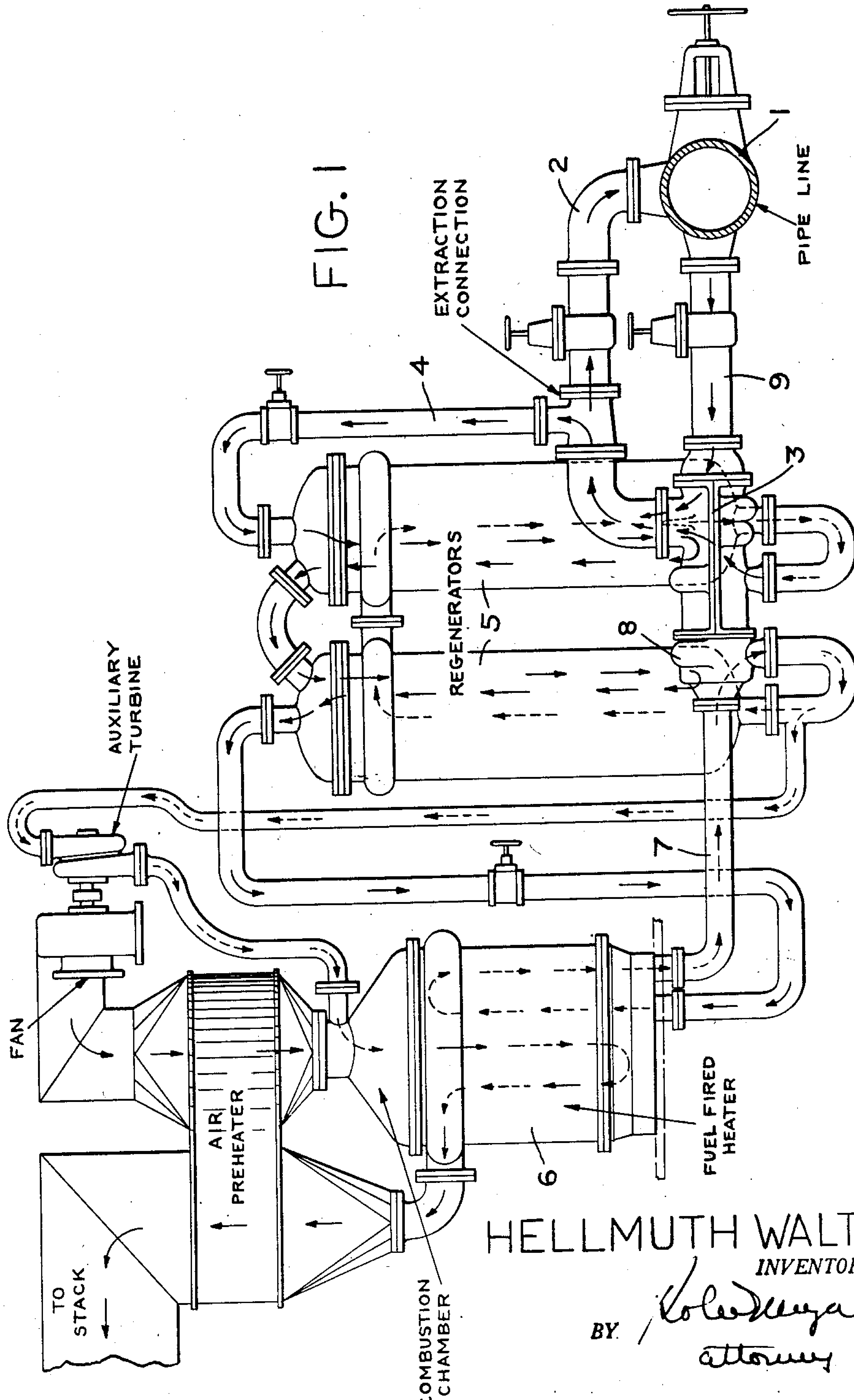
Dec. 18, 1956 H. WALTER 2,774,575

REGENERATOR

Filed March 7, 1952 6 Sheets-Sheet 1

FIG. 1



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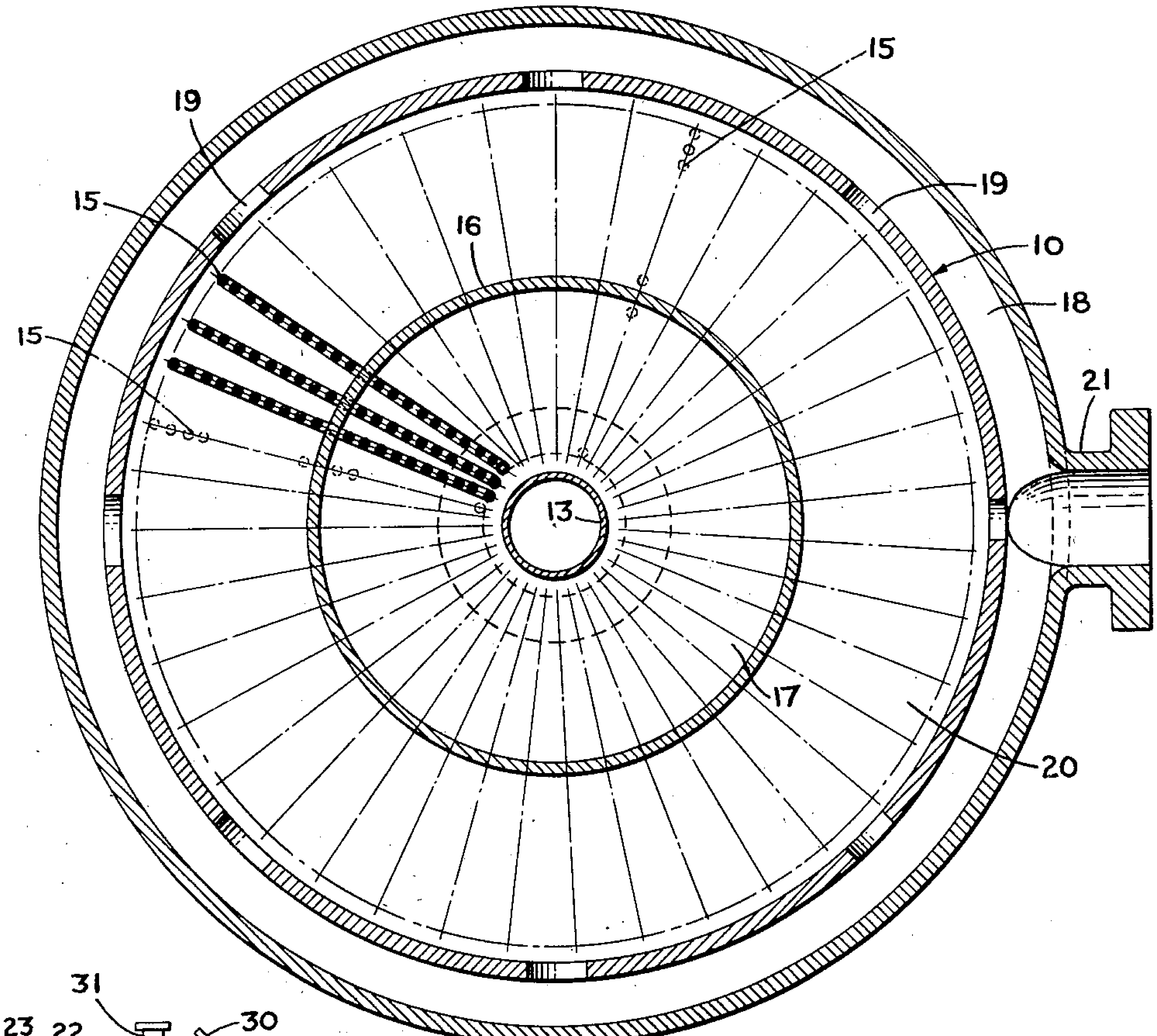

FIG. 4

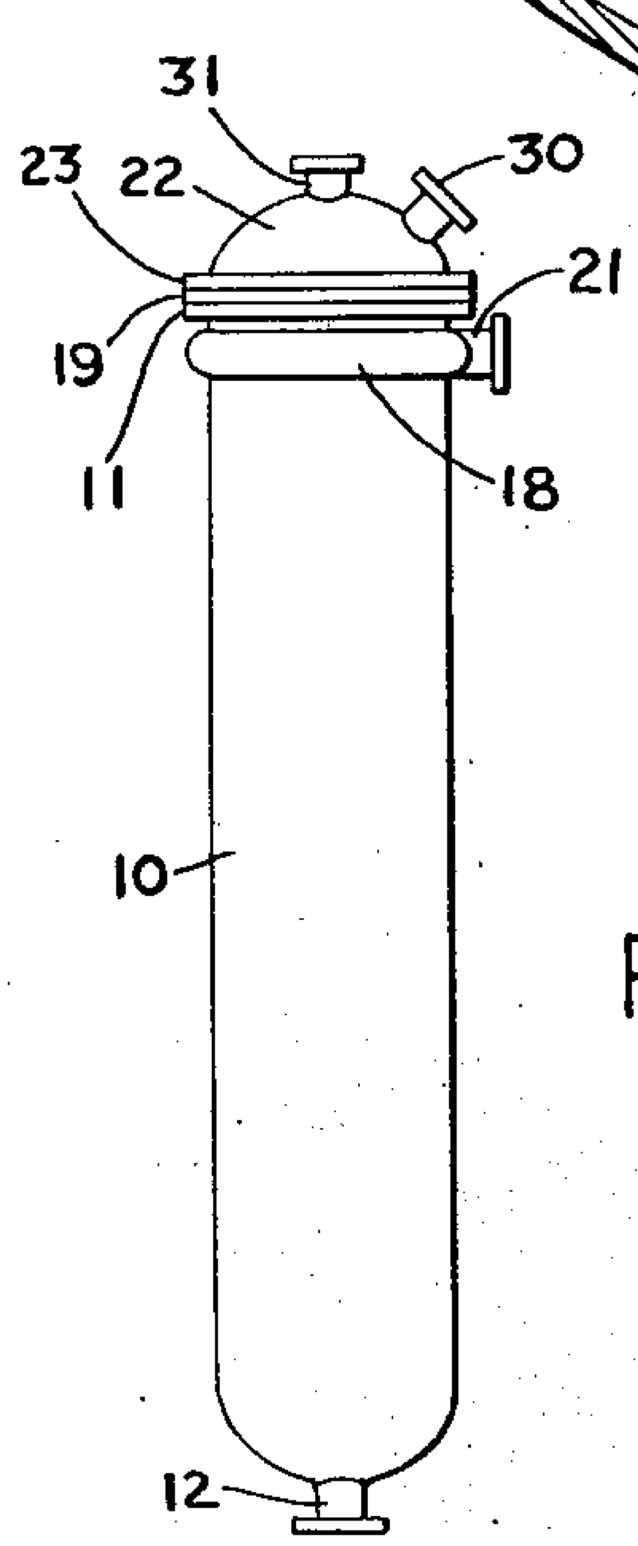

FIG. 2

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REGENERATOR

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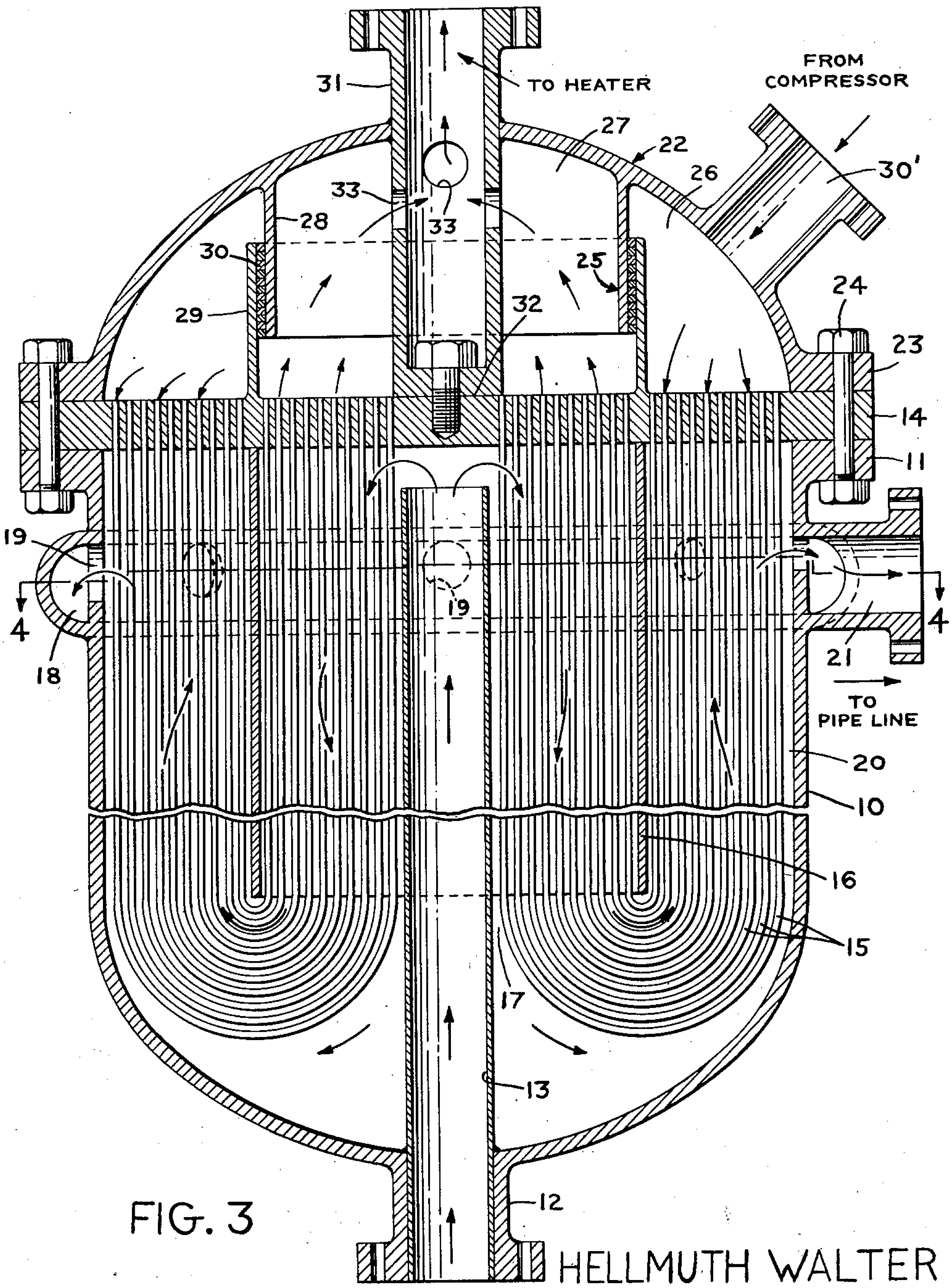

FIG. 3

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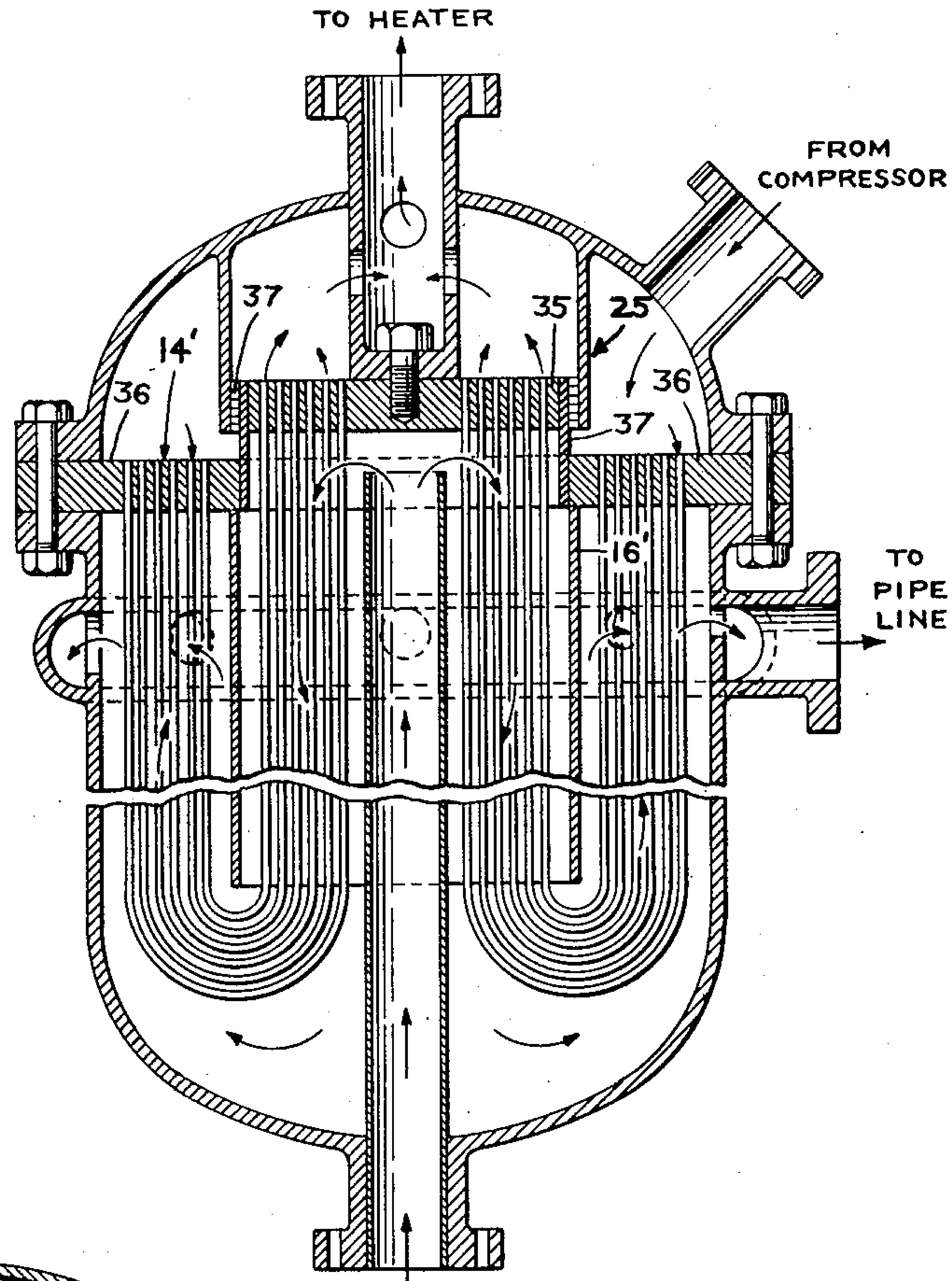

FIG. 3A

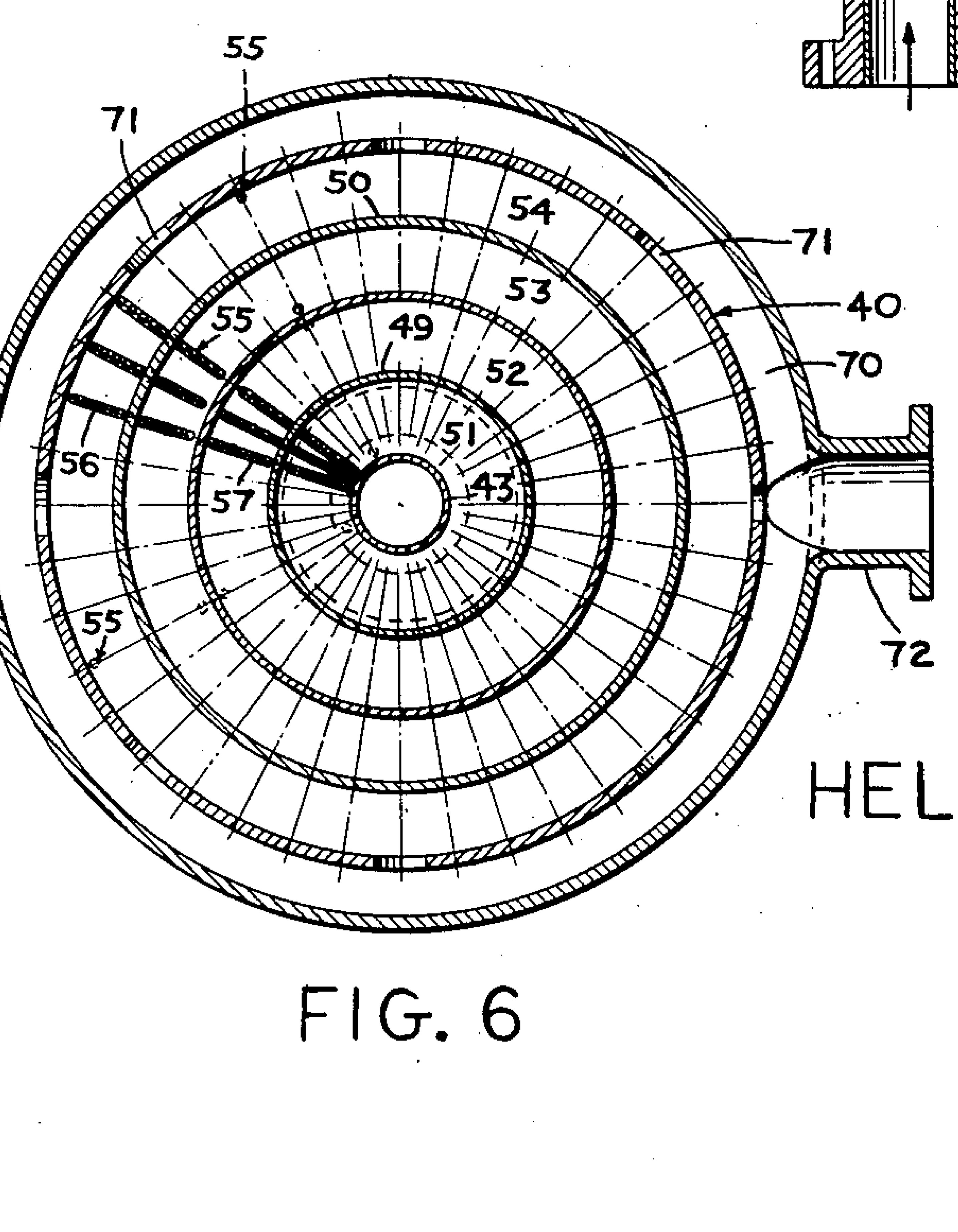

FIG. 6

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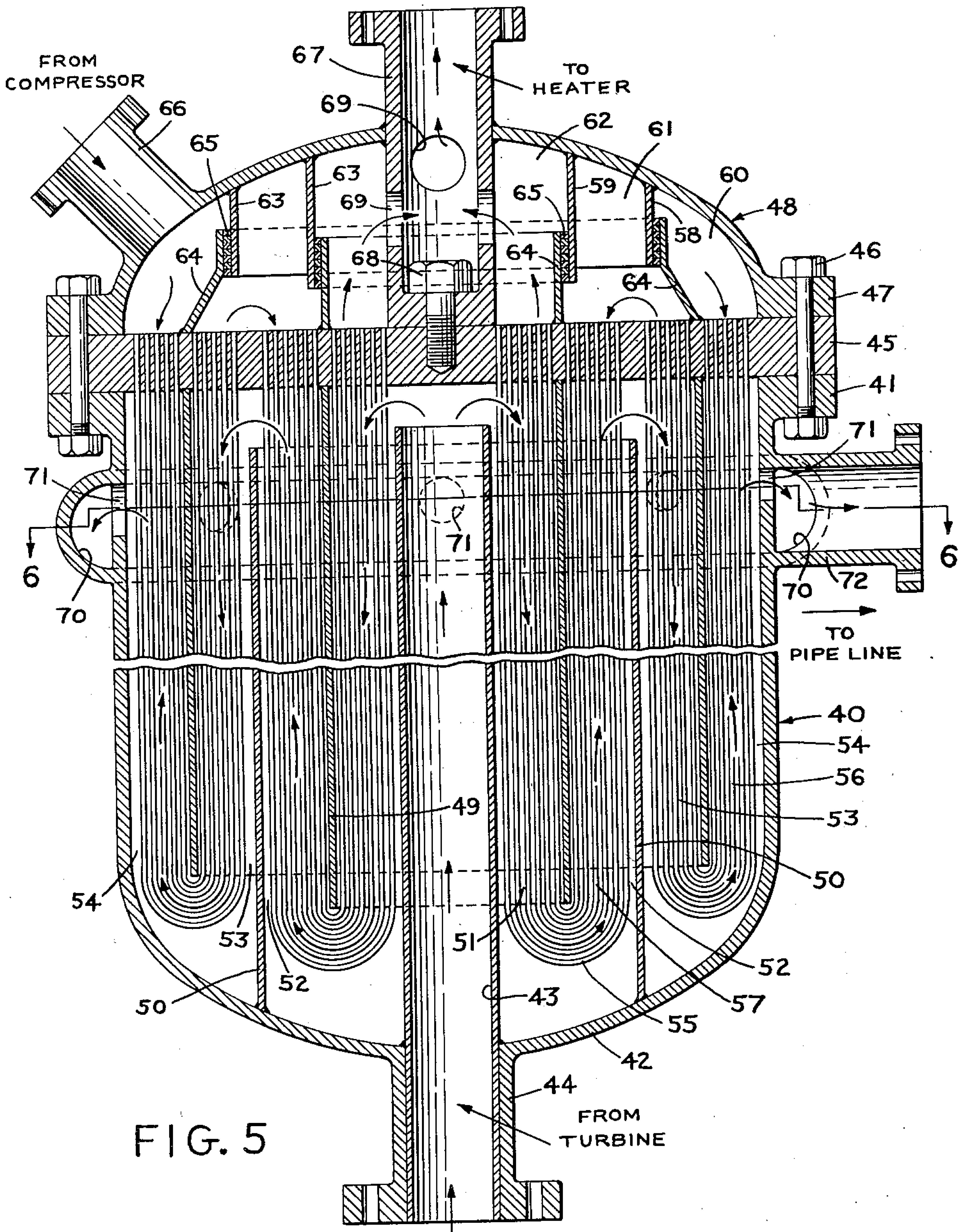

FIG. 5

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REGENERATOR

Filed March 7, 1952

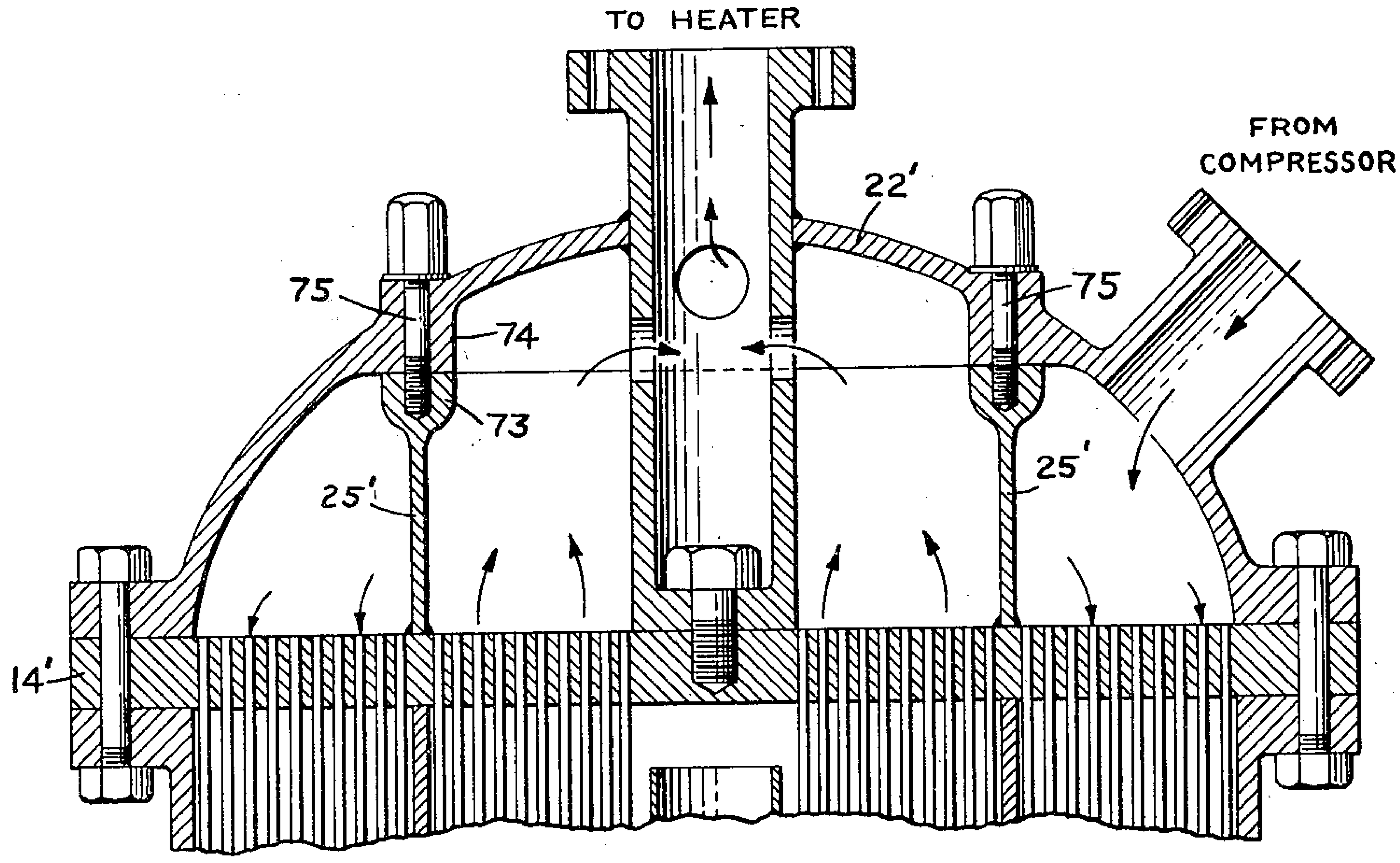

FIG. 7

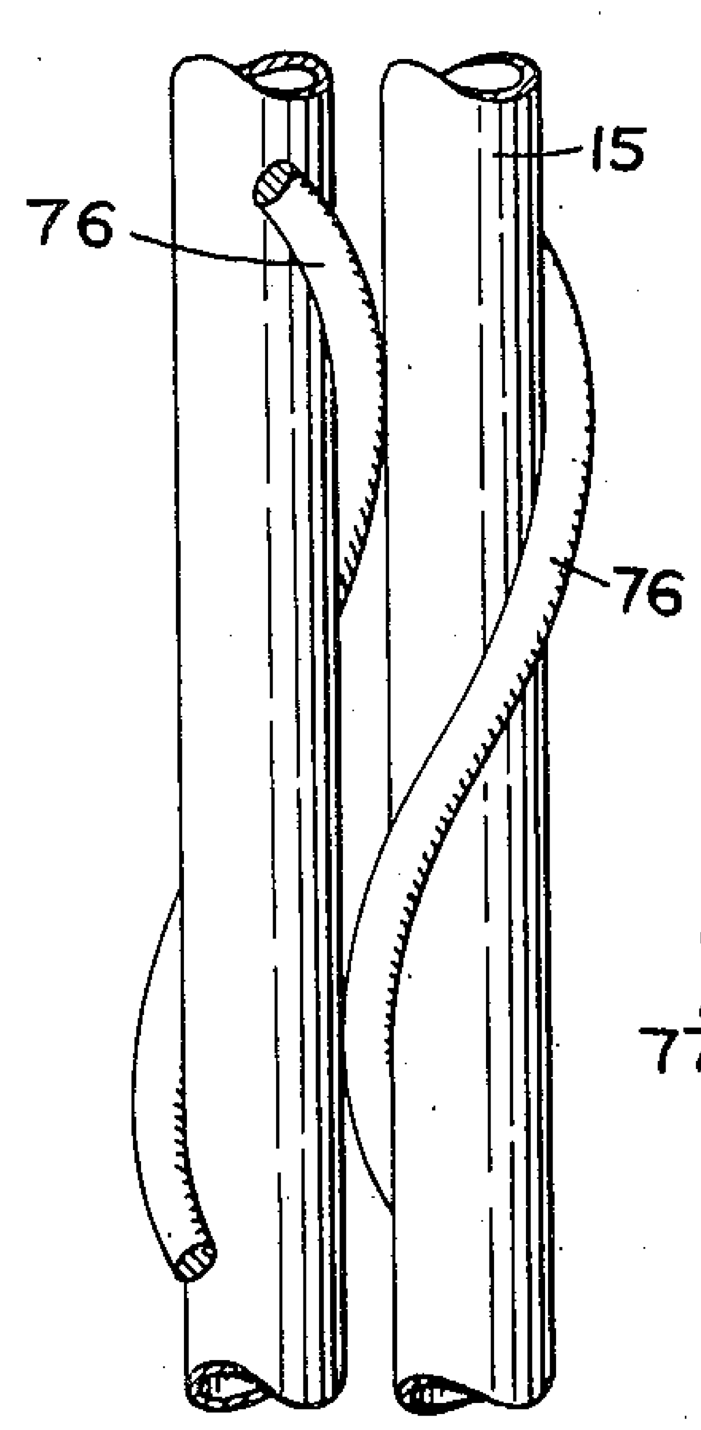

FIG. 8

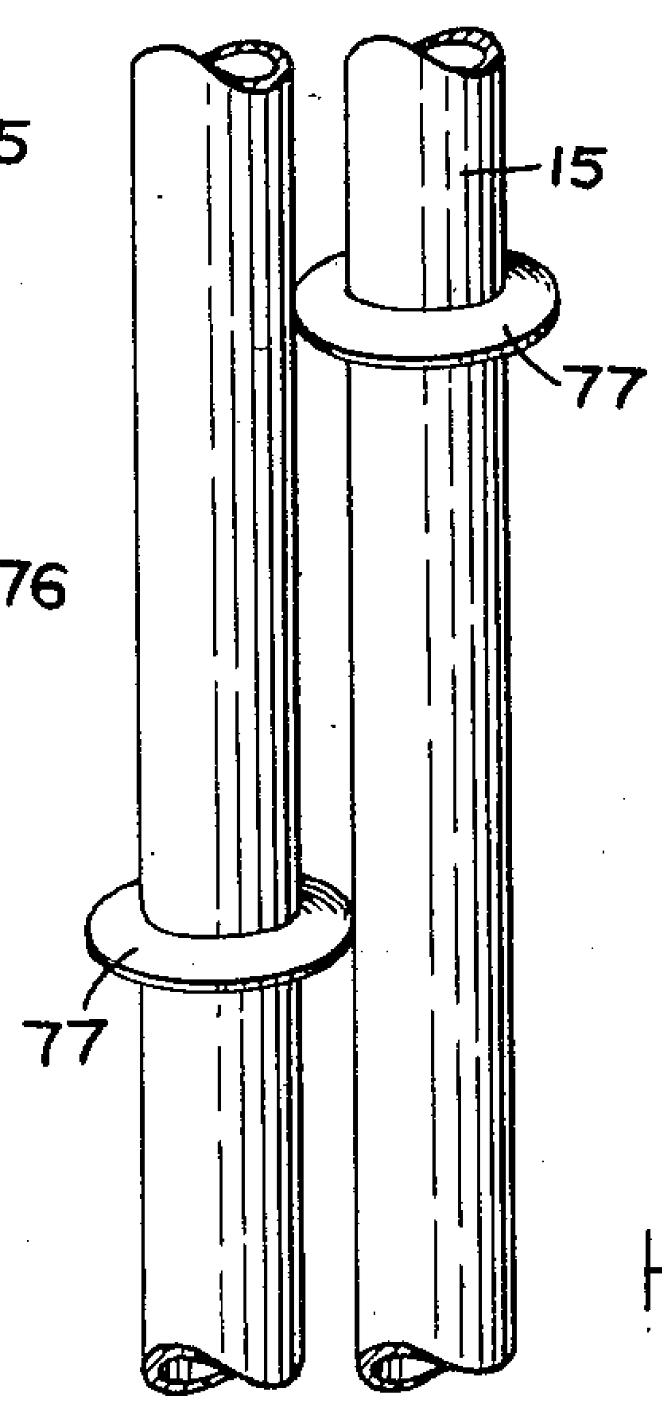

FIG. 9

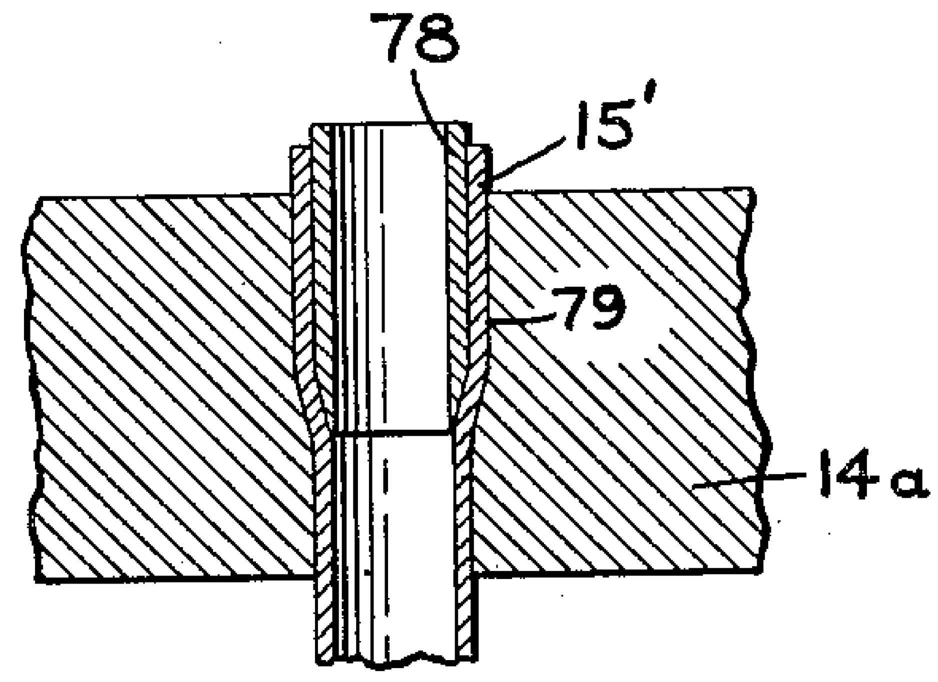

FIG. 10

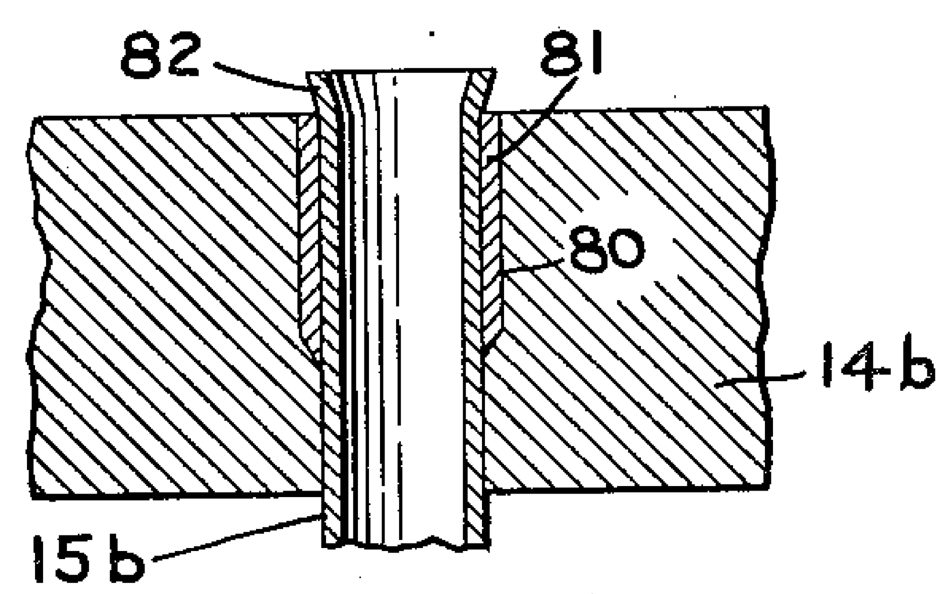

FIG. 11

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2,774,575

Patented Dec. 18, 1956

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 3*a* 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.

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.

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.

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 diagrammatical layout of a compressing unit for compresisng 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**.

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.

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 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 threthrough 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 3*a* 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 3*a* 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.

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 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 **14***a*. In Figure 11 the tube sheet **14***b* is counterbored as shown at **80** and a ferrule **81** is driven into the counterbore about the outside of the tube **15***b*, while the extreme outer end of the tube **15***b* 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 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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