US 20100276130A1

(19) United States
(12) Patent Application Publication
de Larminat et al.

(10) Pub. No.: US 2010/0276130 A1
(43) Pub. Date: Nov. 4, 2010

(54) **HEAT EXCHANGER**

(75) Inventors: **Paul de Larminat**, Nantes (FR); **Jay A. Kohler**, York, PA (US); **Mustafa Kemal Yanik**, York, PA (US); **William F. McQuade**, New Cumberland, PA (US); **Justin Kauffman**, York, PA (US)

Correspondence Address:
MCNEES WALLACE & NURICK LLC
100 PINE STREET, P.O. BOX 1166
HARRISBURG, PA 17108-1166 (US)

(73) Assignee: **JOHNSON CONTROLS TECHNOLOGY COMPANY**, Holland, MI (US)

(21) Appl. No.: **12/740,189**

(22) PCT Filed: **Jan. 11, 2009**

(86) PCT No.: **PCT/US09/30688**

§ 371 (c)(1), (2), (4) Date: **Apr. 28, 2010**

Related U.S. Application Data

(60) Provisional application No. 61/020,533, filed on Jan. 11, 2008.

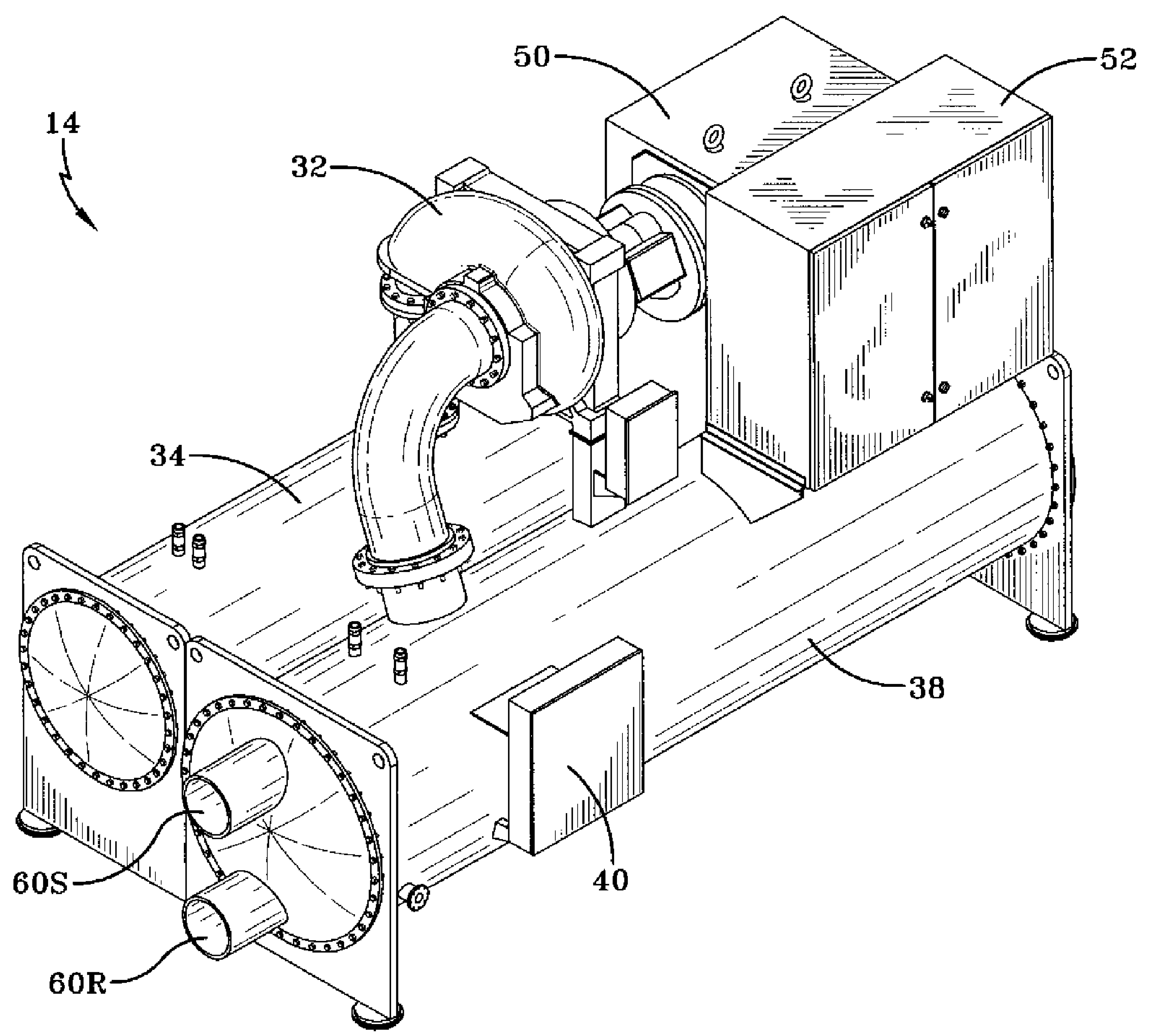
Publication Classification

(51) **Int. Cl.**
F28F 9/00 (2006.01)

(52) **U.S. Cl.** **165/157**

(57) **ABSTRACT**

A vapor compression system including a heat exchanger and a heat exchanger for use in a vapor compression system, the heat exchanger including a shell (**76**), a hood (**86**), a tube bundle (**78**), a distributor (**80**), and a passageway are disclosed. The shell (**76**) can include an outlet (**104**) configured to permit passage of vapor (**96**) from the shell (**76**), the hood (**86**) can be configured and positioned to cover the tube bundle (**78**) and the distributor (**80**), the tube bundle (**78**) can extend substantially horizontally in the shell (**76**), the distributor (**80**) can be configured to apply a fluid to the tube bundle (**78**), and the passageway can be configured and positioned to receive vapor (**96**) and provide a flow path for the vapor (**96**) to the outlet (**104**).



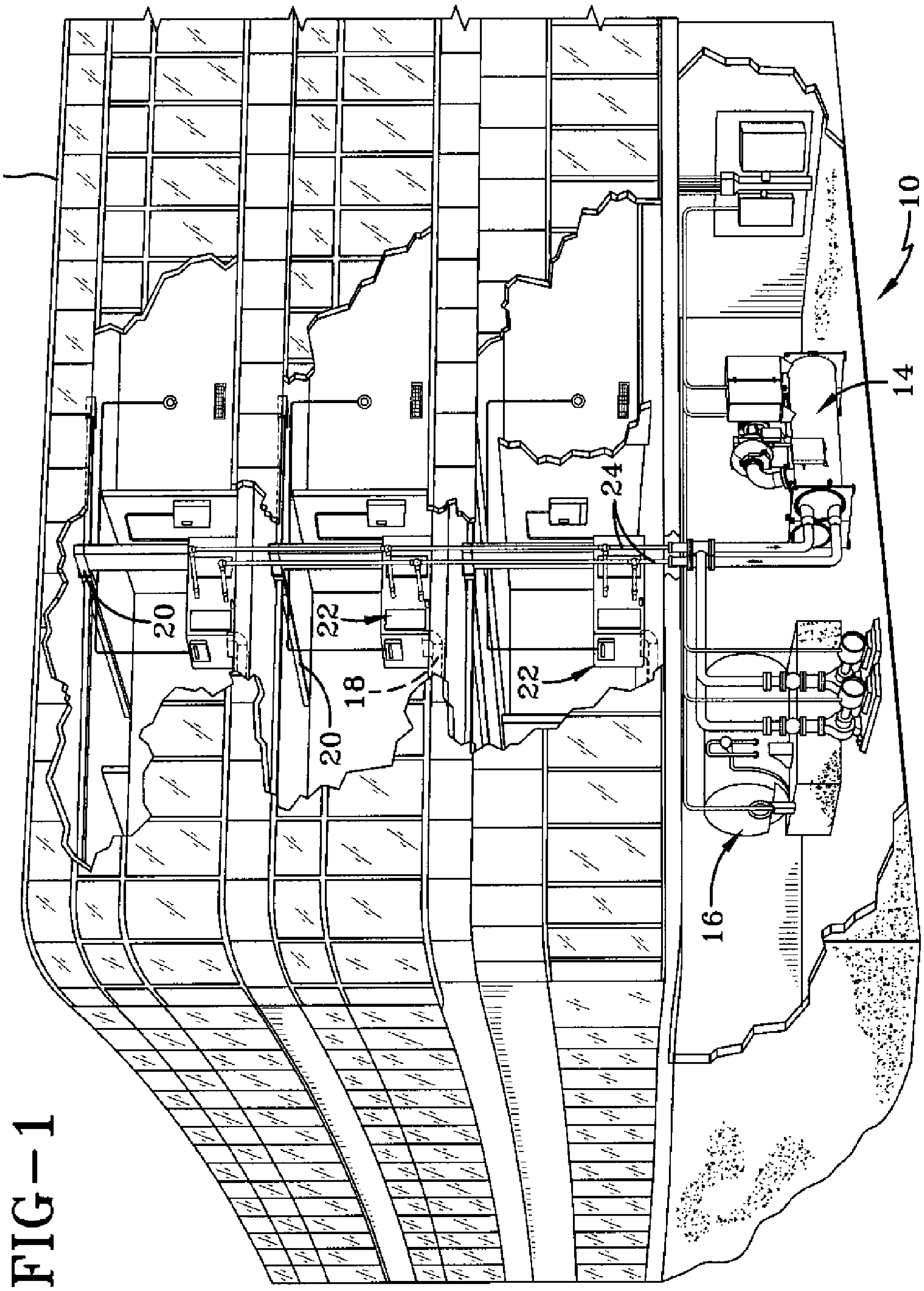


FIG-1

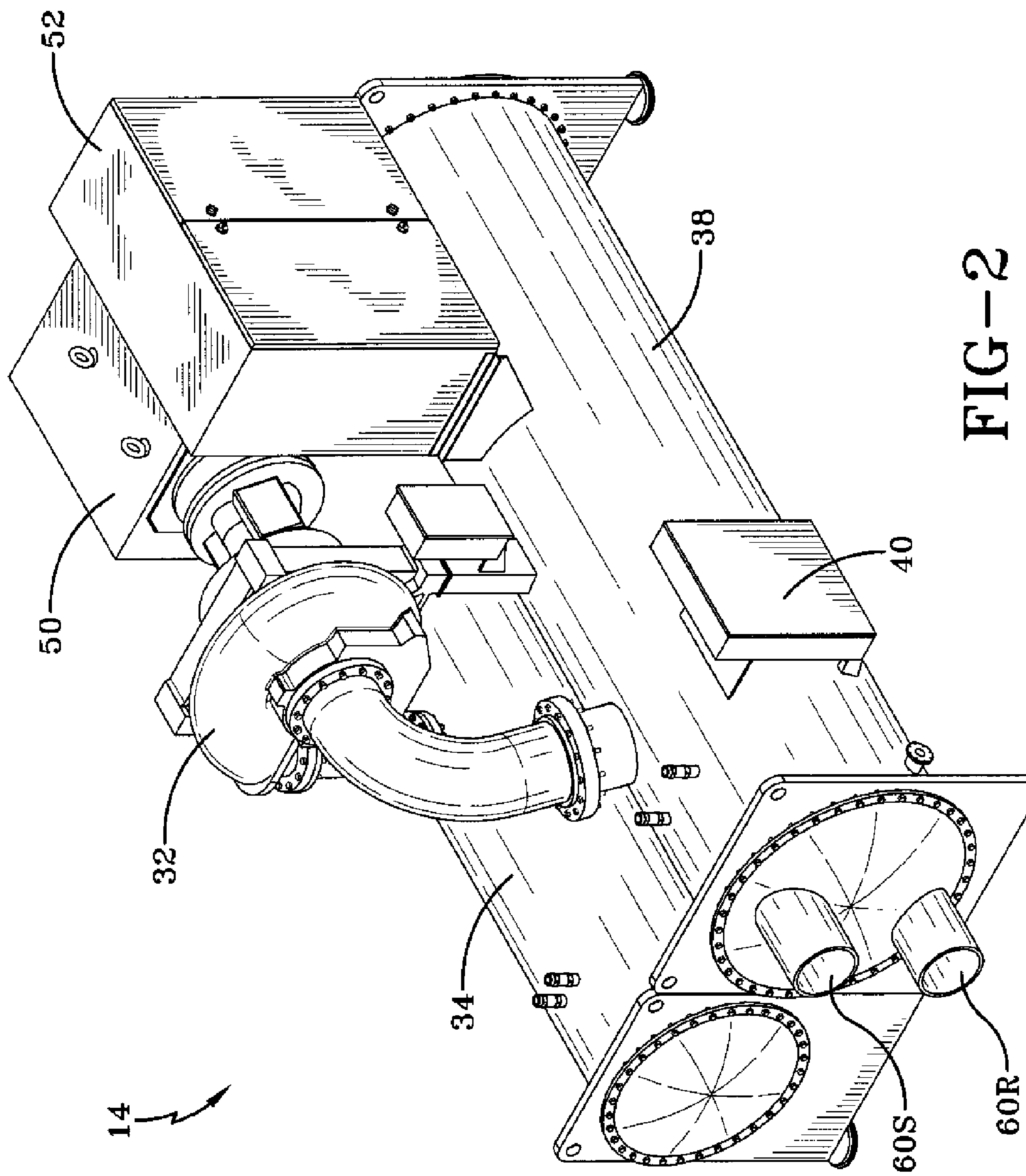


FIG-2

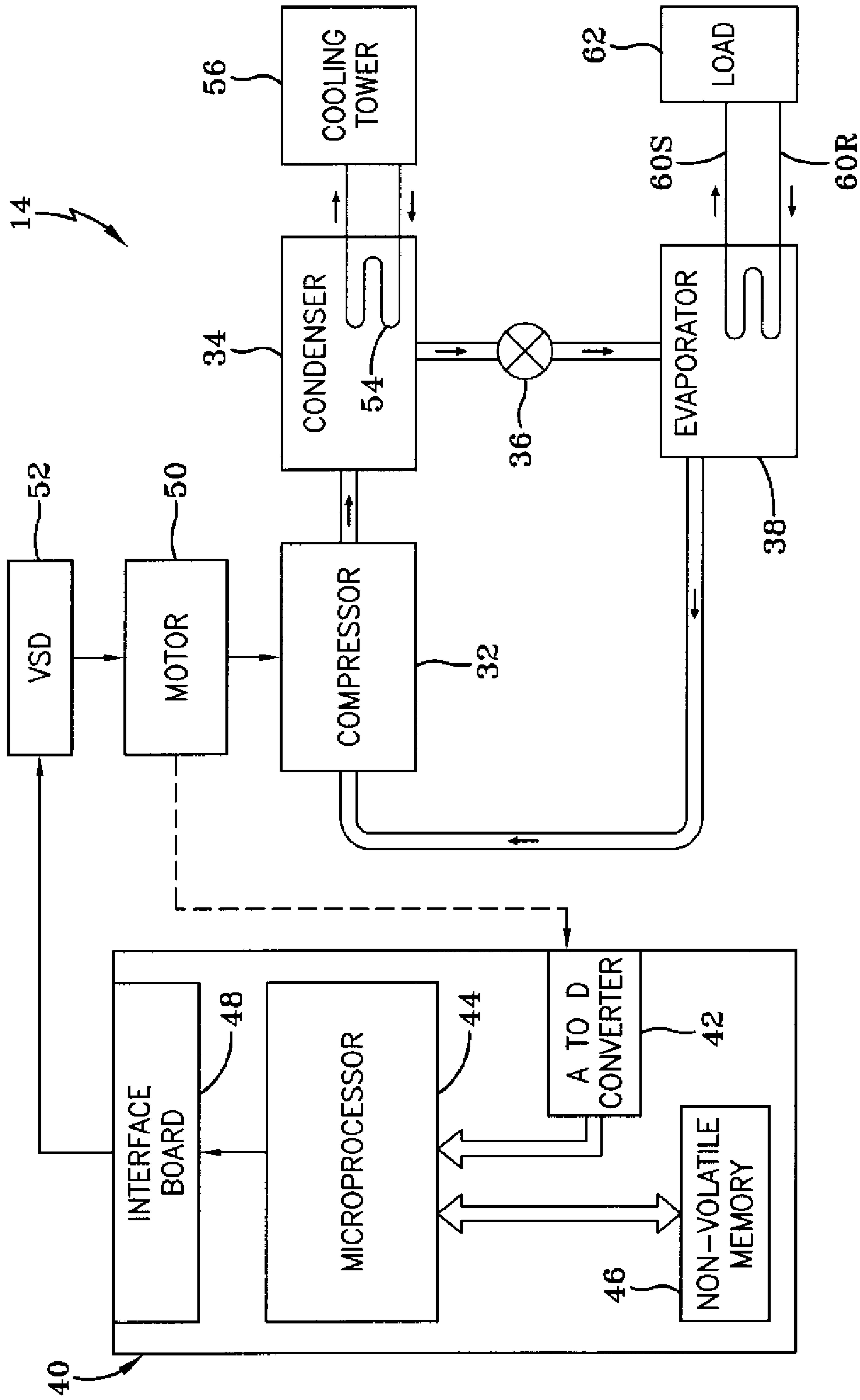

14
COOLING TOWER
56
LOAD
62
60S
60R
CONDENSER
34
54
36
EVAPORATOR
38
VSD
52
MOTOR
50
COMPRESSOR
32
INTERFACE BOARD
48
MICROPROCESSOR
44
A TO D CONVERTER
42
NON-VOLATILE MEMORY
46
40

FIG-3

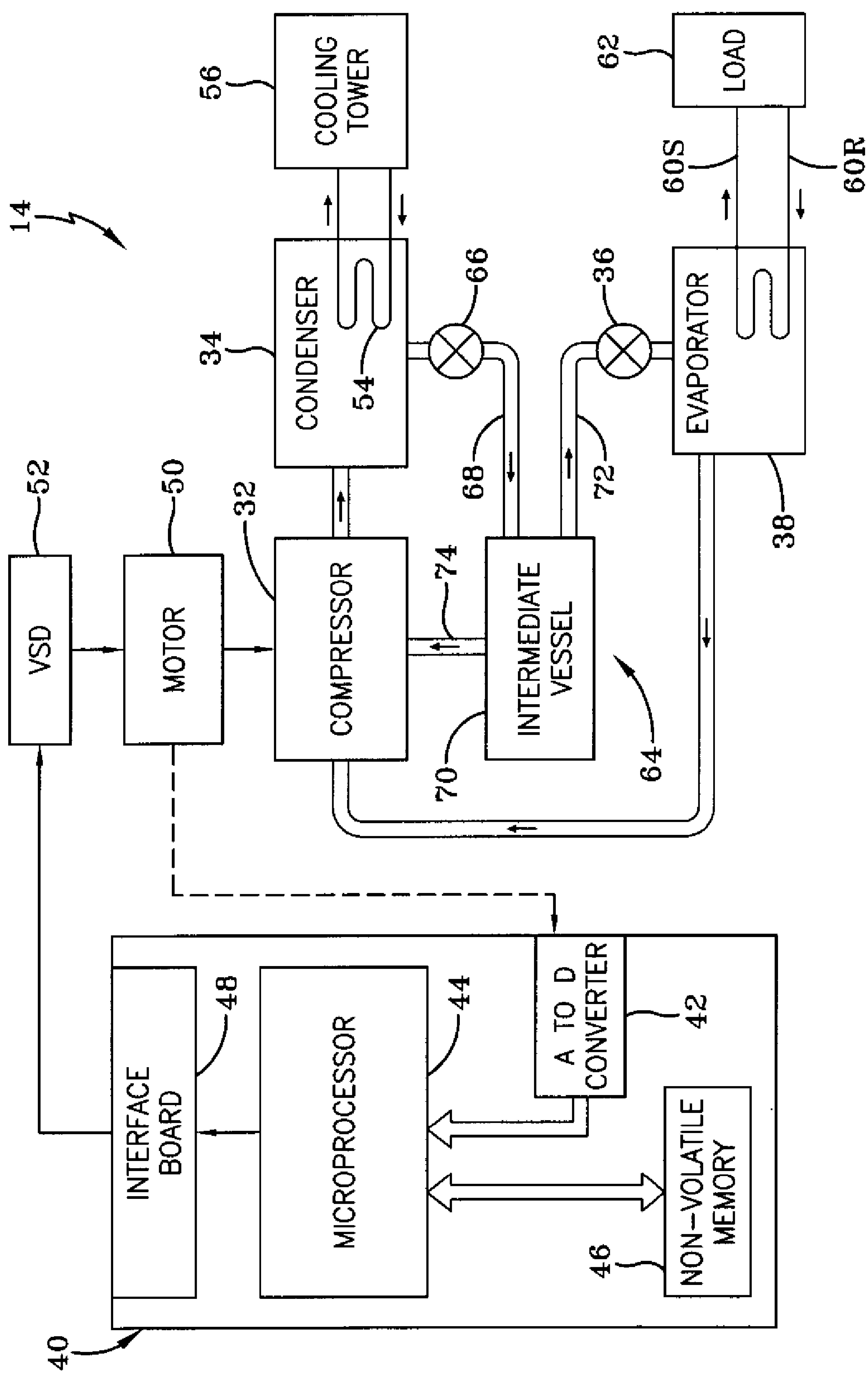
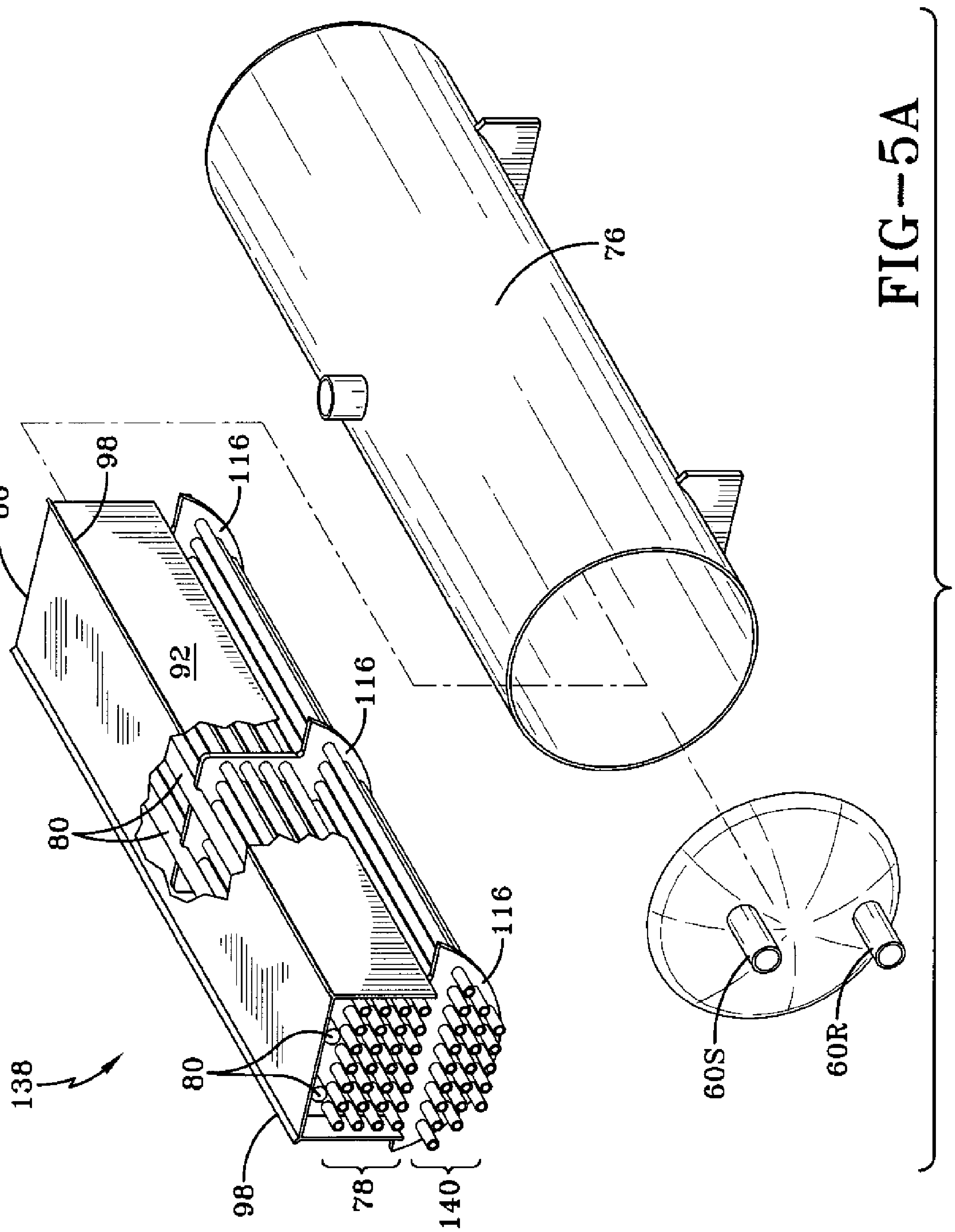
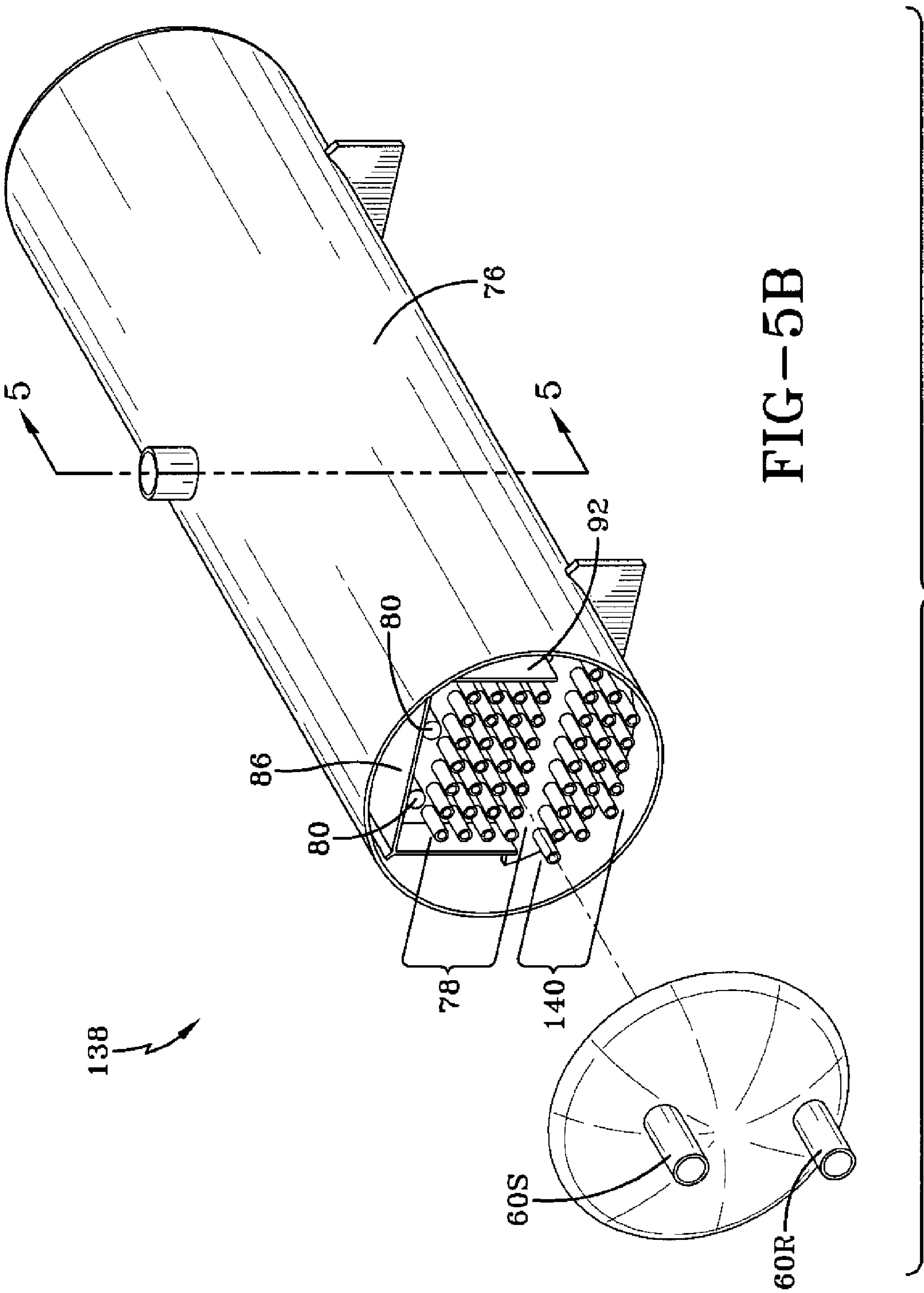

14
COOLING TOWER
56
LOAD
62
60S
60R
CONDENSER
34
54
66
36
EVAPORATOR
38
68
72
VSD
52
MOTOR
50
COMPRESSOR
32
74
INTERMEDIATE VESSEL
70
64
A TO D CONVERTER
42
INTERFACE BOARD
48
MICROPROCESSOR
44
NON-VOLATILE MEMORY
46
40

FIG-4



FIG—5A



FIG—5B

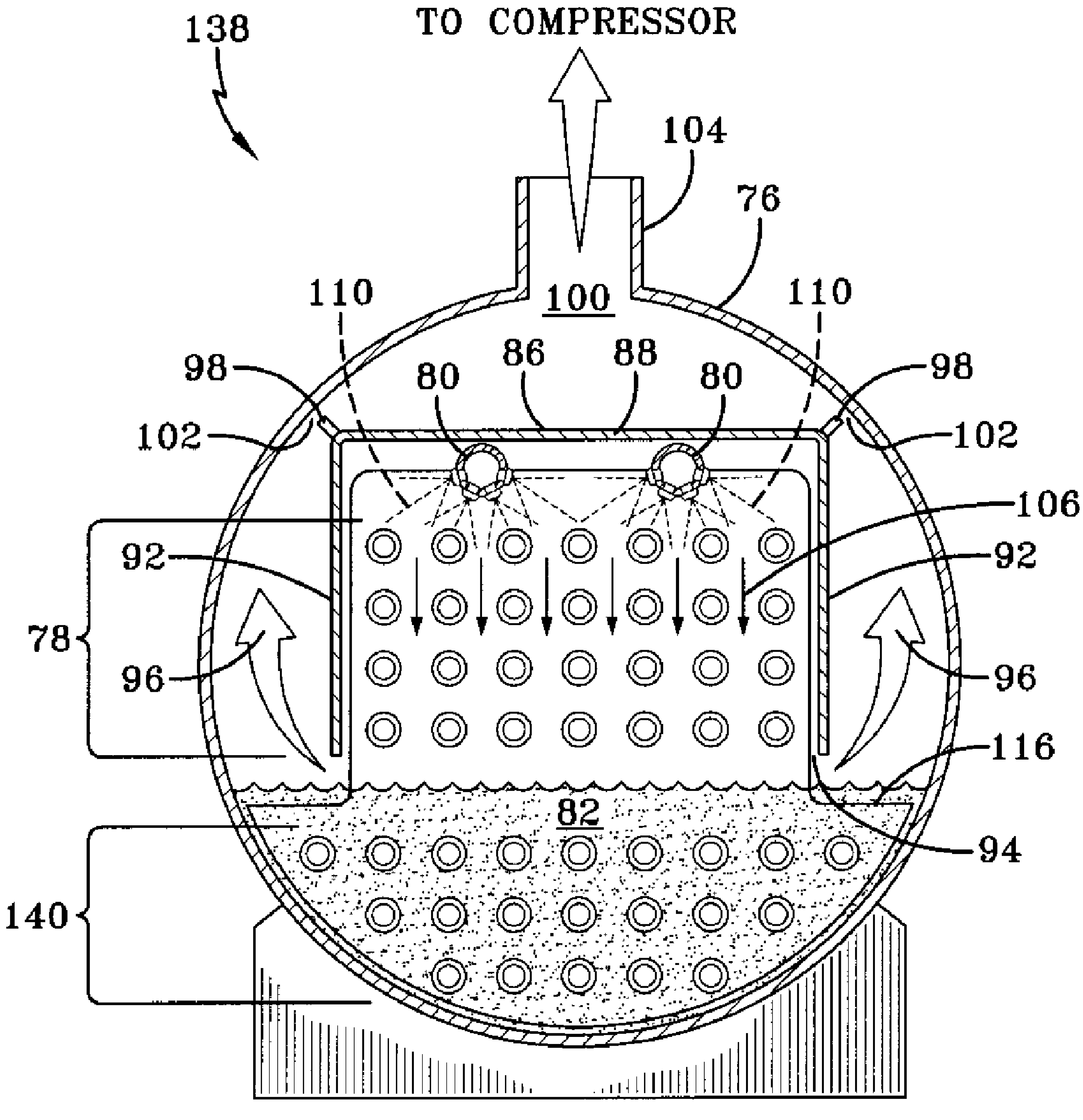
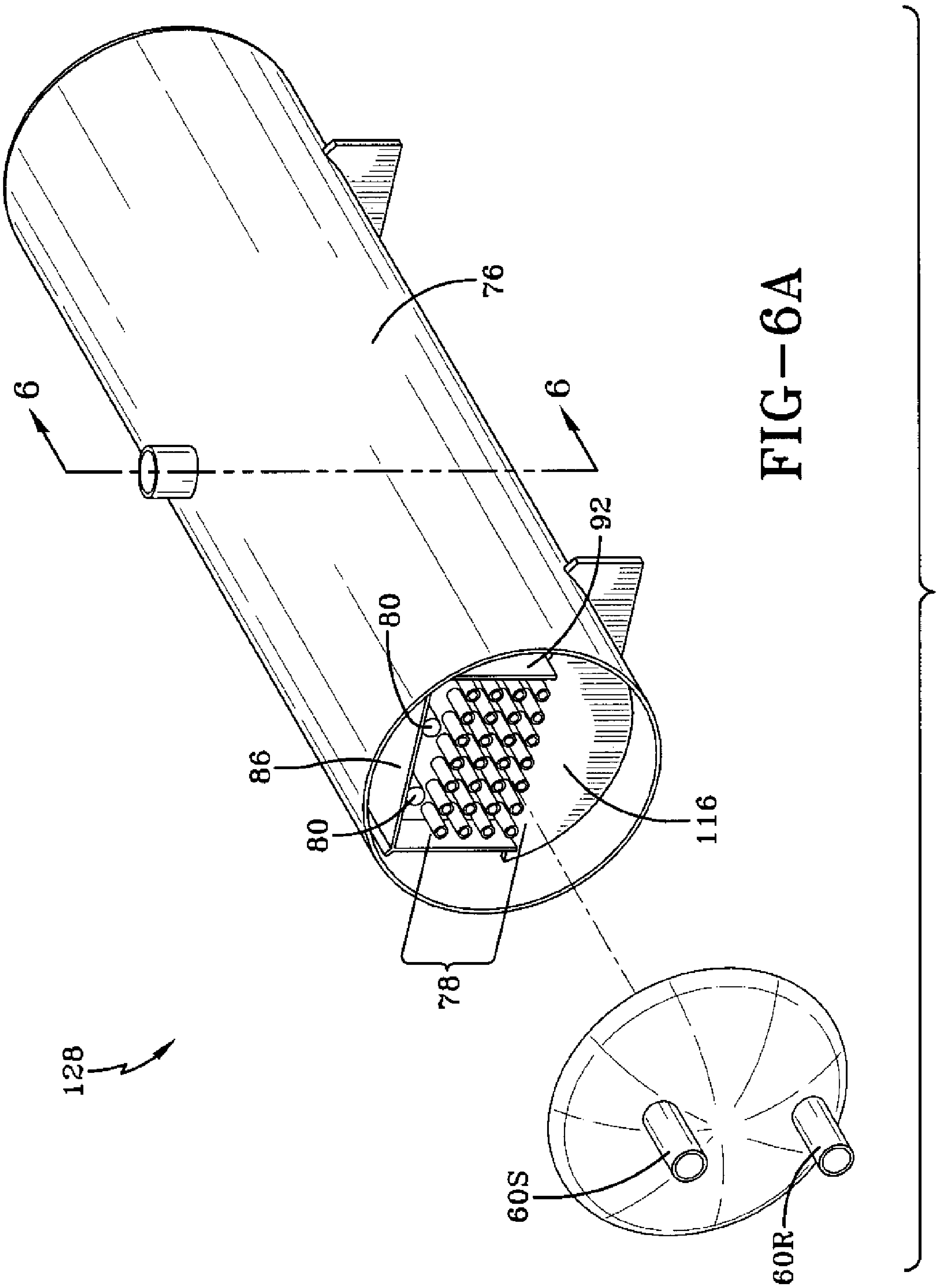

138
TO COMPRESSOR
104
76
110
100
110
98
86
88
98
80
80
102
102
106
92
92
78
96
96
116
82
94
140

FIG-5C



FIG—6A

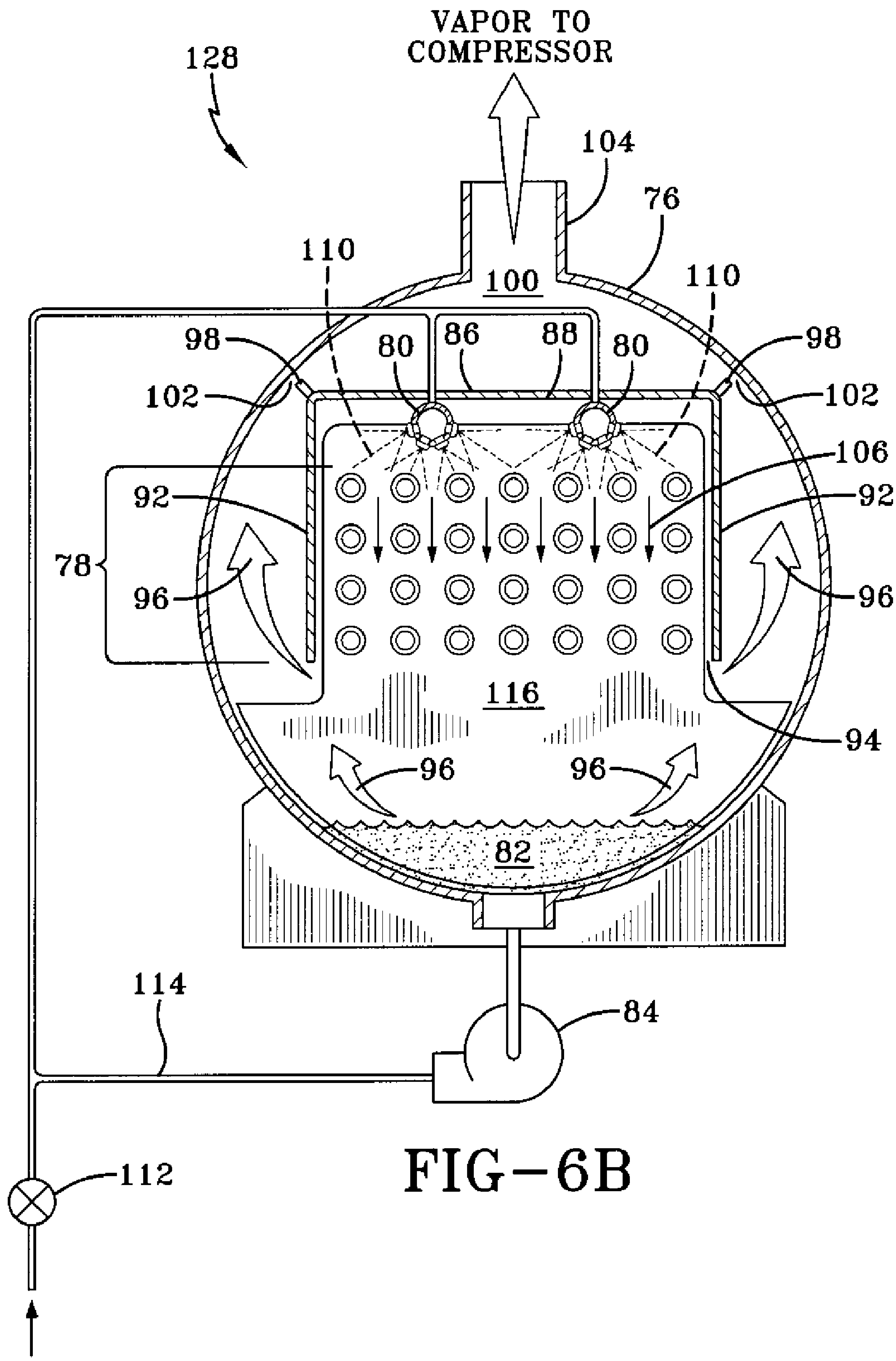
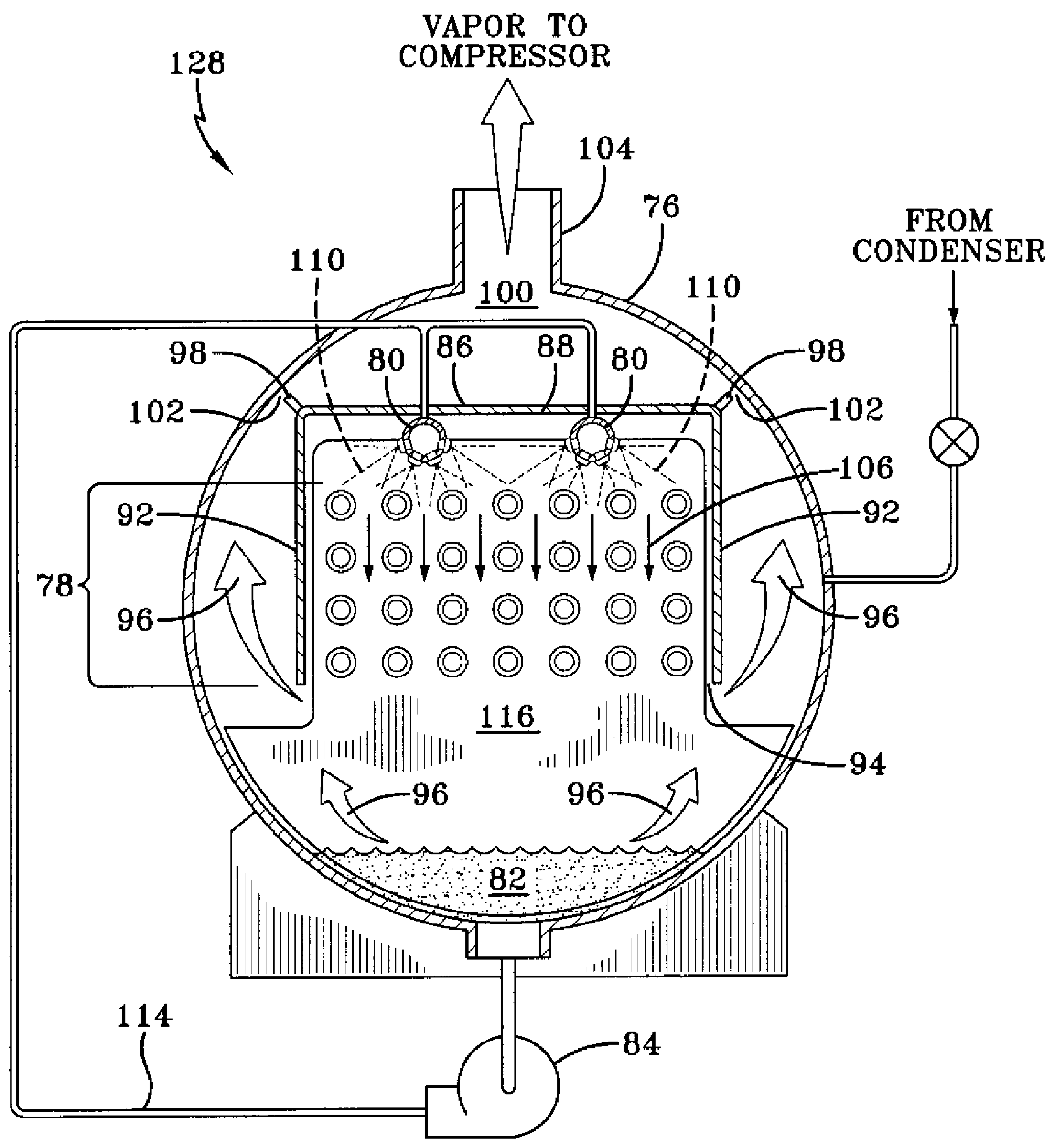

VAPOR TO
COMPRESSOR
128
104
76
110
100
110
98
86
88
80
80
98
102
102
106
92
92
78
96
96
116
94
96
96
82
114
84
112

FIG-6B


VAPOR TO
COMPRESSOR
128
104
76
FROM
CONDENSER
110
100
110
98
80
86
88
80
98
102
102
106
92
92
78
96
96
116
94
96
96
82
114
84

FIG–6C

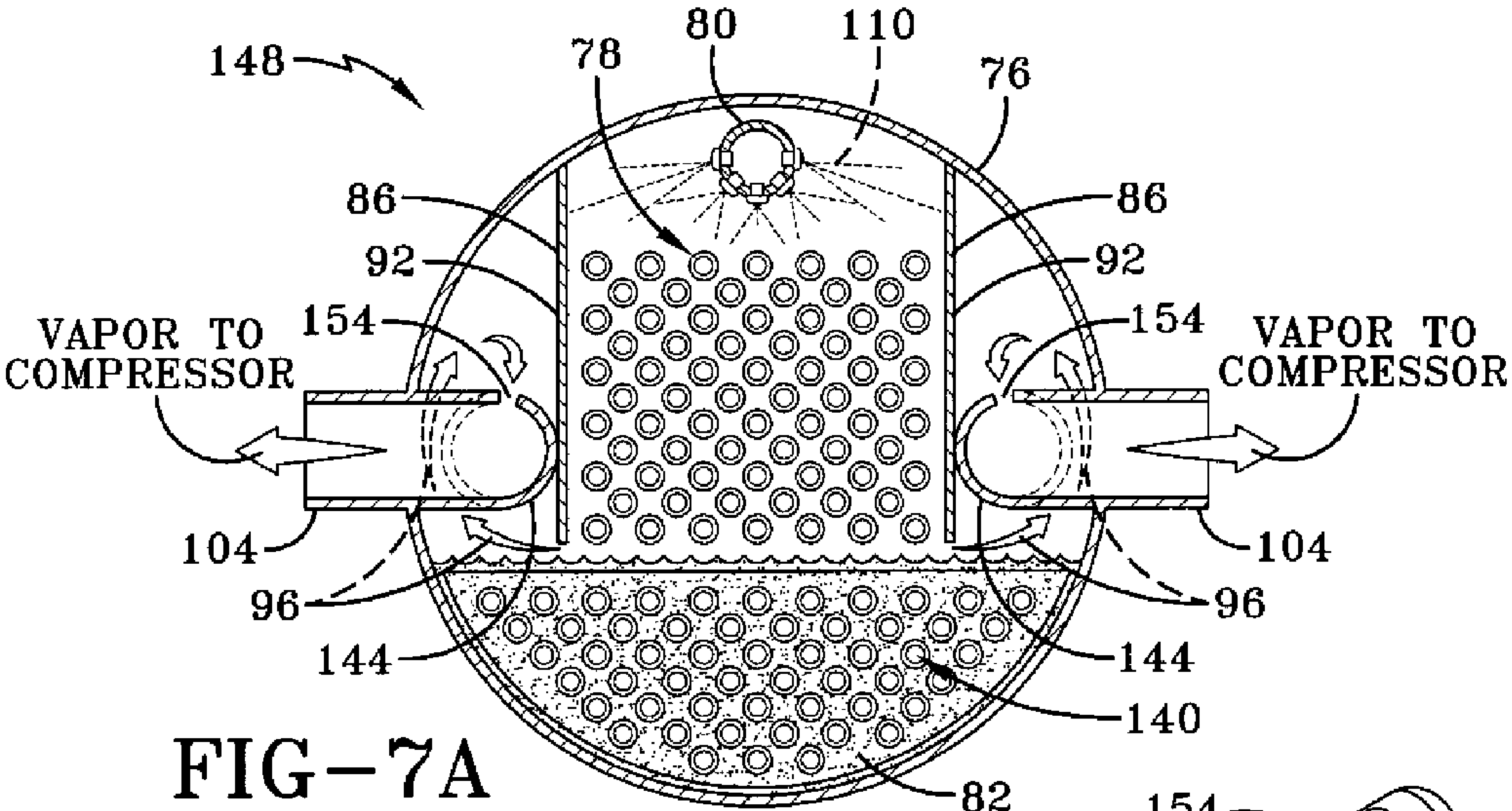


FIG-7A

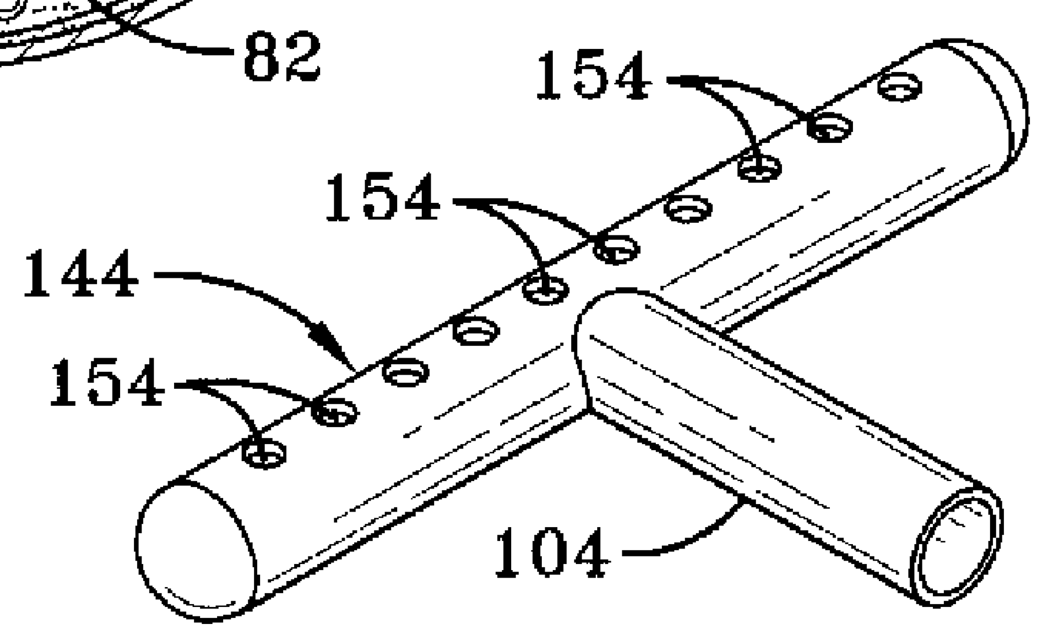


FIG-7B

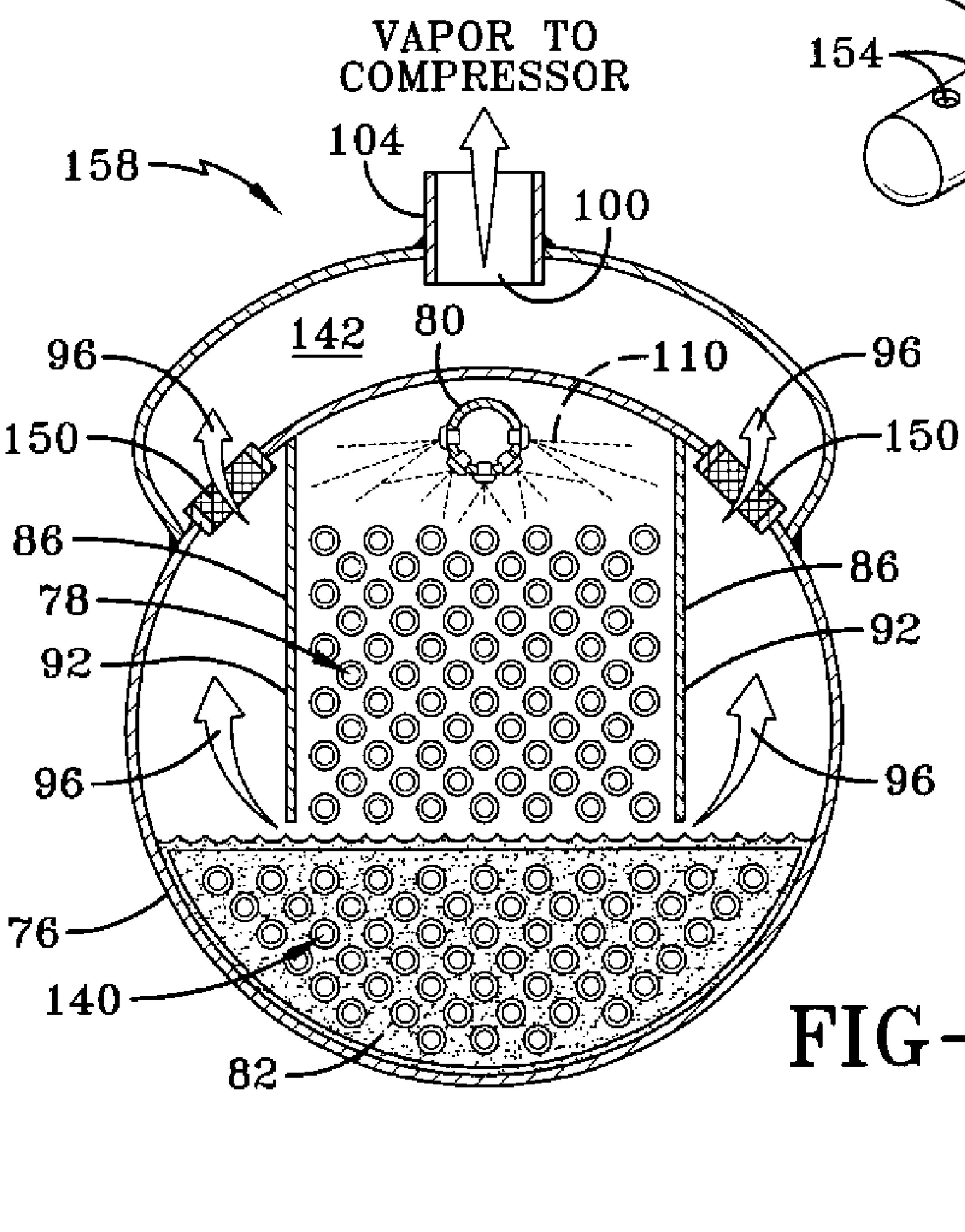


FIG-8

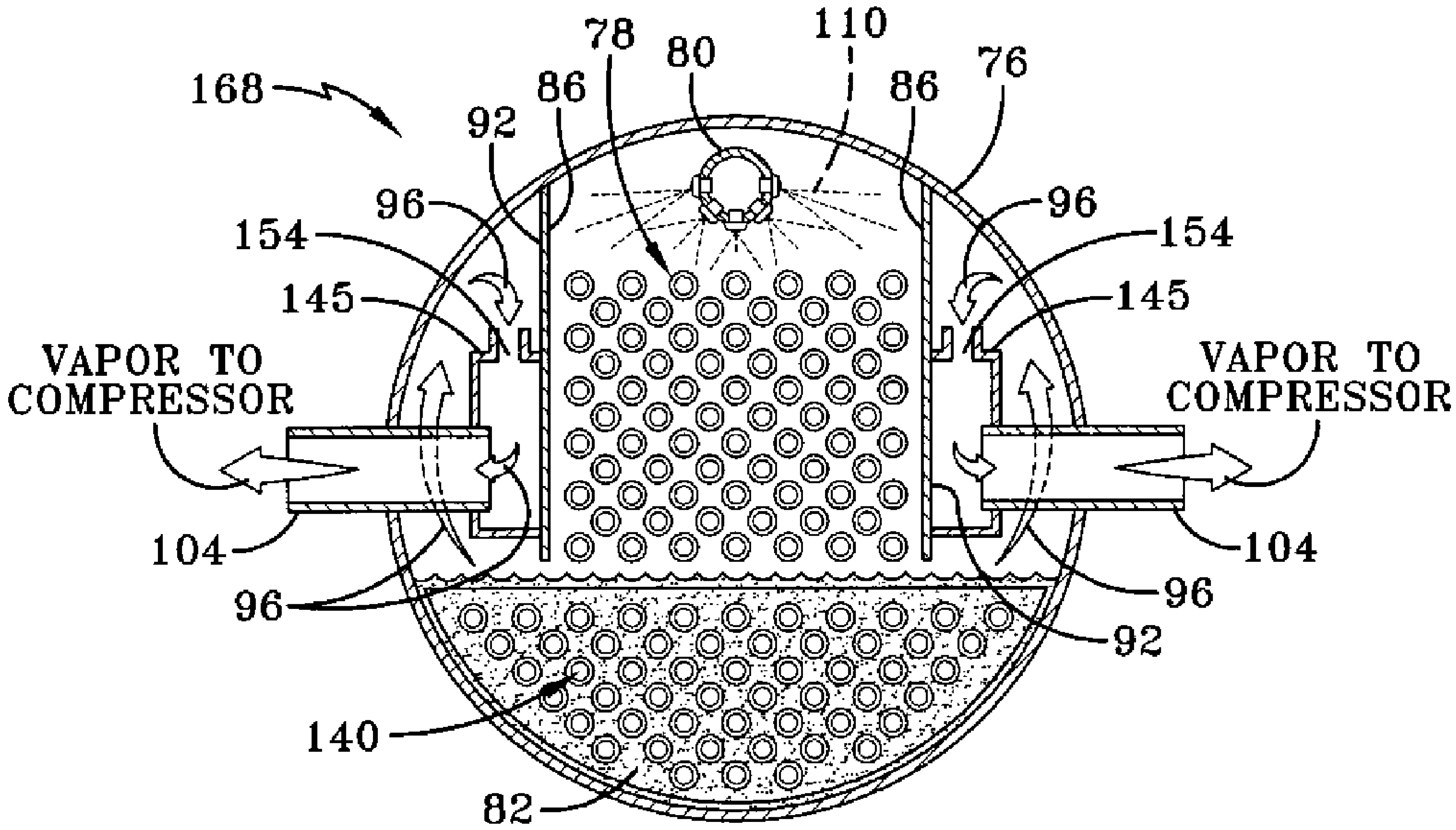

168
78
80
110
86
86
76
92
96
96
154
154
145
145
VAPOR TO COMPRESSOR
VAPOR TO COMPRESSOR
104
104
96
96
92
140
82

FIG-9

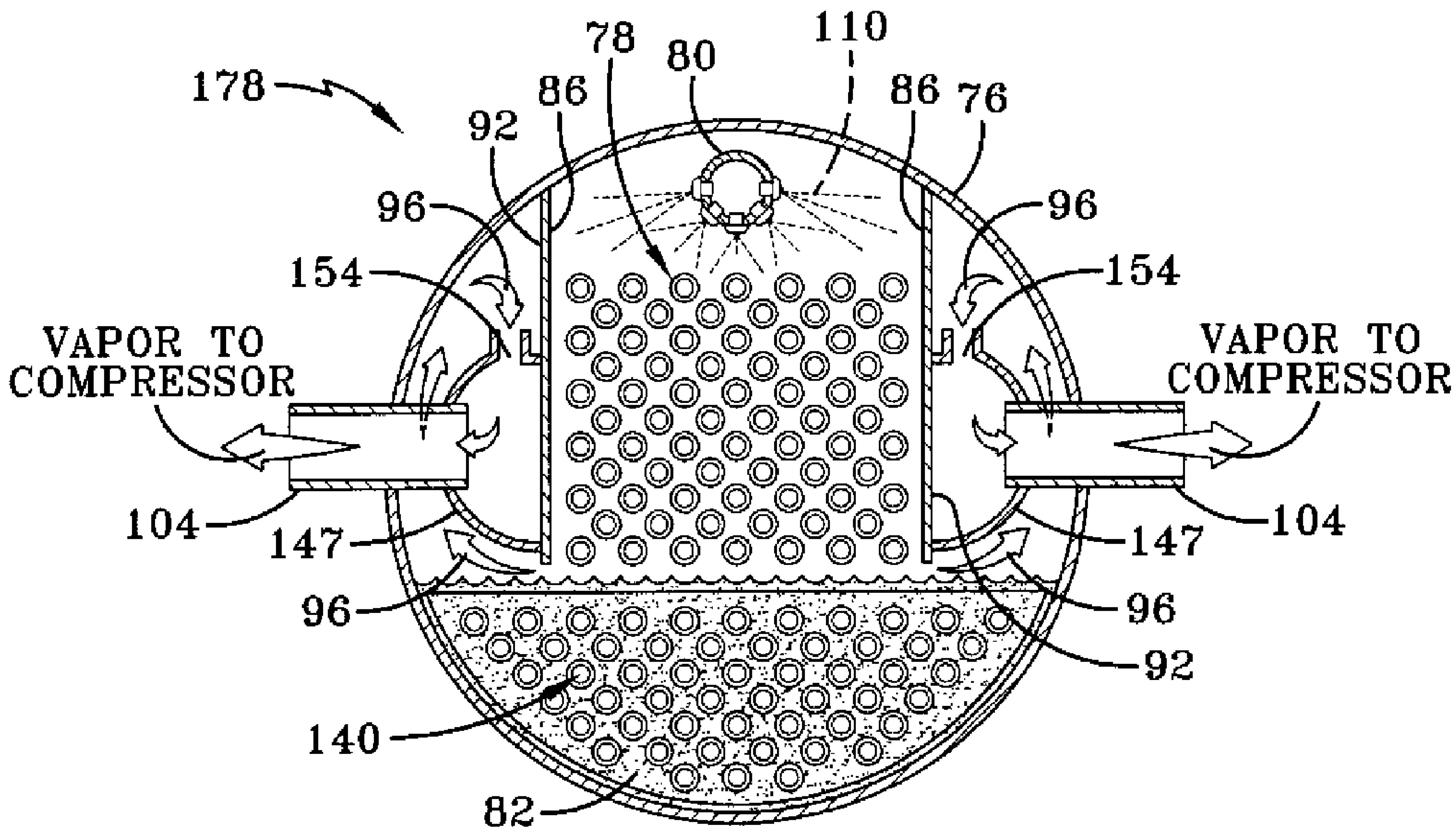

178
78
80
110
86
86
76
92
96
96
154
154
VAPOR TO COMPRESSOR
VAPOR TO COMPRESSOR
104
147
147
104
96
96
92
140
82

FIG-10

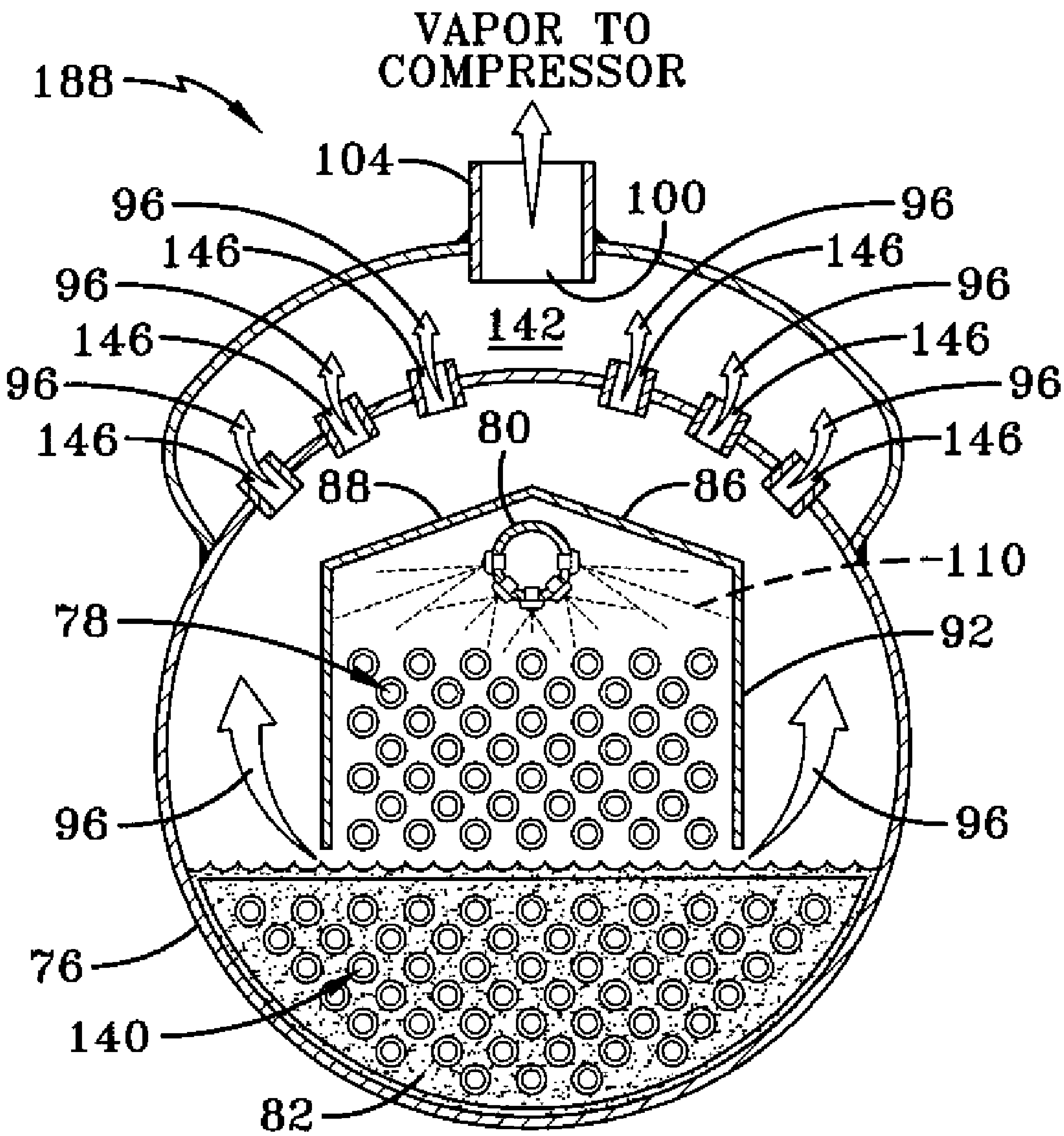

VAPOR TO COMPRESSOR
188
104
96
146
100
142
80
88
86
110
78
92
76
140
82

FIG-11

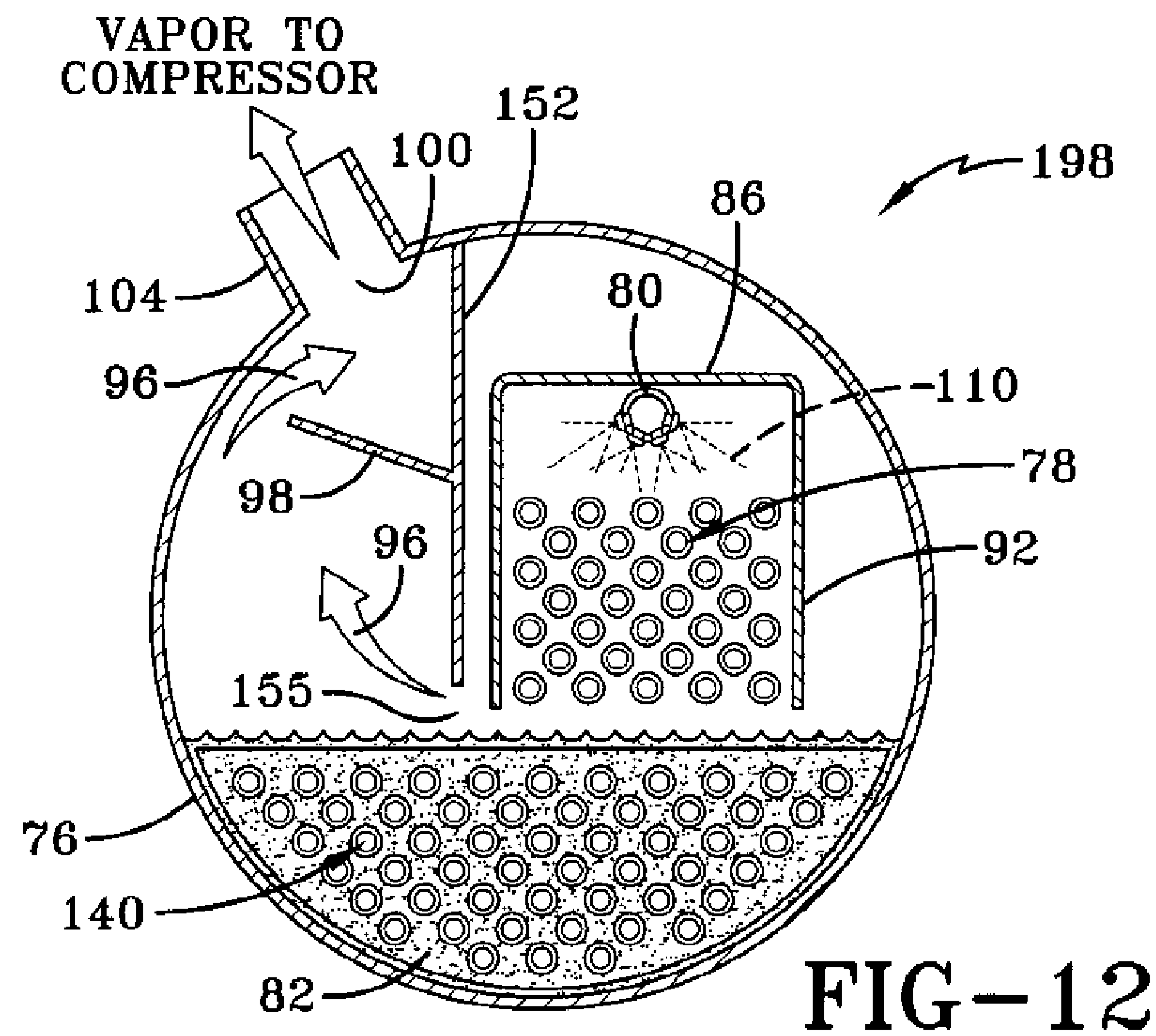

VAPOR TO
COMPRESSOR
152
100
198
86
104
80
110
96
78
98
92
96
155
76
140
82

FIG-12

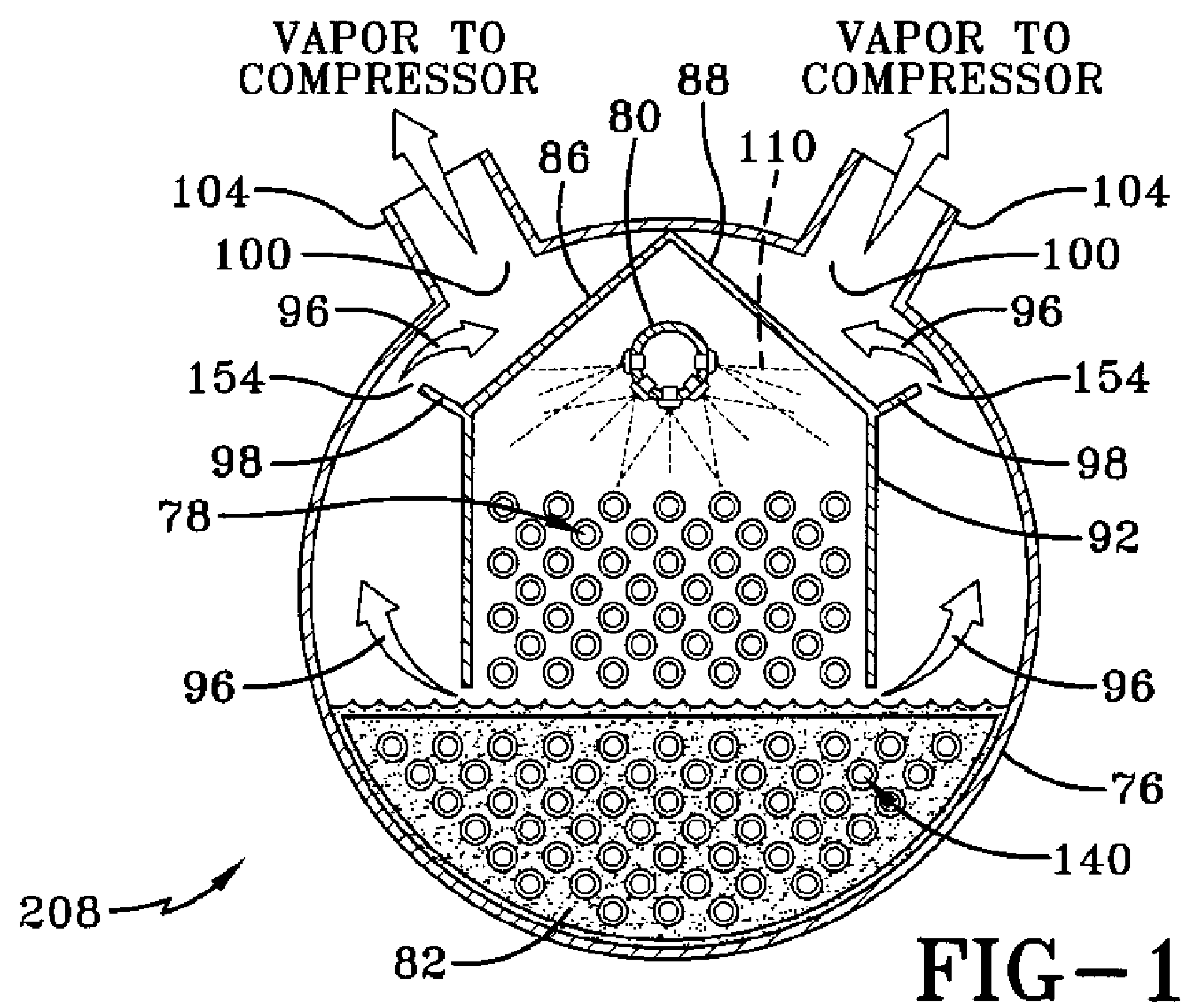

VAPOR TO
COMPRESSOR
VAPOR TO
COMPRESSOR
88
80
86
110
104
104
100
100
96
96
154
154
98
98
78
92
96
96
76
140
208
82

FIG-13

HEAT EXCHANGER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from and the benefit of U.S. Provisional Application No. 61/020,533, entitled FALLING FILM EVAPORATOR SYSTEMS, filed Jan. 11, 2008, which is hereby incorporated by reference.

BACKGROUND

[0002] The application relates generally to heat exchangers. The application relates more specifically to heat exchanger shell constructions.

[0003] Conventional chilled liquid systems used in heating, ventilation and air conditioning systems include an evaporator to effect a transfer of thermal energy between the refrigerant of the system and another liquid to be cooled. One type of evaporator includes a shell with a plurality of tubes forming a tube bundle(s) through which the liquid to be cooled is circulated. The refrigerant is brought into contact with the outer or exterior surfaces of the tube bundle inside the shell, resulting in a transfer of thermal energy between the liquid to be cooled and the refrigerant. For example, refrigerant can be deposited onto the exterior surfaces of the tube bundle by spraying or other similar techniques in what is commonly referred to as a "falling film" evaporator. In a further example, the exterior surfaces of the tube bundle can be fully or partially immersed in liquid refrigerant in what is commonly referred to as a "flooded" evaporator. In yet another example, a portion of the tube bundle can have refrigerant deposited on the exterior surfaces and another portion of the tube bundle can be immersed in liquid refrigerant in what is commonly referred to as a "hybrid falling film" evaporator.

[0004] As a result of the thermal energy transfer with the liquid, the refrigerant is heated and converted to a vapor state, which is then returned to a compressor where the vapor is compressed, to begin another refrigerant cycle. The cooled liquid can be circulated to a plurality of heat exchangers located throughout a building. Warmer air from the building is passed over the heat exchangers where the cooled liquid is warmed, while cooling the air for the building. The liquid warmed by the building air is returned to the evaporator to repeat the process.

SUMMARY

[0005] The present invention relates to a heat exchanger for use in a vapor compression system including a shell, a hood, a tube bundle, a distributor, and an enclosed passageway. The passageway includes an outlet configured to permit passage of vapor to a component of the vapor compression system, the hood is configured and positioned to cover the tube bundle and the distributor, the tube bundle extends substantially horizontally in the shell, the distributor is configured to apply a fluid to the tube bundle, and the enclosed passageway is configured and positioned to receive vapor from in the shell and provide a flow path for the vapor to the outlet.

[0006] The present invention also relates to a vapor compression system including a compressor, a condenser, an expansion device and an evaporator connected in a refrigerant line. The evaporator includes a shell, a hood, a tube bundle, a distributor, and a passageway. The shell includes an outlet configured to permit passage of vapor from the shell, the hood is configured and positioned to cover the tube bundle and the distributor, the tube bundle extends substantially horizontally in the shell, the distributor is configured to apply a fluid to the tube bundle, and the passageway is configured and positioned to receive vapor and provide a flow path for the vapor to the outlet.

[0007] The present invention also relates to a heat exchanger for use in a vapor compression system including a shell, a hood, a tube bundle, a distributor, a partition, and a chamber. The shell includes an outlet configured to permit passage of vapor from the shell, the hood is configured and positioned to cover the tube bundle and the distributor, the tube bundle extends substantially horizontally in the shell, the distributor is configured to apply a fluid to the tube bundle, the partition is configured and positioned to separate the hood and the chamber, and the chamber is in fluid communication with the outlet.

[0008] The present invention also relates to a heat exchanger for use in a vapor compression system including a shell, a hood, a tube bundle, and a distributor. The shell includes an outlet configured to permit passage of vapor from the shell, the hood extends from the shell and being configured and positioned to cover the tube bundle and the distributor, the tube bundle extends substantially horizontally in the shell, and the distributor is configured to apply a fluid to the tube bundle.

BRIEF DESCRIPTION OF THE FIGURES

[0009] FIG. **1** shows an exemplary embodiment for a heating, ventilation and air conditioning system.

[0010] FIG. **2** shows an isometric view of an exemplary vapor compression system.

[0011] FIGS. **3** and **4** schematically illustrate exemplary embodiments of the vapor compression system.

[0012] FIG. **5**A shows an exploded, partial cutaway view of an exemplary evaporator.

[0013] FIG. **5**B shows a top isometric view of the evaporator of FIG. **5**A.

[0014] FIG. **5**C shows a cross section of the evaporator taken along line **5-5** of FIG. **5**B.

[0015] FIG. **6**A shows a top isometric view of an exemplary evaporator.

[0016] FIGS. **6**B and **6**C show a cross section of the evaporator taken along line **6-6** of FIG. **6**A.

[0017] FIG. **7**A shows a cross section of an exemplary embodiment of an evaporator.

[0018] FIG. **7**B shows an isometric view of a manifold from the evaporator of FIG. **7**A.

[0019] FIGS. **8** through **13** show cross sections of exemplary embodiments of an evaporator.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0020] FIG. **1** shows an exemplary environment for a heating, ventilation and air conditioning (HVAC) system **10** incorporating a chilled liquid system in a building **12** for a typical commercial setting. System **10** can include a vapor compression system **14** that can supply a chilled liquid which may be used to cool building **12**. System **10** can include a boiler **16** to supply heated liquid that may be used to heat building **12**, and an air distribution system which circulates air through building **12**. The air distribution system can also include an air return duct **18**, an air supply duct **20** and an air handler **22**. Air handler **22** can include a heat exchanger that is connected to boiler **16** and vapor compression system **14** by conduits **24**. The heat exchanger in air handler **22** may receive either heated liquid from boiler **16** or chilled liquid from vapor compression system **14**, depending on the mode of operation of system **10**. System **10** is shown with a separate air handler on each floor of building **12**, but it is appreciated that the components may be shared between or among floors.

[0021] FIGS. **2** and **3** show an exemplary vapor compression system **14** that can be used in an HVAC system, such as HVAC system **10**. Vapor compression system **14** can circulate a refrigerant through a compressor **32** driven by a motor **50**, a condenser **34**, expansion device(s) **36**, and a liquid chiller or evaporator **38**. Vapor compression system **14** can also include a control panel **40** that can include an analog to digital (A/D) converter **42**, a microprocessor **44**, a non-volatile memory **46**, and an interface board **48**. Some examples of fluids that may be used as refrigerants in vapor compression system **14** are hydrofluorocarbon (HFC) based refrigerants, for example, R-410A, R-407, R-134a, hydrofluoro olefin (HFO), "natural" refrigerants like ammonia (NH_3), R-717, carbon dioxide (CO_2), R-744, or hydrocarbon based refrigerants, water vapor or any other suitable type of refrigerant. In an exemplary embodiment, vapor compression system **14** may use one or more of each of VSDs **52**, motors **50**, compressors **32**, condensers **34** and/or evaporators **38**.

[0022] Motor **50** used with compressor **32** can be powered by a variable speed drive (VSD) **52** or can be powered directly from an alternating current (AC) or direct current (DC) power source. VSD **52**, if used, receives AC power having a particular fixed line voltage and fixed line frequency from the AC power source and provides power having a variable voltage and frequency to motor **50**. Motor **50** can include any type of electric motor that can be powered by a VSD or directly from an AC or DC power source. For example, motor **50** can be a switched reluctance motor, an induction motor, an electronically commutated permanent magnet motor or any other suitable motor type. In an alternate exemplary embodiment, other drive mechanisms such as steam or gas turbines or engines and associated components can be used to drive compressor **32**.

[0023] Compressor **32** compresses a refrigerant vapor and delivers the vapor to condenser **34** through a discharge line. Compressor **32** can be a centrifugal compressor, screw compressor, reciprocating compressor, rotary compressor, swing link compressor, scroll compressor, turbine compressor, or any other suitable compressor. The refrigerant vapor delivered by compressor **32** to condenser **34** transfers heat to a fluid, for example, water or air. The refrigerant vapor condenses to a refrigerant liquid in condenser **34** as a result of the heat transfer with the fluid. The liquid refrigerant from condenser **34** flows through expansion device **36** to evaporator **38**. In the exemplary embodiment shown in FIG. **3**, condenser **34** is water cooled and includes a tube bundle **54** connected to a cooling tower **56**.

[0024] The liquid refrigerant delivered to evaporator **38** absorbs heat from another fluid, which may or may not be the same type of fluid used for condenser **34**, and undergoes a phase change to a refrigerant vapor. In the exemplary embodiment shown in FIG. **3**, evaporator **38** includes a tube bundle having a supply line **60**S and a return line **60**R connected to a cooling load **62**. A process fluid, for example, water, ethylene glycol, calcium chloride brine, sodium chloride brine, or any other suitable liquid, enters evaporator **38** via return line **60**R and exits evaporator **38** via supply line **60**S. Evaporator **38** chills the temperature of the process fluid in the tubes. The tube bundle in evaporator **38** can include a plurality of tubes and a plurality of tube bundles. The vapor refrigerant exits evaporator **38** and returns to compressor **32** by a suction line to complete the cycle.

[0025] FIG. **4**, which is similar to FIG. **3**, shows the refrigerant circuit with an intermediate circuit **64** that may be incorporated between condenser **34** and expansion device **36** to provide increased cooling capacity, efficiency and performance. Intermediate circuit **64** has an inlet line **68** that can be either connected directly to or can be in fluid communication with condenser **34**. As shown, inlet line **68** includes an expansion device **66** positioned upstream of an intermediate vessel **70**. Intermediate vessel **70** can be a flash tank, also referred to as a flash intercooler, in an exemplary embodiment. In an alternate exemplary embodiment, intermediate vessel **70** can be configured as a heat exchanger or a "surface economizer". In the flash intercooler arrangement, a first expansion device **66** operates to lower the pressure of the liquid received from condenser **34**. During the expansion process in a flash intercooler, a portion of the liquid is evaporated. Intermediate vessel **70** may be used to separate the evaporated vapor from the liquid received from the condenser. The evaporated liquid may be drawn by compressor **32** to a port at a pressure intermediate between suction and discharge or at an intermediate stage of compression, through a line **74**. The liquid that is not evaporated is cooled by the expansion process, and collects at the bottom of intermediate vessel **70**, where the liquid is recovered to flow to the evaporator **38**, through a line **72** comprising a second expansion device **36**.

[0026] In the "surface intercooler" arrangement, the implementation is slightly different, as known to those skilled in the art. Intermediate circuit **64** can operate in a similar matter to that described above, except that instead of receiving the entire amount of refrigerant from condenser **34**, as shown in FIG. **4**, intermediate circuit **64** receives only a portion of the refrigerant from condenser **34** and the remaining refrigerant proceeds directly to expansion device **36**.

[0027] FIGS. **5**A through **5**C show an exemplary embodiment of an evaporator configured as a "hybrid falling film" evaporator. As shown in FIGS. **5**A through **5**C, an evaporator **138** includes a substantially cylindrical shell **76** with a plurality of tubes forming a tube bundle **78** extending substantially horizontally along the length of shell **76**. At least one support **116** may be positioned inside shell **76** to support the plurality of tubes in tube bundle **78**. A suitable fluid, such as water, ethylene, ethylene glycol, or calcium chloride brine flows through the tubes of tube bundle **78**. A distributor **80** positioned above tube bundle **78** distributes, deposits or applies refrigerant **110** from a plurality of positions onto the tubes in tube bundle **78**. In one exemplary embodiment, the refrigerant deposited by distributor **80** can be entirely liquid refrigerant, although in another exemplary embodiment, the refrigerant deposited by distributor **80** can include both liquid refrigerant and vapor refrigerant.

[0028] Liquid refrigerant that flows around the tubes of tube bundle **78** without changing state collects in the lower portion of shell **76**. The collected liquid refrigerant can form a pool or reservoir of liquid refrigerant **82**. The deposition positions from distributor **80** can include any combination of longitudinal or lateral positions with respect to tube bundle **78**. In another exemplary embodiment, deposition positions from distributor **80** are not limited to ones that deposit onto the upper tubes of tube bundle **78**. Distributor **80** may include a plurality of nozzles supplied by a dispersion source of the refrigerant. In an exemplary embodiment, the dispersion source is a tube connecting a source of refrigerant, such as condenser **34**. Nozzles include spraying nozzles, but also include machined openings that can guide or direct refrigerant onto the surfaces of the tubes. The nozzles may apply refrigerant in a predetermined pattern, such as a jet pattern, so that the upper row of tubes of tube bundle **78** are covered. The tubes of tube bundle **78** can be arranged to promote the flow of refrigerant in the form of a film around the tube surfaces, the liquid refrigerant coalescing to form droplets or in some instances, a curtain or sheet of liquid refrigerant at the bottom of the tube surfaces. The resulting sheeting promotes wetting of the tube surfaces which enhances the heat transfer efficiency between the fluid flowing inside the tubes of tube bundle **78** and the refrigerant flowing around the surfaces of the tubes of tube bundle **78**.

[0029] In the pool of liquid refrigerant **82**, a tube bundle **140** can be immersed or at least partially immersed, to provide additional thermal energy transfer between the refrigerant and the process fluid to evaporate the pool of liquid refrigerant **82**. In an exemplary embodiment, tube bundle **78** can be positioned at least partially above (that is, at least partially overlying) tube bundle **140**. In one exemplary embodiment, evaporator **138** incorporates a two pass system, in which the process fluid that is to be cooled first flows inside the tubes of tube bundle **140** and then is directed to flow inside the tubes of tube bundle **78** in the opposite direction to the flow in tube bundle **140**. In the second pass of the two pass system, the temperature of the fluid flowing in tube bundle **78** is reduced, thus requiring a lesser amount of heat transfer with the refrigerant flowing over the surfaces of tube bundle **78** to obtain a desired temperature of the process fluid.

[0030] It is to be understood that although a two pass system is described in which the first pass is associated with tube bundle **140** and the second pass is associated with tube bundle **78**, other arrangements are contemplated. For example, evaporator **138** can incorporate a one pass system where the process fluid flows through both tube bundle **140** and tube bundle **78** in the same direction. Alternatively, evaporator **138** can incorporate a three pass system in which two passes are associated with tube bundle **140** and the remaining pass associated with tube bundle **78**, or in which one pass is associated with tube bundle **140** and the remaining two passes are associated with tube bundle **78**. Further, evaporator **138** can incorporate an alternate two pass system in which one pass is associated with both tube bundle **78** and tube bundle **140**, and the second pass is associated with both tube bundle **78** and tube bundle **140**. In one exemplary embodiment, tube bundle **78** is positioned at least partially above tube bundle **140**, with a gap separating tube bundle **78** from tube bundle **140**. In a further exemplary embodiment, hood **86** overlies tube bundle **78**, with hood **86** extending toward and terminating near the gap. In summary, any number of passes in which each pass can be associated with one or both of tube bundle **78** and tube bundle **140** is contemplated.

[0031] An enclosure or hood **86** is positioned over tube bundle **78** to substantially prevent cross flow, that is, a lateral flow of vapor refrigerant or liquid and vapor refrigerant **106** between the tubes of tube bundle **78**. Hood **86** is positioned over and laterally borders tubes of tube bundle **78**. Hood **86** includes an upper end **88** positioned near the upper portion of shell **76**. Distributor **80** can be positioned between hood **86** and tube bundle **78**. In yet a further exemplary embodiment, distributor **80** may be positioned near, but exterior of, hood **86**, so that distributor **80** is not positioned between hood **86** and tube bundle **78**. However, even though distributor **80** is not positioned between hood **86** and tube bundle **78**, the nozzles of distributor **80** are still configured to direct or apply refrigerant onto surfaces of the tubes. Upper end **88** of hood **86** is configured to substantially prevent the flow of applied refrigerant **110** and partially evaporated refrigerant, that is, liquid and/or vapor refrigerant **106** from flowing directly to outlet **104**. Instead, applied refrigerant **110** and refrigerant **106** are constrained by hood **86**, and, more specifically, are forced to travel downward between walls **92** before the refrigerant can exit through an open end **94** in the hood **86**. Flow of vapor refrigerant **96** around hood **86** also includes evaporated refrigerant flowing away from the pool of liquid refrigerant **82**.

[0032] It is to be understood that at least the above-identified, relative terms are non-limiting as to other exemplary embodiments in the disclosure. For example, hood **86** may be rotated with respect to the other evaporator components previously discussed, that is, hood **86**, including walls **92**, is not limited to a vertical orientation. Upon sufficient rotation of hood **86** about an axis substantially parallel to the tubes of tube bundle **78**, hood **86** may no longer be considered "positioned over" nor to "laterally border" tubes of tube bundle **78**. Similarly, "upper" end **88** of hood **86** may no longer be near "an upper portion" of shell **76**, and other exemplary embodiments are not limited to such an arrangement between the hood and the shell. In an exemplary embodiment, hood **86** terminates after covering tube bundle **78**, although in another exemplary embodiment, hood **86** further extends after covering tube bundle **78**.

[0033] After hood **86** forces refrigerant **106** downward between walls **92** and through open end **94**, the vapor refrigerant undergoes an abrupt change in direction before traveling in the space between shell **76** and walls **92** from the lower portion of shell **76** to the upper portion of shell **76**. Combined with the effect of gravity, the abrupt directional change in flow results in a proportion of any entrained droplets of refrigerant colliding with either liquid refrigerant **82** or shell **76**, thereby removing those droplets from the flow of vapor refrigerant **96**. Also, refrigerant mist traveling along the length of hood **86** between walls **92** is coalesced into larger drops that are more easily separated by gravity, or maintained sufficiently near or in contact with tube bundle **78**, to permit evaporation of the refrigerant mist by heat transfer with the tube bundle. As a result of the increased drop size, the efficiency of liquid separation by gravity is improved, permitting an increased upward velocity of vapor refrigerant **96** flowing through the evaporator in the space between walls **92** and shell **76**. Vapor refrigerant **96**, whether flowing from open end **94** or from the pool of liquid refrigerant **82**, flows over a pair of extensions **98** protruding from walls **92** near upper end **88** and into a channel **100**. Vapor refrigerant **96** enters into channel **100** through slots **102**, which is the space between the ends of extensions **98** and shell **76**, before exiting evaporator **138** at an outlet **104**. In another exemplary embodiment, vapor refrigerant **96** can enter into channel **100** through openings or apertures formed in extensions **98**, instead of slots **102**. In yet another exemplary embodiment, slots **102** can be formed by the space between hood **86** and shell **76**, that is, hood **86** does not include extensions **98**.

[0034] Stated another way, once refrigerant **106** exits from hood **86**, vapor refrigerant **96** then flows from the lower portion of shell **76** to the upper portion of shell **76** along the prescribed passageway. In an exemplary embodiment, the passageways can be substantially symmetric between the surfaces of hood **86** and shell **76** prior to reaching outlet **104**. In an exemplary embodiment, baffles, such as extensions **98** are provided near the evaporator outlet to prevent a direct path of vapor refrigerant **96** to the compressor inlet.

[0035] In one exemplary embodiment, hood **86** includes opposed substantially parallel walls **92**. In another exemplary embodiment, walls **92** can extend substantially vertically and terminate at open end **94**, that is located substantially opposite upper end **88**. Upper end **88** and walls **92** are closely positioned near the tubes of tube bundle **78**, with walls **92** extending toward the lower portion of shell **76** so as to substantially laterally border the tubes of tube bundle **78**. In an exemplary embodiment, walls **92** may be spaced between about 0.02 inch (0.5 mm) and about 0.8 inch (20 mm) from the tubes in tube bundle **78**. In a further exemplary embodiment, walls **92** may be spaced between about 0.1 inch (3 mm) and about 0.2 inch (5 mm) from the tubes in tube bundle **78**. However, spacing between upper end **88** and the tubes of tube bundle **78** may be significantly greater than 0.2 inch (5 mm), in order to provide sufficient spacing to position distributor **80** between the tubes and the upper end of the hood. In an exemplary embodiment in which walls **92** of hood **86** are substantially parallel and shell **76** is cylindrical, walls **92** may also be symmetric about a central vertical plane of symmetry of the shell bisecting the space separating walls **92**. In other exemplary embodiments, walls **92** need not extend vertically past the lower tubes of tube bundle **78**, nor do walls **92** need to be planar, as walls **92** may be curved or have other non-planar shapes. Regardless of the specific construction, hood **86** is configured to channel refrigerant **106** within the confines of walls **92** through open end **94** of hood **86**.

[0036] FIGS. **6**A through **6**C show an exemplary embodiment of an evaporator configured as a "falling film" evaporator **128**. As shown in FIGS. **6**A through **6**C, evaporator **128** is similar to evaporator **138** shown in FIGS. **5**A through **5**C, except that evaporator **128** does not include tube bundle **140** in the pool of refrigerant **82** that collects in the lower portion of the shell. In an exemplary embodiment, hood **86** terminates after covering tube bundle **78**, although in another exemplary embodiment, hood **86** further extends toward pool of refrigerant **82** after covering tube bundle **78**. In yet a further exemplary embodiment, hood **86** terminates so that the hood does not totally cover the tube bundle, that is, substantially covers the tube bundle.

[0037] As shown in FIGS. **6**B and **6**C, a pump **84** can be used to recirculate the pool of liquid refrigerant **82** from the lower portion of the shell **76** via line **114** to distributor **80**. As further shown in FIG. **6**B, line **114** can include a regulating device **112** that can be in fluid communication with a condenser (not shown). In another exemplary embodiment, an ejector (not shown) can be employed to draw liquid refrigerant **82** from the lower portion of shell **76** using the pressurized refrigerant from condenser **34**, which operates by virtue of the Bernoulli effect. The ejector combines the functions of a regulating device **112** and a pump **84**.

[0038] In an exemplary embodiment, one arrangement of tubes or tube bundles may be defined by a plurality of uniformly spaced tubes that are aligned vertically and horizontally, forming an outline that can be substantially rectangular. However, a stacking arrangement of tube bundles can be used where the tubes are neither vertically or horizontally aligned, as well as arrangements that are not uniformly spaced.

[0039] In another exemplary embodiment, different tube bundle constructions are contemplated. For example, finned tubes (not shown) can be used in a tube bundle, such as along the uppermost horizontal row or uppermost portion of the tube bundle. Besides the possibility of using finned tubes, tubes developed for more efficient operation for pool boiling applications, such as in "flooded" evaporators, may also be employed. Additionally, or in combination with the finned tubes, porous coatings can also be applied to the outer surface of the tubes of the tube bundles.

[0040] In a further exemplary embodiment, the cross-sectional profile of the evaporator shell may be non-circular.

[0041] In an exemplary embodiment, a portion of the hood may partially extend into the shell outlet.

[0042] In addition, it is possible to incorporate the expansion functionality of the expansion devices of system **14** into distributor **80**. In one exemplary embodiment, two expansion devices may be employed. One expansion device is exhibited in the spraying nozzles of distributor **80**. The other expansion device, for example, expansion device **36**, can provide a preliminary partial expansion of refrigerant, before that provided by the spraying nozzles positioned inside the evaporator. In an exemplary embodiment, the other expansion device, that is, the non-spraying nozzle expansion device, can be controlled by the level of liquid refrigerant **82** in the evaporator to account for variations in operating conditions, such as evaporating and condensing pressures, as well as partial cooling loads. In an alternative exemplary embodiment, expansion device can be controlled by the level of liquid refrigerant in the condenser, or in a further exemplary embodiment, a "flash economizer" vessel. In one exemplary embodiment, the majority of the expansion can occur in the nozzles, providing a greater pressure difference, while simultaneously permitting the nozzles to be of reduced size, therefore reducing the size and cost of the nozzles.

[0043] FIGS. **7**A through **13** show exemplary embodiments of evaporators for use in a vapor compression system. As shown, the evaporators include shell **76**, hood **86**, tube bundle **78**, distributor **80**, outlet **104**, and one or more passageways for vapor flow from the evaporator. In exemplary embodiments, shell **76**, hood **86**, tube bundle **78**, distributor **80**, and outlet(s) **104** may be similar to the corresponding components in evaporator **128** of FIGS. **5**A through **5**C and/or evaporator **138** of FIGS. **6**A through **6**C.

[0044] FIG. **7**A shows an exemplary embodiment of an evaporator **148**. Evaporator **148** includes a pair of manifolds **144** configured to receive vapor refrigerant **96** through apertures **154** and provide vapor refrigerant **96** to outlet(s) **104**. In another exemplary embodiment, only one manifold **144** may be used in evaporator **148**. In yet another exemplary embodiment, multiple manifolds may be positioned on one side of hood **86**. Manifolds **144** can be positioned near walls **92** of hood **86**. Each manifold **144** can extend along the length of hood **86**. Outlet **104** can be connected to manifold **144** at any suitable location along manifold **144**. Walls **92** and shell **76** can form hood **86**. In an exemplary embodiment, hood **86** may be formed by one or more partitions extending from shell **76**, with the partitions forming walls **92** of hood **86**. In another exemplary embodiment, an upper portion of hood may extend from one wall **92** of hood **86** to the other wall **92** of hood **86** while abutting shell **76**. Referring to FIGS. **7**A and **7**B, vapor refrigerant **96** flows from hood **86** and liquid refrigerant **82**

around manifold **144** and into apertures **154** after a change in direction of vapor refrigerant **96**.

[0045] In an exemplary embodiment, protrusions (not shown) can be used to assist with the change of direction of vapor refrigerant **96** prior to vapor refrigerant **96** entering apertures **154** in manifold **144**. In an exemplary embodiment, the protrusion(s) may protrude from hood **86**, although in another exemplary embodiment, the protrusion(s) may extend from shell **76** toward hood **86**. The protrusion(s) may create a flow path that may increase the amount of entrained liquid removed from vapor refrigerant **96** prior to vapor refrigerant **96** reaching outlet **104**.

[0046] Referring to FIGS. 7A and 7B, in an exemplary embodiment, selectively sized and spaced apertures **154** may be positioned along manifold(s) **144**, including apertures **154**, extending from near outlet **104** along hood **86**. The varying size and spacing of apertures **154** may permit a more consistent flow of refrigerant **96** to outlet **104** by controlling the pressure of vapor refrigerant **96** provided to apertures **154**. In an exemplary embodiment, flow of vapor refrigerant **96** to outlets **104** may be configured to reduce the velocity of vapor refrigerant **96** flowing toward compressor **32**. In another exemplary embodiment, aperture **154** is positioned to further create a flow path for refrigerant **96**. For example, aperture **154** may be positioned with protrusion **98** partially obstructing the flow path to aperture **154**. Manifold **144** may have a substantially cylindrical geometry as depicted in FIG. 7B, a substantially cuboid geometry, a partially curved geometry, or any suitable geometry. In a further exemplary embodiment, manifold **144** may have a non-uniform cross-sectional area extending along hood **86**.

[0047] FIG. **9** shows an exemplary embodiment of an evaporator **168**. Evaporator **168** includes a pair of manifolds **145** configured to receive vapor refrigerant **96** through apertures **154** and provide vapor refrigerant **96** to outlet(s) **104**. Manifolds **145** can be positioned near walls **92** of hood **86** and can be substantially rectilinear. Each manifold **145** can extend along the length of hood **86**. Outlet **104** can be connected to manifold **145** at any suitable location along manifold **145**. Walls **92** and shell **76** can form hood **86**. In an exemplary embodiment, hood **86** may be formed by one or more partitions extending from shell **76**, with the partitions forming walls **92** of hood **86**. In another exemplary embodiment, an upper portion of hood may extend from one wall **92** of hood **86** to the other wall **92** of hood **86** while abutting shell **76**. Vapor refrigerant **96** flows from hood **86** and pool of liquid refrigerant **82** around manifold **145** and into apertures **154**. In another exemplary embodiment, only one manifold **145** may be used in evaporator **168**. Manifold **145** can be partially formed by wall **92** of hood **86**. In an exemplary embodiment, manifold **145** may be attached to wall **92** of hood **86**. Aperture **154** of manifold **145** can form a channel extending along manifold **145**. The channel can be of varying size and location on manifold **145** to permit more consistent flow of vapor refrigerant **96** by maintaining a substantially constant pressure along the manifold.

[0048] FIG. **10** shows an exemplary embodiment of an evaporator **178**. Evaporator **178** includes a pair of manifolds **147** configured to receive vapor refrigerant **96** through apertures **154** and provide vapor refrigerant **96** to outlet(s) **104**. Manifolds **147** can be positioned near walls **92** of hood **86** and can be substantially curved. Each manifold **147** can extend along the length of hood **86**. Outlet **104** can be connected to manifold **147** at any suitable location along manifold **147**. Walls **92** and shell **76** can form hood **86**. In an exemplary embodiment, hood **86** may be formed by one or more partitions extending from shell **76**, with the partitions forming walls **92** of hood **86**. In another exemplary embodiment, an upper portion of hood may extend from one wall **92** of hood **86** to the other wall **92** of hood **86** while abutting shell **76**. Vapor refrigerant **96** flows from hood **86** and pool of liquid refrigerant **82** around manifold **147** and into apertures **154**. In another exemplary embodiment, only one manifold **147** may be used in evaporator **178**. Manifold **147** can be partially formed by wall **92** of hood **86**. In an exemplary embodiment, manifold **147** may be attached to wall **92** of hood **86**. Aperture **154** of manifold **147** can be a channel extending along manifold **147**. The channel can be of varying size and location on manifold **147** to permit more consistent flow of vapor refrigerant **96** by maintaining a substantially constant pressure along the manifold.

[0049] FIG. **12** shows an exemplary embodiment of an evaporator **198**. Evaporator **198** includes a protrusion **98** to assist in the removal of liquid refrigerant droplets entrained within vapor refrigerant **96**, with a partition **152** and shell **76** forming a passageway for vapor refrigerant **96**. Vapor refrigerant **96** flows to outlet **104** from hood **86** and pool of liquid refrigerant **82** through a gap **155** and around and/or along partition **152** and/or protrusion **98** before reaching outlet **104**. Protrusion **98** can be positioned on partition **152**. In an exemplary embodiment, protrusion **98** can be positioned on hood **86**, when a wall of hood **86** replaces partition **152**. In another exemplary embodiment, protrusion **98** can be positioned on shell **76**. In another exemplary embodiment, hood **86** may be omitted and the hood may be formed by the partition extending from the shell. In a further exemplary embodiment, hood **86** may be omitted and the hood may be formed by two partitions extending from the shell, the partitions being positioned on opposing sides of the distributor. In other exemplary embodiments, the components of the evaporator can be asymmetrically formed corresponding to one or more walls **92** of hood **86**. In an exemplary embodiment, the partition may extend substantially vertically.

[0050] FIG. **13** shows an exemplary embodiment of an evaporator **208**. Evaporator **208** includes upper end **88** of hood **86** extending to shell **76**. Evaporator **208** includes protrusion **98** extending from hood **86** and forming a flow path of vapor refrigerant **96**. Vapor refrigerant **96** flows from hood **86** and pool of liquid refrigerant **82** around and/or along protrusion **98** and through opening **154**. In an exemplary embodiment, protrusion **98** is positioned on shell **76**. In another exemplary embodiment, upper end **88** of hood **86** may extend toward outlet **104**, thereby permitting a smaller size of evaporator **208**. For example, when outlet **104** is positioned substantially at the top of evaporator **208**, upper end **88** of hood **86** may extend such that the very top of upper end **88** of hood **86** extends toward outlet **104**. That is, in one exemplary embodiment, upper end **88** of hood **86** may extend toward the outlet and be substantially flush with the inner surface of the shell.

[0051] FIG. **8** shows an exemplary embodiment of an evaporator **158**. Evaporator **158** includes a chamber **142** configured to receive vapor refrigerant **96** through one or more openings having filter **150**, such as eliminators or liquid-vapor separators. Vapor refrigerant **96** can then flow through chamber **142** to outlet(s) **104**. Chamber **142** can be positioned on the top of shell **76** to reduce the size of shell **76**. Outlet **104** can be connected to chamber **142** at any suitable location along chamber **142**. Walls **92** and shell **76** can form hood **86**. In an exemplary embodiment, hood **86** may be formed by one or more partitions extending from shell **76**, with the partitions forming walls **92** of hood **86**. In another exemplary embodiment, an upper portion of hood may extend from one wall **92** of hood **86** to the other wall **92** of hood **86** while abutting shell **76**. Vapor refrigerant **96**, including evaporated refrigerant from liquid refrigerant **82**, flows in a passageway positioned between shell **76** and hood **86** from the hood around walls **92** of hood **86** through filters **150** into chamber **142** and into outlet(s) **104**. In an exemplary embodiment, evaporator **158** can include protrusion **98** extending from hood **86**. In an exemplary embodiment, the passageway for vapor refrigerant **96** flow may include chamber aperture(s) **146** (see FIG. **11**), filter(s) **150**, or a combination. In an exemplary embodiment, chamber **142** can be formed in the shell.

[0052] FIG. **11** shows an exemplary embodiment of an evaporator **188**. Evaporator **188** includes a chamber **142** configured to receive vapor refrigerant **96** through one or more chamber apertures **146**. Vapor refrigerant **96** can then flow through chamber **142** to outlet(s) **104**. Chamber **142** can be positioned on the top of shell **76** to reduce the size of shell **76**. Outlet **104** can be connected to chamber **142** at any suitable location along chamber **142**. Vapor refrigerant **96**, including evaporated refrigerant from liquid refrigerant **82**, flows in a passageway positioned between shell **76** and hood **86** from the hood around walls **92** of hood **86** through apertures **146** into chamber **142** and into outlet(s) **104**. In an exemplary embodiment, evaporator **188** can include protrusion **98** extending from hood **86**. In an exemplary embodiment, the passageway for vapor refrigerant **96** flow may include chamber aperture(s) **146**, filter(s) **150** (see FIG. **8**), or a combination. In an exemplary embodiment, chamber **142** can be formed in the shell.

[0053] While only certain features and embodiments of the invention have been shown and described, many modifications and changes may occur to those skilled in the art (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters (e.g., temperatures, pressures, etc.), mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter recited in the claims. The order or sequence of any process or method steps may be varied or re-sequenced according to alternative embodiments. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention. Furthermore, in an effort to provide a concise description of the exemplary embodiments, all features of an actual implementation may not have been described (i.e., those unrelated to the presently contemplated best mode of carrying out the invention, or those unrelated to enabling the claimed invention). It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation specific decisions may be made. Such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure, without undue experimentation.

1. (canceled)

2. (canceled)

3. (canceled)

4. (canceled)

5. (canceled)

6. (canceled)

7. (canceled)

8. (canceled)

9. (canceled)

10. (canceled)

11. (canceled)

12. (canceled)

13. (canceled)

14. (canceled)

15. (canceled)

16. (canceled)

17. (canceled)

18. (canceled)

19. (canceled)

20. (canceled)

21. (canceled)

22. A heat exchanger for use in a vapor compression system comprising:

a shell;

a hood;

a first tube bundle;

a distributor;

a partition; and

a chamber;

the shell comprising an outlet configured to permit passage of vapor from the shell;

the hood being configured and positioned to overlie the first tube bundle and the distributor and substantially laterally surround substantially all tubes of the first tube bundle;

the first tube bundle extending substantially horizontally in the shell;

the distributor being configured to apply a fluid to the first tube bundle;

the partition being configured and positioned to separate the hood and the chamber; and

the chamber being in fluid communication with the outlet.

23. The heat exchanger of claim **22**, wherein the partition comprises a portion of the hood.

24. The heat exchanger of claim **22**, further comprising a protrusion, the protrusion extending from the partition to disturb vapor flow in the chamber.

25. The heat exchanger of claim **24**, wherein the protrusion extends from the shell.

26. The heat exchanger of claim **22**, wherein the partition extends substantially vertically within the shell.

27. The heat exchanger of claim **22**, further comprising:

a second tube bundle configured to operate at least partially in at least an immersed mode in a continuous liquid mass; and

wherein the first tube bundle is at least partially above the second tube bundle;

wherein the hood terminates after covering the first tube bundle.

28. A heat exchanger for use in a vapor compression system comprising:

a shell;

a hood;

a first tube bundle;

a distributor; and

the shell comprising an outlet configured to permit passage of vapor from the shell;

the hood being configured and positioned to overlie the first tube bundle and the distributor and substantially laterally surround substantially all tubes of the first tube bundle;
the first tube bundle extending substantially horizontally in the shell; and
the distributor being configured to apply a fluid to the first tube bundle.

29. The heat exchanger of claim **28**, further comprising a protrusion extending from the shell.

30. The heat exchanger of claim **28**, further comprising a protrusion extending from the hood.

31. The heat exchanger of claim **28**, further comprising:
a second tube bundle configured to operate at least partially in at least an immersed mode in a continuous liquid mass; and
wherein the first tube bundle is at least partially above the second tube bundle;
wherein the hood terminates after covering the first tube bundle.

32. The heat exchanger of claim **22**, wherein the hood is formed by the partition and a second partition extending from the shell.

33. The heat exchanger of claim **32**, wherein the partition and the second partition are positioned on opposing sides of the distributor.

34. The heat exchanger of claim **32**, wherein the heat exchanger is asymmetric corresponding to the hood.

35. A heat exchanger for use in a vapor compression system, comprising:
a shell;
a hood;
a first tube bundle;
a distributor;
a partition; and
a chamber;
wherein the heat exchanger is asymmetric corresponding to the hood.

36. The heat exchanger of claim **35**, wherein:
the shell comprising an outlet configured to permit passage of vapor from the shell;
the hood being configured and positioned to overly the first tube bundle and the distributor;
the first tube bundle extending substantially horizontally in the shell;
the distributor being configured to apply a fluid to the first tube bundle;
the partition being configured and positioned to separate the hood and the chamber; and
the chamber being in fluid communication with the outlet.

37. The heat exchanger of claim **36**, wherein the partition comprises a portion of the hood.

38. The heat exchanger of claim **36**, further comprising a protrusion, the protrusion extending from the partition to disturb vapor flow in the chamber.

39. The heat exchanger of claim **38**, where the protrusion extends from the shell.

40. The heat exchanger of claim **36**, wherein the partition extends substantially vertically within the shell.

41. The heat exchanger of claim **36**, further comprising:
a second tube bundle; and
wherein the first tube bundle is at least partially above the second tube bundle;
wherein the hood terminates after covering the first tube bundle.

42. The heat exchange of claim **36**, wherein the hood is formed by the partition and a second partition extending from the shell.

43. The heat exchanger of claim **42**, wherein the partition and the second partition are positioned on opposing sides of the distributor.

44. A heat exchanger for use in a vapor compression system, comprising:
a shell;
a hood;
a first tube bundle;
a distributor;
a partition;
a chamber; and
a protrusion;
the shell comprising an outlet configured to permit passage of vapor from the shell;
the hood being configured and positioned to overlie the first tube bundle and the distributor and substantially laterally surround substantially all tubes of the first tube bundle;
the first tube bundle extending substantially horizontally in the shell;
the distributor being configured to apply a fluid to the tube bundle;
the partition being configured and positioned to separate the hood and the chamber;
the chamber being in fluid communication with the outlet;
the partition comprising a portion of the hood;
the protrusion extending from the partition to disturb vapor flow in the chamber.

45. The heat exchanger of claim **44**, wherein the protrusion extends from the shell.

* * * * *