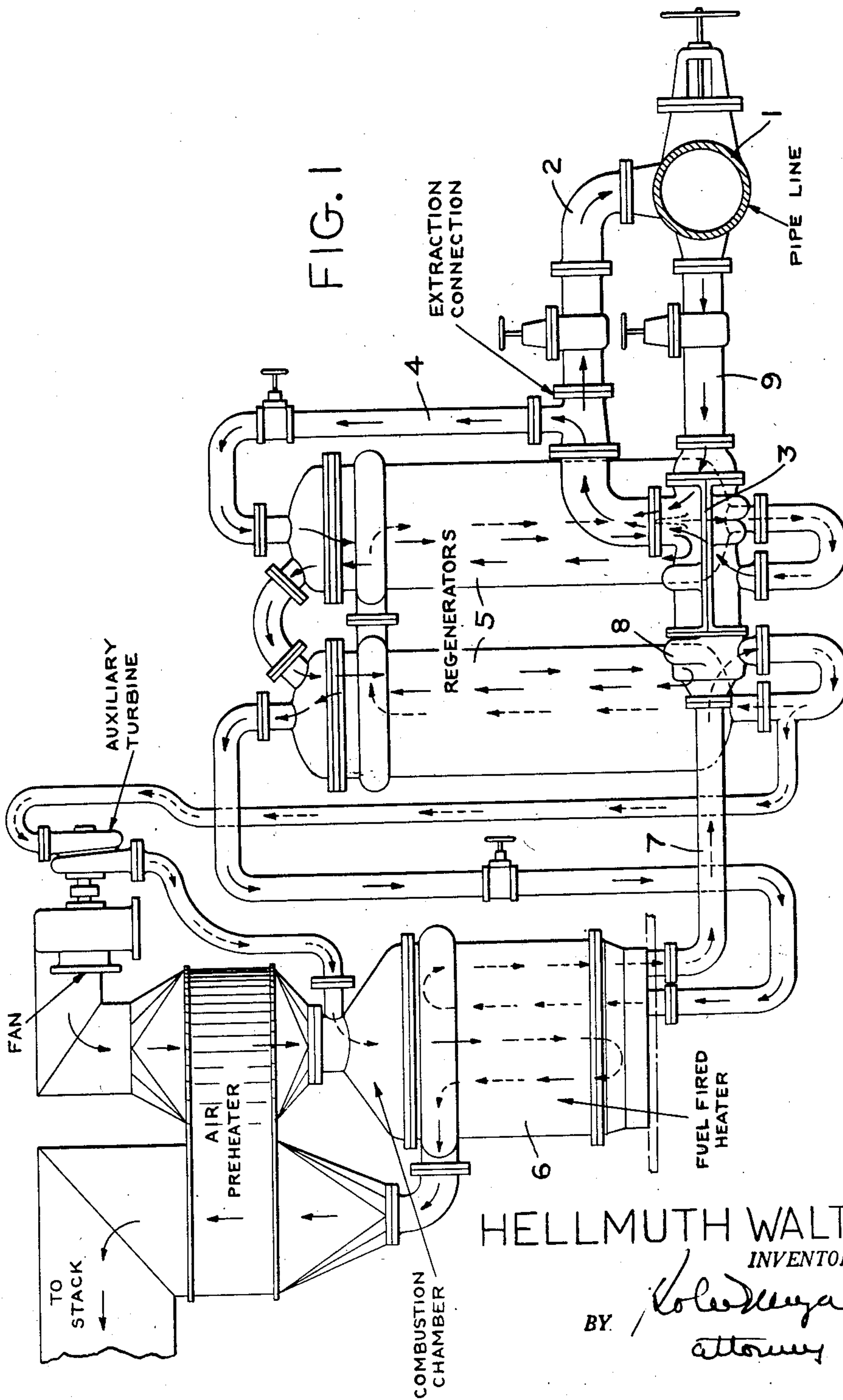
H. WALTER

2,774,575

REGENERATOR

Filed March 7, 1952

6 Sheets-Sheet 1



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6 Sheets-Sheet 2

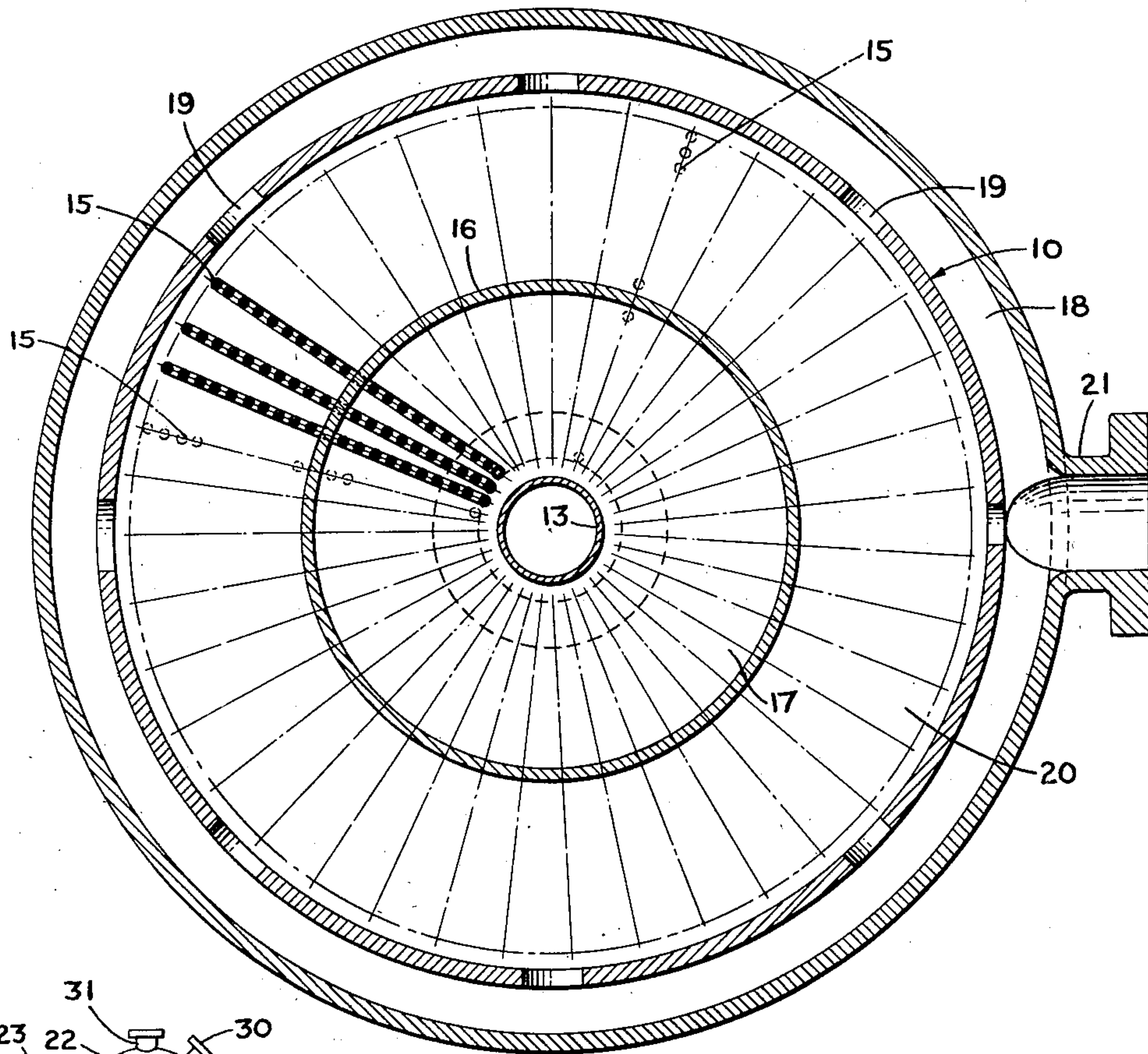


FIG. 4

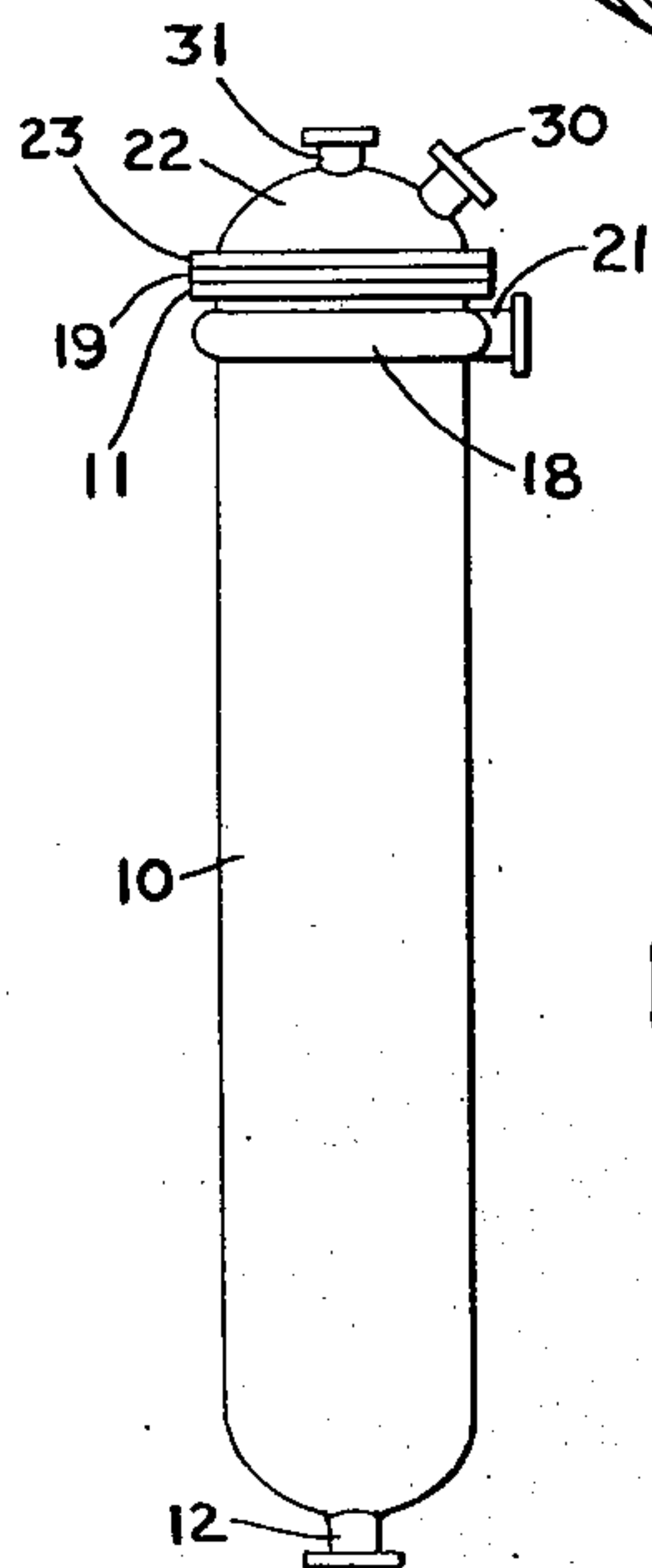


FIG. 2

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6 Sheets-Sheet 3

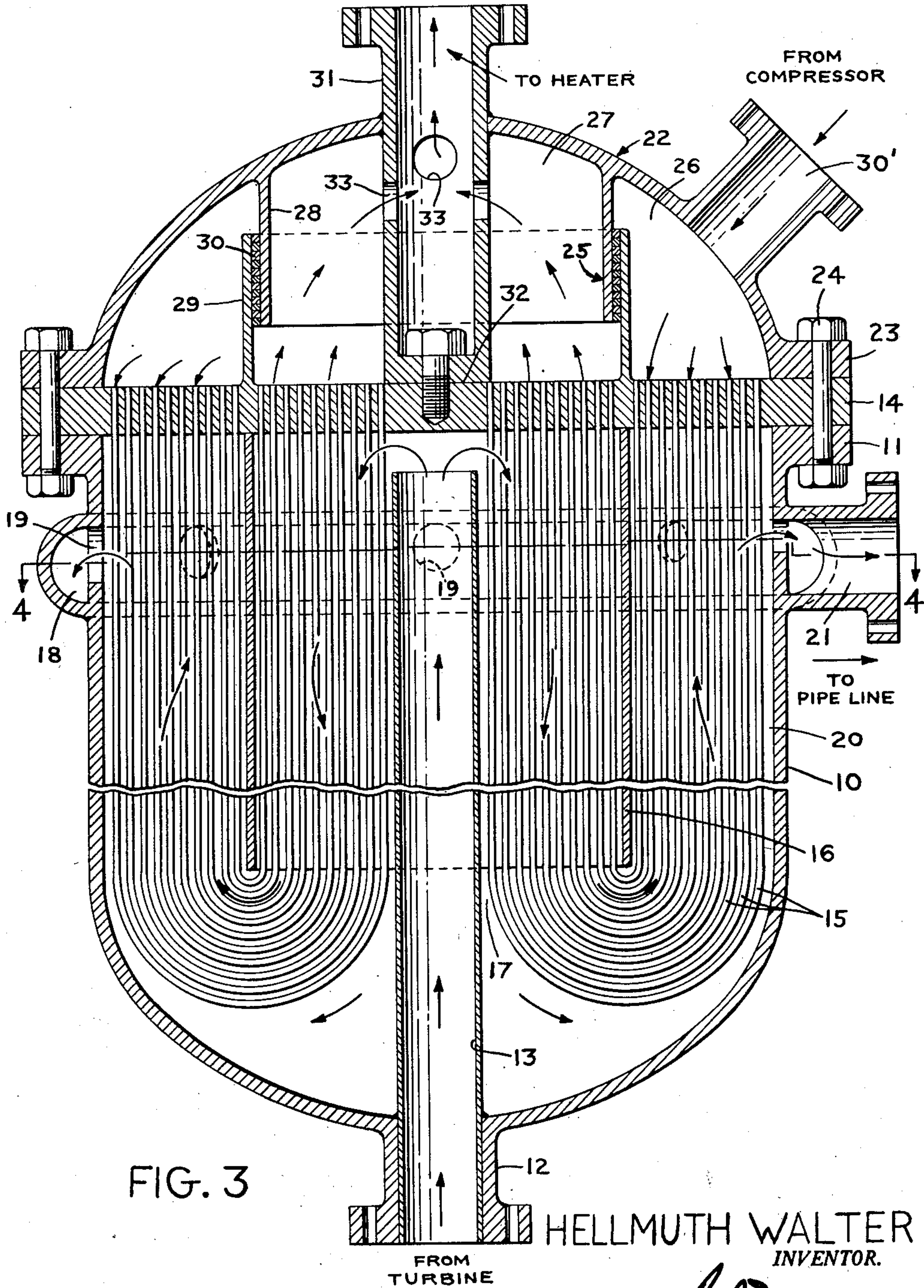


FIG. 3

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6 Sheets-Sheet 4

FIG. 3A

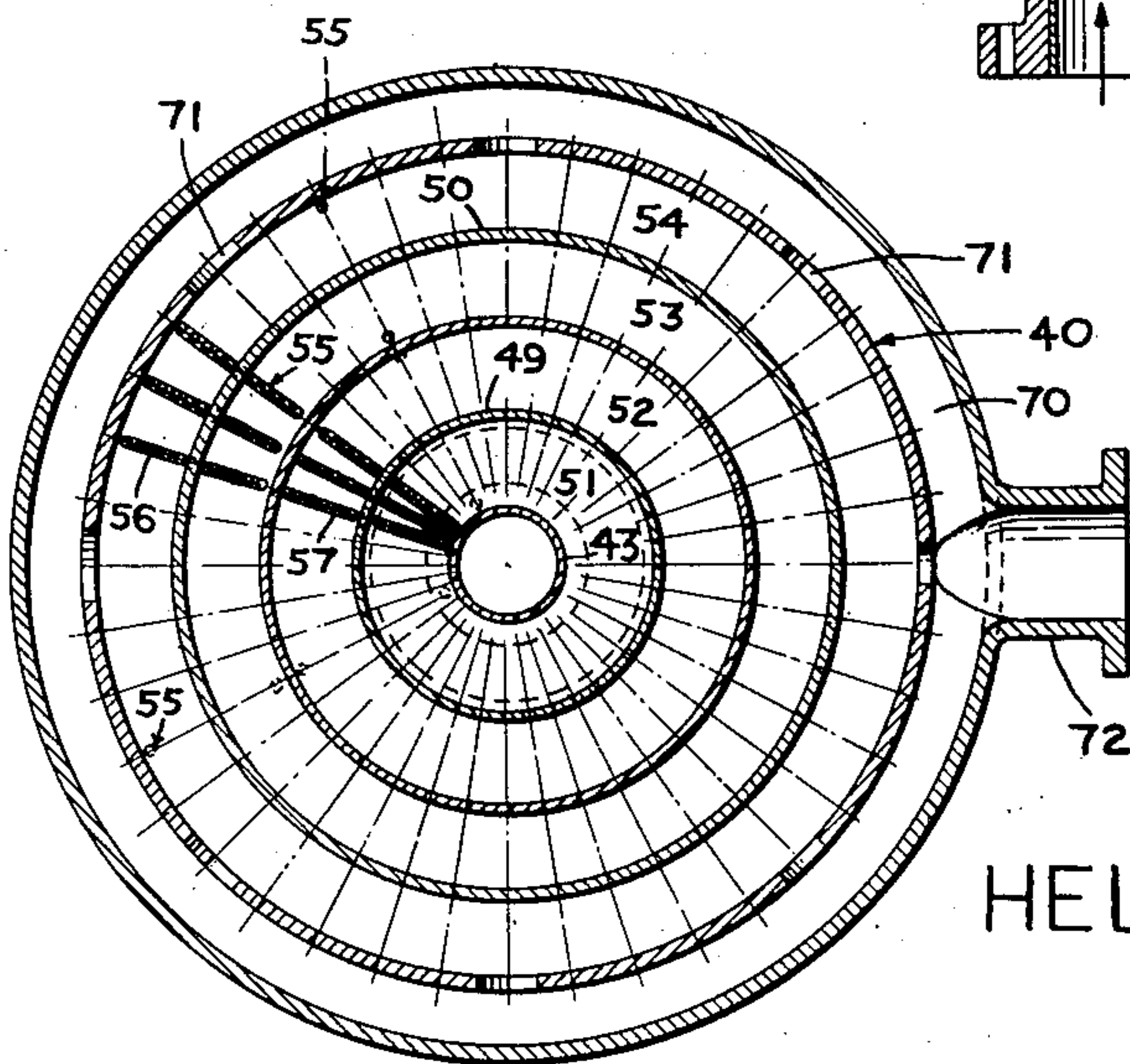
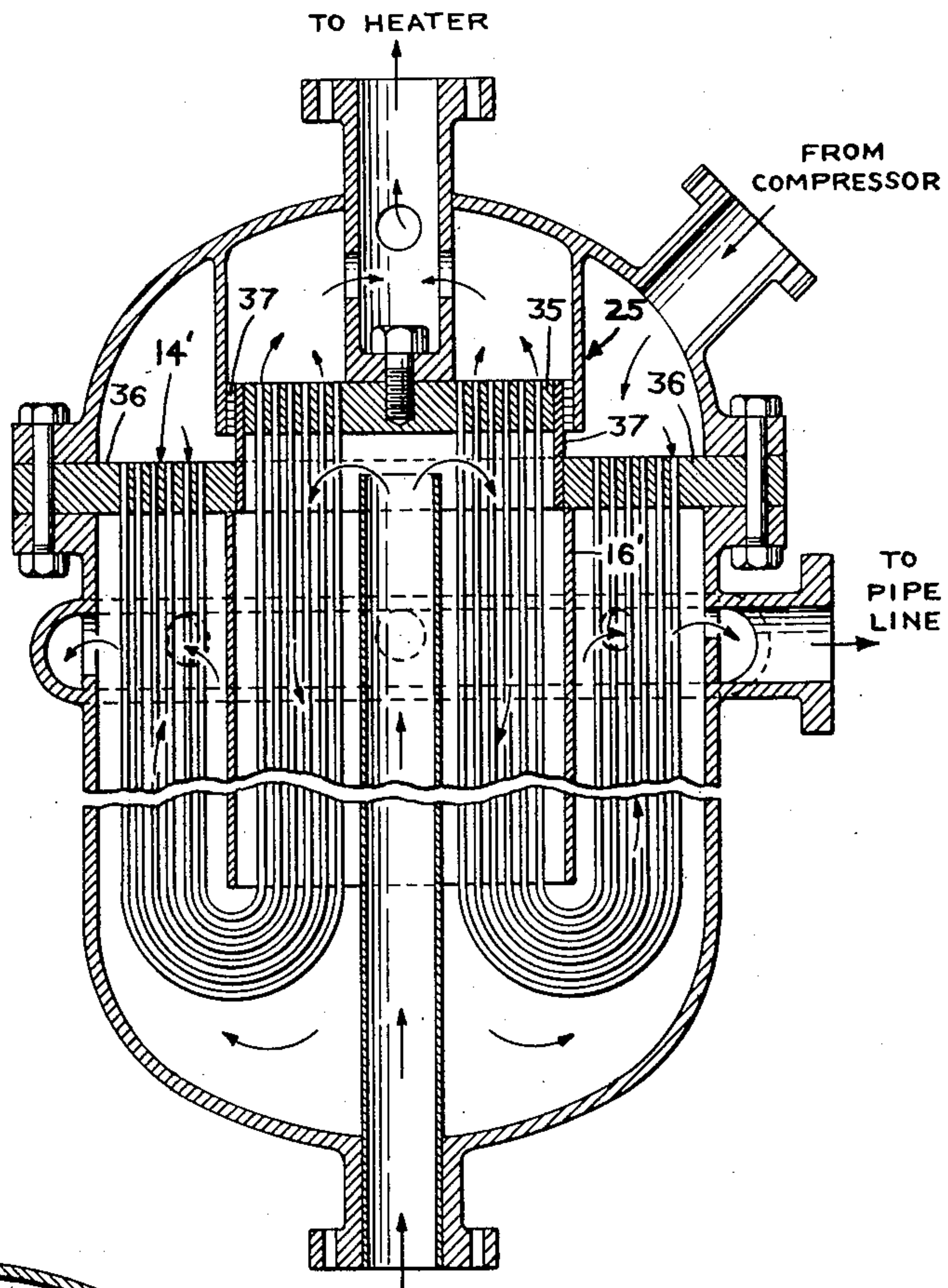


FIG. 6

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6 Sheets-Sheet 5

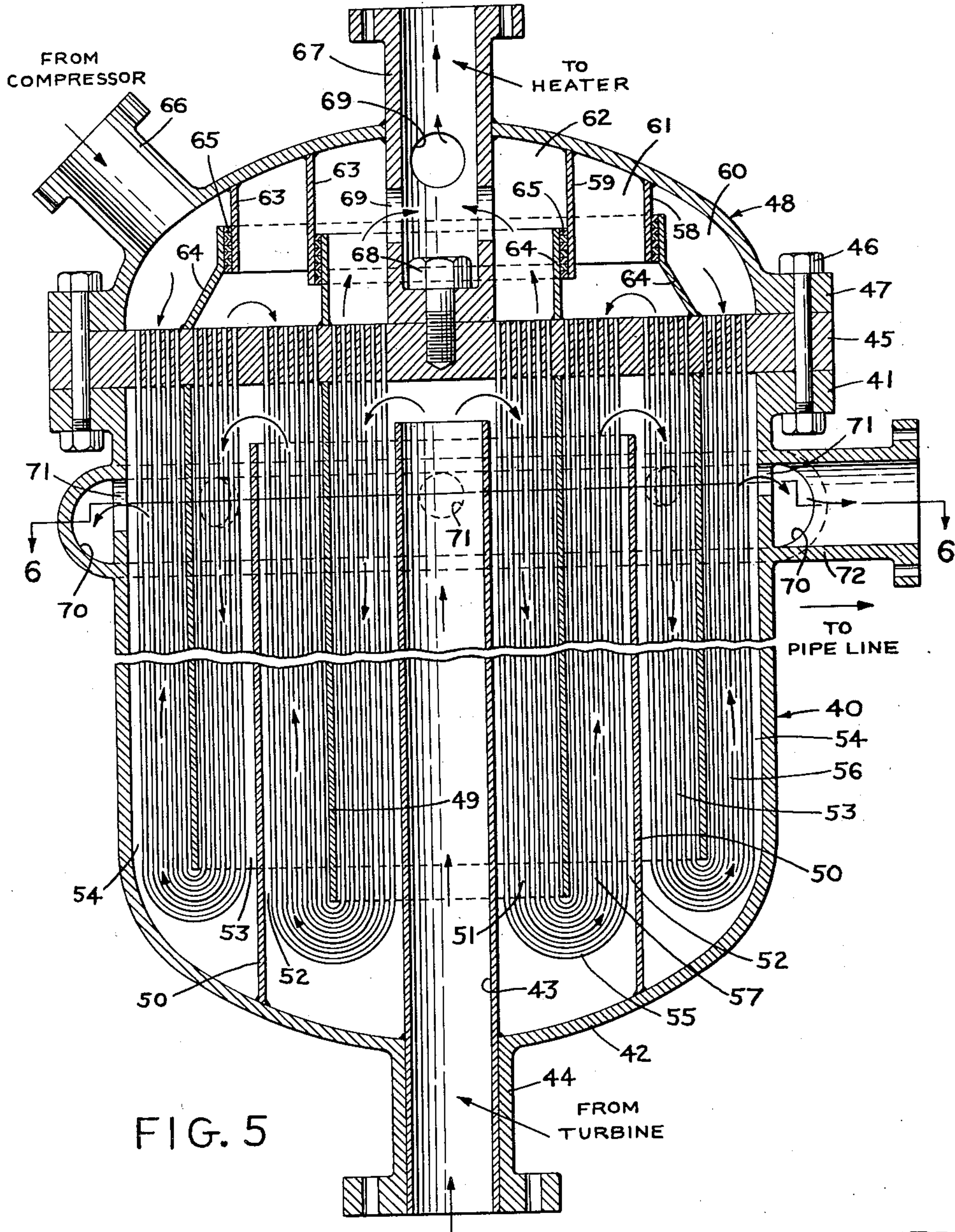


FIG. 5

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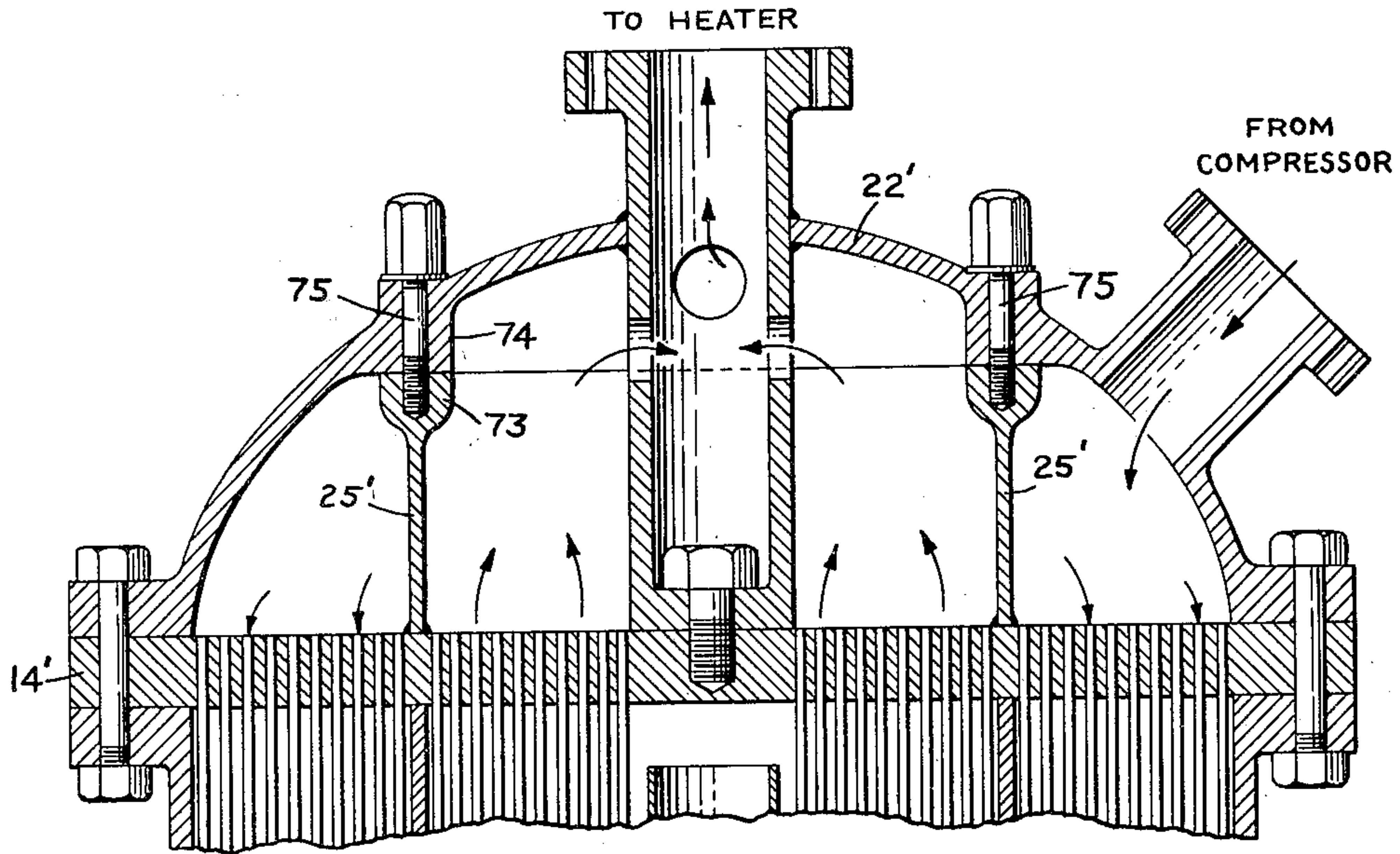


FIG. 7

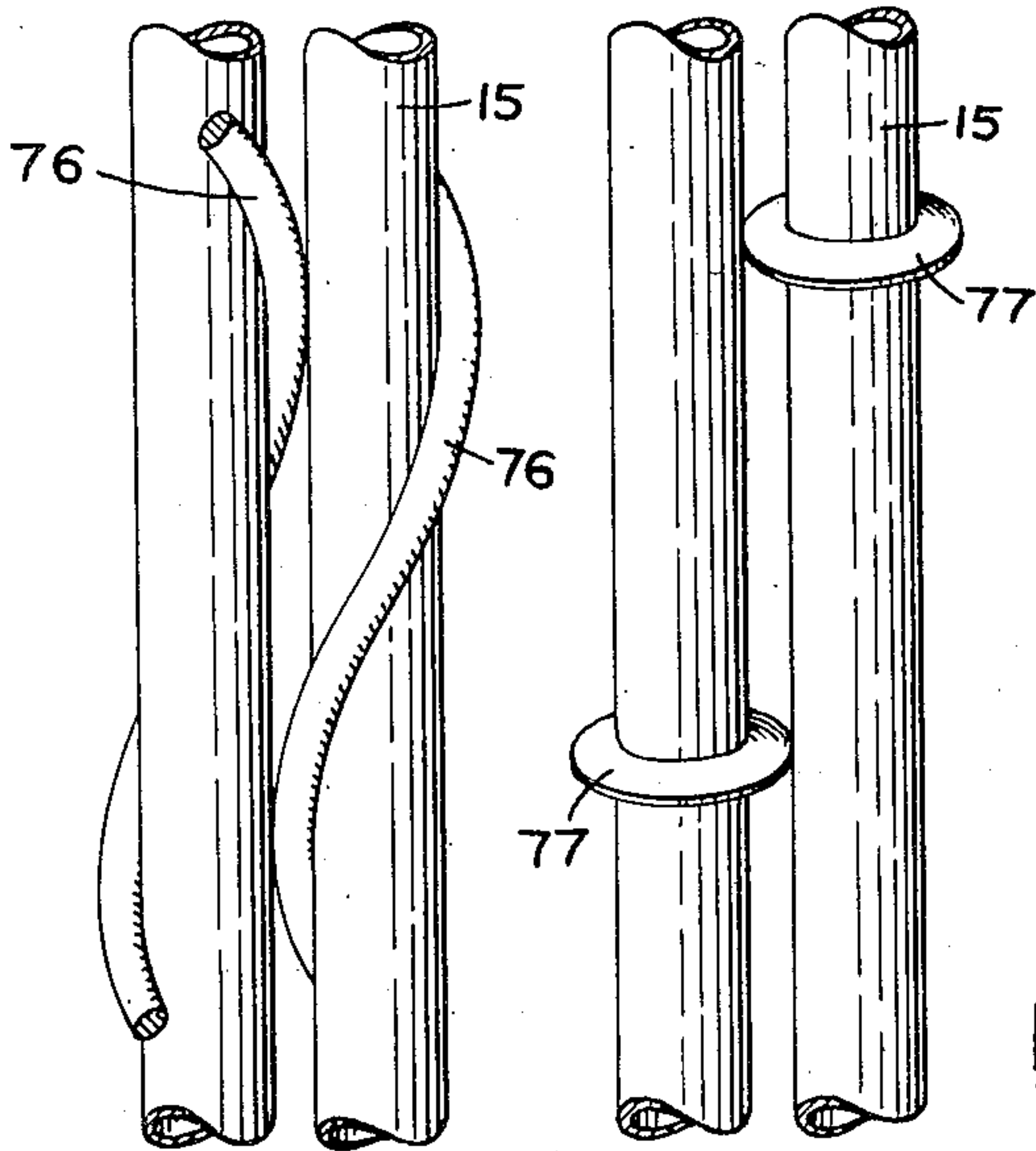


FIG. 8

FIG. 9

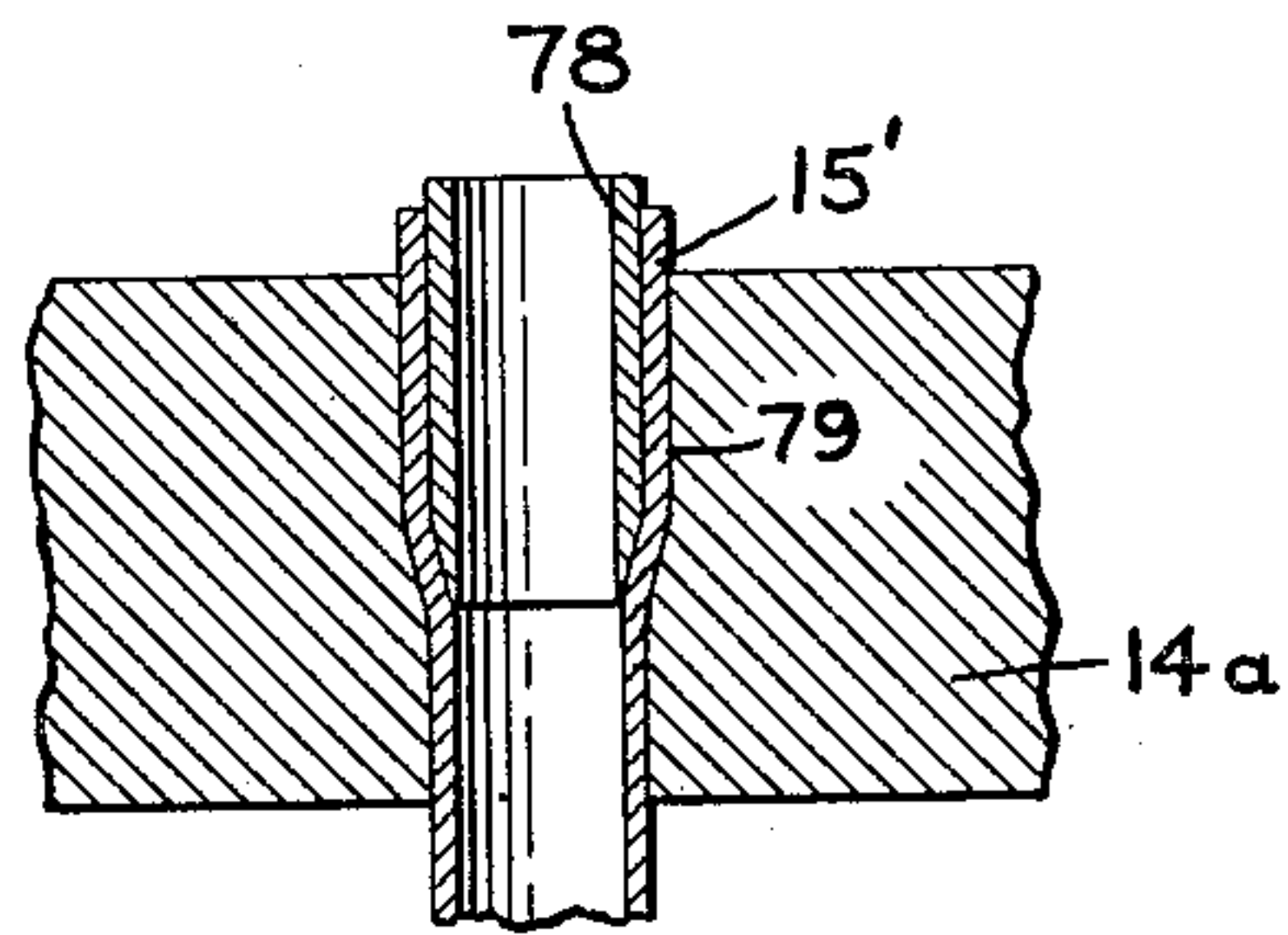


FIG. 10

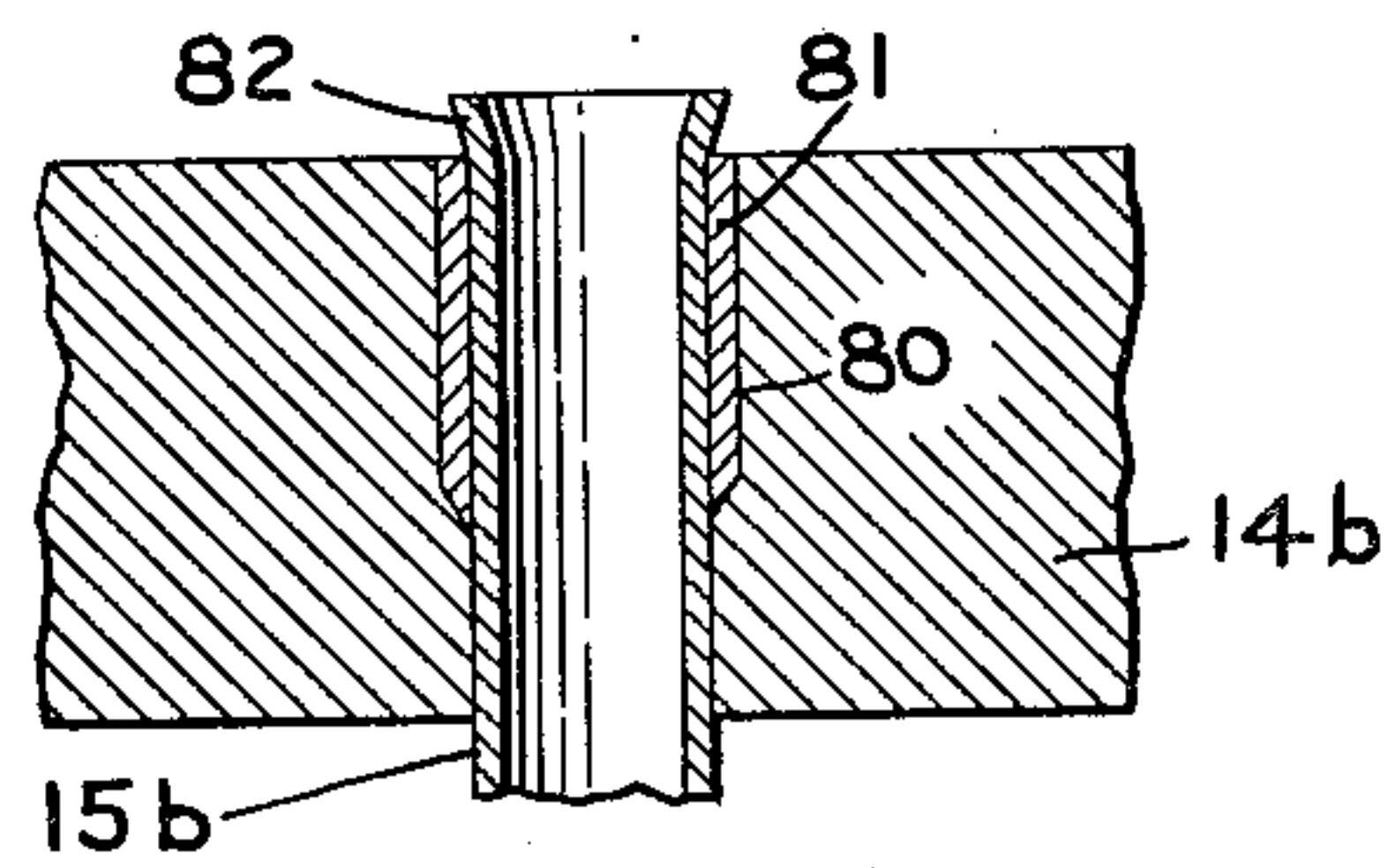


FIG. 11

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2,774,575

REGENERATOR

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Application March 7, 1952, Serial No. 275,304

5 Claims. (Cl. 257-221)

This invention relates to regenerators, that is, to heat exchangers which transfer heat from the working medium, in a land gas turbine plant, a compressing unit for compressing flowing gas or vapor, or like installation, and restores the heat to the working medium at a lower temperature point in the unit or plant.

An object of the present invention is to provide a regenerator wherein the hottest gas is introduced into the regenerator at the center thereof so that the highest temperature at which the gases come in contact with the shell of the regenerator is intermediate of the inlet and outlet temperatures of the gases and wherein danger of warping of the flanges and heads of the regenerator is eliminated due to the fact that in the heads of the regenerator the temperature is in a concentric pattern, i. e., decreasing from the center to the radius.

Another object of the present invention is to provide a regenerator structure which will permit unrestricted expansion and contraction of the shell and tube elements thereof, as well as permit ready removal of the tube sheet and tubes from the shell without disrupting pipe connections to the shell.

A regenerator of the present invention is particularly adaptable for use in land gas turbine plants, or in a gas or vapor compressing unit for compressing flowing gases or vapor in an isolated system, wherein the energy required for compression is derived from heating the gases in one or more components of the system or unit. Some such units wherein use of the present regenerator is applicable are disclosed in my co-pending application, Serial Number 181,512, filed August 25, 1950, now abandoned. However, the regenerator of the present invention is not limited to such use, the present invention being limited to the regenerator per se, which may be adapted to any use where practical.

With these and other objects in view, as may appear from the accompanying specification, the invention consists of various features of construction and combination of parts, which will be first described in connection with the accompanying drawings, showing a regenerator of a preferred form embodying the invention, and the features forming the invention will be specifically pointed out in the claims.

In the drawings:

Figure 1 is a diagrammatic layout of a compressing unit for compressing flowing gases or vapor in an isolated system and illustrating one use for the regenerator.

Figure 2 is a side elevation of the regenerator.

Figure 3 is a longitudinal section through the regenerator.

Figure 3a is a detail section through a modified form of the tube sheet employed in the regenerator.

Figure 4 is a cross section taken on the line 4-4 of Figure 3.

Figure 5 is a longitudinal section through a modified form of the regenerator.

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Figure 6 is a horizontal section through the regenerator taken on the line 6-6 of Figure 5.

Figure 7 is a fragmentary horizontal section through another form of the regenerator.

5 Figures 8 and 9 are detail views showing different types of spacers employed for maintaining the tubes in proper spaced relation within the shell of the regenerator.

10 Figures 10 and 11 are detailed views showing different constructions of mounting the tubes in the tube sheet of the regenerator.

Figure 1 of the drawings shows a diagrammatic layout of a compressing unit for compressing flowing gas or vapor wherein the energy required for compression is derived from heating the gases or vapors in one or more components of the system or unit. Generically the compressing unit includes a line pipe 1 through which the gas or vapor to be compressed flows. The gas or vapor is taken from the line 1 through a pipe 2 and delivered to the suction of a compressor 3. Part of the gas from the pipe 2 is extracted through an extraction pipe 4 and passes through one or more regenerators 5 which form the subject matter of the present invention and wherein the extracted gas subsequently heated in the unit flows in heat exchange relationship with the incoming gas from the pipe 4 for restoring the heat to the working medium at this point where the incoming gas is at a lower temperature than the subsequently heated gas. After the gas passes through the regenerators 5, which may be connected either in series or in parallel, it passes into a fuel-fired heater or heat exchanger 6 of any preferred form or construction. The heated gas is delivered from the fuel-fired heater or heat exchanger 6 through a pipe 7 to a turbine 8 which drives the compressor 3 and thus the energy required for operating the turbine 8 and compressor 3 and thereby compressing the gas or vapor is derived from heating part of the gases in the regenerators 5 and fuel fired heat exchanger 6. The compressed gas is returned to the pipe line 1 through a suitable connection 9.

15 In the form of the regenerator shown in Figures 2 to 4 inclusive of the drawings and which discloses a two-pass regenerator, i. e., a regenerator wherein the heating medium flows in two passes or in a flow path so that it passes longitudinally along the tubes containing the cooler gas or vapor to be heated.

20 The regenerator includes a shell 10 which is shown in Figure 3 of the drawings as having an upper open end about which a flange 11 is formed and a dished lower end provided with an axially disposed protruding flanged connection 12 to which the inlet pipe 13 for the hot gas or vapor is connected. A tube sheet 14 is attached to the flange 11 and extends entirely across the open end of the casing 10. A plurality of heat exchange tubes 15 are carried by the tube sheet 14 and extended into the shell 10. The heat exchange tubes 15, which conduct the gas of the lower temperature or the gas to be heated through the regenerator are U-shaped and an annular partition 16 is disposed within the shell 10 to provide a central chamber for directing the hot gases longitudinally along the inner legs of the U-shaped tubes 15 in a direction counter-current to the flow of the cool gas or vapor through the tubes and a second outer annular chamber wherein the gas flows in the opposite direction to its flow path in the central chamber 17 and longitudinally of the outer legs of the U-shaped tubes 15 in counter-current flow direction to the flow of the cooled gas through the outer legs. The inlet tube or pipe 13 for the hot gases extends axially into the shell 10 to a point in close proximity to the inner side of the tube sheet 14 so that the gas issuing therefrom will be deflected laterally and downwardly by the tube sheet along the inner legs of the tubes 15. By locating the inlet pipe 13 for the hot gases axially or

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in the center of the shell 10 the hottest gas is introduced into the regenerator at the central portion of the regenerator so that the highest temperature at which the hot gas comes into contact with the shell 10 is intermediate of the inlet and outlet temperatures of the regenerator.

An annular exhaust passage 18 is formed upon the shell 10 in close proximity with the flange 11 and the shell is provided with a plurality of circumferentially spaced openings 19 which communicate with the annular outer chamber 20 formed by the partition 16 and with the annular exhaust passage 18. A suitable outlet 21 is provided from the annular exhaust passage 18.

A dished head 22 is attached to the tube sheet 14 and the flange 11 through the medium of the flange 23 formed thereon and suitable bolts 24. An annular partition 25 is formed in the dished head 22 and forms an outer annular inlet chamber 26 and a central outlet chamber 27. The partition 25 is formed of a flange 28 which depends from the dished head 22 and a second flange 29 which rises from the tube sheet 14. Sealing means shown at 30 of any suitable type is provided so as to prevent leakage of gas between the chambers 26 and 27. The annular partition 25 is formed of the two sections 28 and 29 so that the dished head may be removed and the tube sheet 14 with all of the tubes attached thereto may be drawn longitudinally out of the shell 10 for repair or replacement of the tubes.

An inlet pipe 30' for the cooled gas opens into the annular inlet chamber 26 and from the annular inlet chamber 26 the cooler gas which is to be heated passes downwardly through the outer legs of the U-shaped tubes 15 in heat exchange relationship with the hotter gas flowing upwardly through and then the cooler gas flows upwardly through the inner legs of the U-shaped tubes 15 in heat exchange relationship with the hotter gases flowing downwardly through the central passage or chamber 17. The cooler gases, after they have passed through the inner legs of the tubes 15, flow into the central outlet chamber 27.

An outlet pipe 31 extends axially into the dished head 22 and is connected at its inner end to the tube sheet 14, as shown at 32. The outlet pipe 31 has a plurality of circumferentially spaced openings 33 therein which establish communication with the interior of the pipe and the inner outlet chamber 27 so that the gas flows from the outlet chamber 27 through the openings 33 and thence outwardly through the pipe 31.

With a regenerator of this type thermal stresses will be set up in the tube sheet 14 because of the temperature differences of the inner or central portion of the tube sheet which is contacted by the hottest gas and the outer portion of the tube sheet which is contacted by the hot gas after it has passed through the flow spaces 17 and 20 in heat exchange relationship with the tubes 15 and, consequently, is much cooler than the gas which contains the central portion of the tube sheet.

Figure 3a of the drawings shows a form of tube sheet which will compensate for the thermal stresses in the outer portion of the tube sheet due to the temperature variances between the inner and outer portions thereof. In Figure 3a the central portion 35 of the tube sheet 14' and the outer portion 36 thereof are made of separate pieces which are connected, at the outer edge of the inner section 35 and the inner edge of the section 36, that is, at a point corresponding to the location of the annular partition 16' by a metallic ring 37 which is of such a nature that it may flex to compensate for expansion and contraction of the central section 35 and prevent the transmission of stresses from the central section 35 to the outer section 36.

The construction of the regenerator shown in Figures 5 and 6 of the drawings is quite similar to the construction of the regenerator shown in Figures 2 to 4 inclusive of the drawings, differing therefrom primarily in that a multiple number of passes of the gases in heat exchange relationship is provided.

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In this form of the invention the regenerator includes a shell 40 which is open at one end and has an annular flange 41 surrounding the open end while the other end of the shell is preferably dished as shown at 42 and is provided with an axial opening through which the inlet pipe 43 for the hot gases passes in both Figures 3 and 5 of the drawings. The pipe 43 is shown as carried by a flange extension 44 of the regenerator so that a connection may be made with a pipe delivering the hot gases to the regenerator. A tube sheet 45 extends across the open end of the shell 40 and is attached to the flange 41 by means of bolts 46 which also extend through the flange 47 formed on the dished head 48. Like in Figure 3 of the drawings, the inlet pipe 43 extends axially into the shell 40 to a point a short distance inwardly of the tube sheet 45 so that the hot gasses will be deflected outwardly and downwardly as they issue from the inlet pipe 43. In Figure 5 of the drawings an annular partition 49 depends from the tube sheet 45 and a second annular partition 50 rises or extends inwardly from the bottom 42 of the shell 40 thus providing an annular inner downflow space 51 for the hot gases, an annular upflow passage or space 52, a second annular downflow space or passage 53 and a second annular outer upflow passage or space 54.

A plurality of U-shaped tubes 55 are carried by the tube sheet 45 and extend into the shell 40. The U-shaped tubes 55 are arranged in groups 56 and 57 with the legs of the tubes 55 the group 56 located on opposite sides of the annular partition 50 while the legs of the tubes 55 of the group 57 are located on opposite sides of the annular partition 49 and thus the hot gases will flow downwardly through the passages or spaces 51 and 53 longitudinally of the inner legs of the tubes 55 of the two groups in countercurrent direction to the flow of the cooler gases through the tubes (as hereinafter explained) while the hot gases will flow upwardly through the spaces or flow passages 52 and 54 longitudinally of the outer legs of the tubes 55 and countercurrent to the flow direction of the cooler gases through the tubes.

Annular partitions 58 and 59 are located within the dished head 48 and provide an outer annular inlet chamber 60, an intermediate flow reversing chamber 61 and an inner outlet chamber 62. Both of the partitions 58 and 59 are formed of sections 63 depending from the dished head 48 and section 64 rising from the tube sheet 45 and overlapping at their meeting ends with suitable sealing means indicated at 65 between their overlapping ends so as to prevent leakage of the gases from one of the chambers 60, 61 or 62 to the other and so as to permit removal of the head 48 and tube sheet 45 for access to the tubes for replacement or repair. The outer annular inlet chamber 60 in the dished head 48 has an inlet 66 for the cooler gas. The cooler gas flows from the outer annular inlet chamber 60 downwardly through the outer legs of the tubes 55 of the group 56 and thence upwardly through the inner legs of the tubes 55 of the group 56 into the chamber 61 where it is again directed downwardly through the outer legs of the tubes 55 of the group 57 passing from these outer legs through the inner legs of the U-shaped tubes 55 of the group 57 into the central outlet chamber 62. An outlet pipe 67 extends axially through the dished head 45 and is attached in any suitable manner as indicated at 68 to the tube sheet 45. The pipe 67 has a plurality of openings 69 therein through which the gas flows from the outlet chamber 62 into the pipe 67.

An annular exhaust passage for the hotter gases is provided about the shell 40 at a point in close proximity to the flange 41 and the shell is provided with a plurality of openings 71 circumferentially spaced thereabout which open into the annular exhaust passage 70 to provide for the outlet of the hot gases from the regenerator. A suitable outlet connection 72 communicates with the annular exhaust passage 70.

The form of the invention shown in Figure 7 of the drawings differs from the form shown in Figure 3 in that

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the annular partition 25' is continuous being attached to the tube sheet 14' and having an enlarged annular portion 73 formed at its outermost edge. The dished head 22' has an annular enlargement 74 thereon which abuts the outer surface of the annular enlargement 73 and is attached thereto by means of cap screws 75 whereby the tube sheet 14' will be partially supported from the dished head 22'.

In the construction of the regenerators it may be necessary or desirable to provide means for maintaining the various tubes 15 or 55 in proper spaced relation one to the other so as to permit unimpeded flow of the hot gases about the tubes. Figures 8 and 9 show two different constructions for maintaining the tubes in proper spaced relation.

Figure 8 shows wires or rods 76 spirally coiled about the legs of the tubes and engaging the legs of adjacent tubes to maintain the tubes in their proper spaced relation, while Figure 9 shows a plurality of spacing discs 77 mounted on the tubes in longitudinally spaced relation with the peripheries of the spacing discs engaging the adjacent tubes so as to maintain the tubes in proper spaced relation without providing undesirable impedance to the flow of the gas about the tubes.

Figures 10 and 11 illustrate two different forms of attaching the tubes to the tube sheets, either of which may be employed or, in fact, other practical methods of attaching the tubes to the tube sheets may be employed without departing from the spirit of the present invention, those shown in Figures 10 and 11 being merely by way of illustration.

In Figure 10 the tubes 15' have their outer ends expanded by ferrules 78 which are driven into the tube ends forcing the ends of the tubes into the counterbores 79 formed in the tube sheet 14a. In Figure 11 the tube sheet 14b is counterbored as shown at 80 and a ferrule 81 is driven into the counterbore about the outside of the tube 15b, while the extreme outer end of the tube 15b is flared or rolled as shown at 82.

It will be understood that the invention is not to be limited to the specific construction or arrangement of parts shown, but that they may be widely modified within the invention defined by the claims.

What is claimed is:

1. In a regenerator, a shell having one end open, a tube sheet closing said open end, said tube sheet constructed of a plurality of sections disposed parallel and in spaced relation to each other, means connecting the sections of the tube sheet to permit expansion and contraction of one section of the tube sheet without transferring thermal stresses to the other section, a removable head attached to said tube sheet and shell having an inlet for the medium to be heated and an outlet pipe for heated medium, at least one partition means coacting with one of the tube sheet sections to form an inlet chamber and an outlet chamber inwardly of said inlet chamber, said inlet chamber communicating with said inlet and said outlet chamber communicating with said outlet pipe, a plurality of U-shaped tubes having their inner legs connected to one of said sections of the tube sheet and their outer legs connected to another of said sections of the tube sheet and disposed to extend into said shell to form an inner heat exchange section and an outer heat exchange section, the outer legs of said U-shaped tubes communicating with said inlet chamber and the inner legs of said U-shaped tubes communicating with said outlet chamber, means in said shell forming an inlet for hot gases, means on said shell forming an outlet to exhaust cool the gases from said shell, and means in said shell coacting with said inlet and outlet means to direct the flow of hot gases in a sinuous path over and about said inner and outer heat exchange sections.

2. A regenerator as claimed in claim 1 having a slip joint between said partition and the coacting tube sheet

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section to permit relative axial movement between said tube sheet section and said partition and to maintain the seal between said inlet chamber and said outlet chamber.

3. In a regenerator as claimed in claim 1 wherein said outlet pipe is attached for supporting engagement at its inner end to one of said sections of the tube sheet.

4. A regenerator as claimed in claim 1 wherein said tube sheet includes an outer section fixedly connected between said shell and removable head and an inner section supportably carried by said outlet pipe, said means connecting said inner section to said outer section comprising an annular ring, said partition means overlapping said annular ring to form said inlet chamber and said outlet chamber, and slip joint means provided to permit movement of said inner tube sheet section relative to said partition means and to seal said inlet chamber from said outlet chamber.

5. In a regenerator, a shell having one end open, a tube sheet closing said open end, said tube sheet constructed of a plurality of sections disposed parallel and in spaced relation to each other, means connecting the sections of the tube sheet to permit expansion and contraction of one section of the tube sheet without transferring thermal stresses to the other section, a removable head attached to said tube sheet and shell having an inlet for the medium to be heated and an outlet pipe for heated medium, at least one partition means coacting with one of the tube sheet sections to form an inlet chamber and an outlet chamber inwardly of said inlet chamber, said inlet chamber communicating with said inlet and said outlet chamber communicating with said outlet pipe, a plurality of U-shaped tubes having their inner legs connected to one of said sections of the tube sheet and their outer legs connected to another of said sections of the tube sheet and disposed to extend into said shell to form an inner heat exchange section and an outer heat exchange section, the outer legs of said U-shaped tubes communicating with said inlet chamber and the inner legs of said U-shaped tubes communicating with said outlet chamber, the inner legs of said U-shaped tubes adjacent the axial line in spaced relation to form a centrally disposed space in said shell, an inlet pipe having one end connected to said shell and extending centrally between the spaced inner legs of said U-shaped tubes, said inlet pipe having an opening at the end remote from the connected end opening near said tube sheet for delivering hot gases into said shell, at least one annular partition connected to said tube sheet between the inner and outer heat exchange sections and extending into said shell between the legs of said U-shaped tubes, and outlet means on said shell to exhaust cooled gases from said shell, said inlet pipe, tube sheet, annular partition and outlet means constructed and arranged to direct the flow of gases in a sinuous path across said U-shaped tubes in the shell.

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